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Trade, Supply Chain Activities and Transport: Contemporary Logistics and Maritime Issues

3 - 5 June 2013 Hong Kong, China

Edited By: Xiaowen Fu Chung-Lun Li Meifeng Luo Adolf K.Y. Ng Tsz Leung Yip Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2013

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

The roots of IFSPA can be dated back to 2006 when it was started as a workshop with the objective to promote high-quality research papers. Since then it has experienced significant successes and has attracted more than 600 participants from different countries and regions of the world.

# Preface

The Sixth International Forum on Shipping, Ports and Airports (IFSPA 2013) was successfully held from 3 to 5 June 2013, in Hong Kong, China. This proceedings contained a collection of Sixty-three papers presented during the Conference. The topics covered include shipping economics, port strategy, airport management, logistics development, environmental issues in logistics, port efficiency and competition, and maritime safety and security.

The theme of IFSPA 2013 is *"Trade, Supply Chain Activities and Transport: Contemporary Logistics and Maritime Issues*". It aimed to provide an interactive platform for international academics to discuss important issues related to shipping, ports, and airports. It also advocated adoption of interdisciplinary business approach for maximization of competitive advantage and economic benefits of transport, logistics and trading industries worldwide. This year the Forum comprised three Keynote Sessions, one Industrial Session, two Special Sessions and 17 Parallel Sessions. During the event, world-famous scholars and industry leaders shared with participants their insights on issues relevant to maritime and trade economics, policy and management. More than 120 delegates came from different parts of the world including Australia, Belgium, Canada, China, Estonia, Finland, Germany, Japan, Korea, the Netherlands, Norway, Spain, Sri Lanka, Switzerland, Thailand, the U.K., and the U.S.

Led by the C.Y. Tung International Centre for Maritime Studies of The Hong Kong Polytechnic University, IFSPA is an annual international event devoted to maritime, aviation and logistics studies to discuss and exchange views on contemporary issues facing the sectors, 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.

The Conference gratefully acknowledges the supports from Bernhard Schulte Shipmanagement, the Chartered Institute of Logistics and Transport in Hong Kong, DHL Global Forwarding (Asia Pacific), Hong Kong Air Cargo Terminals Limited, Hong Kong Logistics Association, and the Hong Kong Shipowners Association.

The IFSPA 2013 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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Xiaowen Fu Chung-Lun Li Meifeng Luo Adolf K.Y. Ng Tsz Leung Yip

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# A Multi-Variate QFD Design for the Service Quality Assessment of Kansai International Airport-Japan

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### Abstract

This paper investigates multi-agent service quality problems in the area of airport management and proposes the use of the multi-layer quality function deployment (QFD) model to compromise the requirements of both airline companies and passengers to ensure generality and sustainability of quality implementation. In air transportation, customers and service providers engage each other as a result of the complex suppliercustomer structure. An Airport provides services simultaneously in a nested framework for both the airline companies and the passengers. On the other hand, airline companies serve the passengers from their own specific perspective. Therefore, the airports deal with the satisfaction of the airline companies and the passengers while the airline companies distinctly deal with the satisfaction of the passenger. The satisfaction of the passengers in terms of airport services is a derived form of the airline company's distinct position on service quality. The conventional QFD method is limited to compromise the multi-layer customer phenomenon and the multi-layer QFD model is capable of analyzing the requirements of all agents in order to find appropriate solutions.

Keywords: Multi-agent service quality; Airport management; Quality Function Deployment; Conflict resolution

### 1. Introduction

From the seamless transport perspective, quality of service in airports is an emerging issue and its sophisticated dynamics attract academic interest. Airport service is usually perceived as passenger service, although such service is not limited to just the individual customer. Since passenger traffic is broadly defined by airline company services, airline companies, as institutional customers, are probably the most important stakeholders of the service quality framework. If an airport attracts airline companies that improve and extend their service through the intended airport, then passenger volume will be increased and publicity will be gained correspondingly. Although this paper does not deal with the internal customer and employee, it is of particular interest from a managerial performance viewpoint. The impact of increasing motivation and the satisfaction of the internal customer has non-negligible contributions to the entire service quality performance. Rather than approaching the problem from the traditional service quality perspective, this investigation takes into account the multi-dimensional aspects of airports and examines the expectations of all customers.

According to the report published by the Ministry of Land, Infrastructure and Tourism-Japan (2009), the plan to improve the service quality of an airport and passenger terminal facility from the airport user's viewpoint has become the most important issue in competing with the neighbouring high density East Asian airports (Adler, Liebert, & Yazhemsky, 2013; Vowles, 2006; Yeh & Kuo, 2003; Yu, 2010). Since the airport is the nation's first impression and the hub airport challenge is a serious issue, the contest is severe between each government (Kansai airport review, 2011). The typical airport users usually consist of passenger, airport staff, airline companies, immigration, brokers, cargo companies and other users with their own concept about the cost, convenience, efficiency or other related expectations about service quality of the terminal (Carey, 2011). In general, one of the most important revenue sources for the airport is from the passenger, so both the passenger's and the airline's perception of a terminal service level must be measured in order to deliver high

quality service and to achieve passenger satisfaction (Tierney & Kuby, 2008). Therefore, service quality has an effect on an airport's competitive advantage and can be an important driver of passenger loyalty and good reputation.

The perspective of terminal service quality from the airline's point of view may totally differ from the passenger's point of view (Masemola & Chaka, 2011; Yu, Chern, & Hsiao, 2013). The airline may prefer an economic design for ticket counters in a busy departure region, fewer ground staff, an efficient baggage handling facility, useful runways with a long time belt, an apron with an acceptable walking distance, a lower landing fee or facility charge rather than terminal comfort, a well-equipped facility, and a decent layout. In order to maintain service level and minimize ground operating costs, the technical measures to enhance service quality, especially during peak hours or congestion, are complex and could be determined through interviews or surveys with the airline executives or other related experts. The service quality of an airport terminal is hard to determine and measure because of its inseparability, heterogeneity, ambiguity and intangibility. It involves a series of interactions between customers and service providers; therefore, these service attributes of an airport are usually evaluated by passengers with quantitative or qualitative surveys. However, we can still find some empirical and conceptual studies built to explore the service quality topic in improving the airport passenger terminal. Tam (2004) investigated the level of service in Hong Kong International Airport (HKIA) with a questionnaire survey. The results detailed a listing of inadequate facilities that included way finding aids, automated people mover (APM), the lost and found office, trolleys, airline information counters, seat number and location of ATMs. Lemer (1992) emphasizes the performance of an airport passenger terminal should be evaluated by external passengers, airlines, and other users as well as the internal airport operator or management. Tam et al. (2010) points out that the most important factor of perceived service quality of airport ground access is the satisfaction level of mode utility in HKIA. Kuo and Liang (2011) applies MCDM to evaluate the service quality of the Northeast-Asian airport terminal with many important attributes such as costs of processing time, convenience, comfort, information visibility, courtesy of staff, security, and reaction capability. Jou (2011) applies a mixed logic model to explore the airport ground access mode choice behavior of air passengers who are travelling abroad from Taiwan. The result reveals that overall time savings and a user-friendly facility are the most important factors.

The quality function deployment (QFD) is originally developed for service (or product) quality assessment and it is frequently implemented by the leading industries (e.g. Ford Motor Co., Toyota Motor Co., F-35 Air Fighter design). The QFD method deals with improved quality rather than handling quality defects as in traditional quality assessment. However, the conventional form of the QFD method is a single layer assessment or uncompromised solution which is incapable of handling customer duality. Rather than the conventional QFD method (Akao & Ohfuji, 1989), the multi-layer QFD collects responses from different perspectives and analyzes them based on their derived contribution to the cumulative outcome. The service quality assessment problem for airports is a typical multi-agent service quality problem with passengers and airline companies contributing to airport utilization. This paper deals with airport service quality, an additional dimension based on the service quality of airline companies for passenger satisfaction is out of scope and a matter for an additional study.

Combining the items of measuring service quality as reported in the literature and professional aviation publications with consultations with consulting airline managers, academic professors and passengers in Japan, ten service attributes and ten technical measures were chosen to evaluate the service quality of the passenger terminal of Kansai Airport (KIX).

### 2. Methodology

The service quality assessment of KIX is performed by a number of processes, including the initial survey for collecting the requirements of airline companies and passengers, and a definition of the technical measures of the airport terminal. In the second step, the priorities of these requirements and their derived interactions with the technical measures are investigated by a fuzzy-AHP process and the multi-layer QFD method respectively. The final outcome reveals the importance of a particular technical aspect and managerial suggestions are made for improving the compromised service quality.

The following sub-sections present the intended methods.

#### 2.1 Fuzzy sets and triangular fuzzy numbers (TFNs)

The fuzzy set theory was first proposed by Zadeh (1965) and it is applied to vague and uncertain problems. In the literature, there are several studies which developed models by using the fuzzy set theory (Kaufmann & Gupta, 1991; Van Laarhoven & Pedrycz, 1983; Zadeh, 1965; Zimmermann, 1991). In this study, triangular fuzzy number  $\tilde{A}$  in R, indicated by (l,m,u), is applied and its definition is as follows:

**Definition 1:** A fuzzy set  $\tilde{A}$  in a universe of discourse *R* is characterized by a membership function  $\mu_{\tilde{A}}(x)$  which associates with each element *x* in *R* is a real number in the interval [0, 1]. The function value  $\mu_{\tilde{A}}(x)$  is termed the grade of membership of *x* in  $\tilde{A}$ .

Definition 2: A fuzzy number is a fuzzy subset in the universe of discourse *R* that is both convex and normal.

**Definition 3:** A triangular fuzzy number denotes as  $\tilde{A} = (l,m,u)$ , where  $l \le m \le u$ , has the following triangular type membership function;

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x < m, \\ 1, & x = m, \\ (u-x)/(u-m), & m < x \le u, \\ 0, & u < x. \end{cases}$$
(1)

where *l* and *u* are the lower and upper bounds of the fuzzy number  $\tilde{A}$ , respectively, and *m* is the midpoint (Fig. 1).

## Figure 1: A triangular fuzzy number $\tilde{A}$



#### 2.2 Fuzzy AHP method

Because of the limitation of the traditional analytic hierarchy process (AHP) method (Saaty, 1977) for a vague and complex problem, the fuzzy analytic hierarchy process (FAHP) was first proposed by Laarhoven and Pedrycz (1983) to extend the traditional AHP method by using triangular fuzzy numbers. After Laarhoven and Pedrycz's study, there were several new approaches for the FAHP method (Boender, de Graan, & Lootsma, 1989; Buckley, 1985; Chan & Kumar, 2007; Chang, 1996; Cheng & Mon, 1994; Duru, Bulut, & Yoshida, 2012; Huang, Chu, & Chiang, 2008; Xu, 2000) and the Chang's theory which is synthetic extent analysis method by using triangular fuzzy numbers (TFNs) is applied. In the following, the extent-synthesis method is described and then the method is applied to reveal the relative importance of customer requirements. Let  $X = \{x_1, x_2, x_3, ..., x_n\}$  be an object set and  $U = \{u_1, u_2, ..., u_m\}$  be a goal set. The extent analysis for each goal is performed under each object. Therefore, *m* extent analysis values for each object are indicated with the following parameters:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \qquad i=1, 2, ..., n,$$
 (2)

where all the  $M_g^{j}$  (*j*=1,2,...,*m*) are TFNs.

The steps of Chang's extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent with respect to the *i*th object is defined as

$$S_{i} = \sum_{j=1}^{m} M_{g_{i}}^{j} \otimes \left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_{i}}^{j} \right]^{-1}$$
(3)

To obtain  $\sum_{j=1}^{m} M_{g_i}^{j}$ , the fuzzy addition operation of *m* extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^{m} M_{g_{i}}^{j} = \left(\sum_{j=1}^{m} l_{j}, \sum_{j=1}^{m} m_{j}, \sum_{j=1}^{m} u_{j}\right)$$
(4)

And to obtain  $\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_{i}}^{j}\right]^{-1}$ , the fuzzy addition operation of  $M_{g_{i}}^{j}$  (*j*=1, 2,..., *m*) values is performed such as:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left( \sum_{i=1}^{m} l_j, \sum_{i=1}^{m} m_j, \sum_{i=1}^{m} u_j \right)$$
(5)

)

and then the inverse of the vector in Eq. (5) is computed, such as:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_{i}}^{j}\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n}u_{i}}, \frac{1}{\sum_{i=1}^{n}m_{i}}, \frac{1}{\sum_{i=1}^{n}l_{i}}\right].$$
(6)

**Step 2:** The degree of possibility of  $M_2 = (l_2, m_2, u_2) \ge M_1 = (l_1, m_1, u_1)$  is defined as

$$V(M_{2} \ge M_{1}) = \sup_{y \ge x} \left[ \min(\mu_{M_{1}}(x), \mu_{M_{2}}(y)) \right]$$
(7)

and can be expressed as follows:

$$V(M_{2} \ge M_{1}) = hgt (M_{1} \cap M_{2})$$

$$= \mu_{M_{2}}(d) = \begin{cases} 1, & \text{if } m_{2} \ge m_{1}, \\ 0, & \text{if } l_{1} \ge u_{2}, \\ \frac{l_{1} - u_{2}}{(m_{2} - u_{2}) - (m_{1} - l_{1})}, & \text{otherwise.} \end{cases}$$
(8)

Figure 2 illustrates Eq. 8 where *d* is the ordinate of the highest intersection point *D* between  $\mu_{M_1}$  and  $\mu_{M_2}$ . To compare  $M_1$  and  $M_2$ , we need both the values of V ( $M_1 \ge M_2$ ) and V ( $M_2 \ge M_1$ ).

**Step 3:** The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy  $M_i$  (*i*=1,2,...,*k*) numbers can be defined by

 $V(M \ge M_1, M_2, ..., M_k) = V[(M \ge M_1) \text{ and } (M \ge M_2) \text{ and } ... \text{ and } (M \ge M_k)] = \min V \quad (M \ge M_i),$ i=1,2,3,...,k. (eq. 9) Assume that  $d'(A_i) = \min V(S_i \ge S_k)$  for k=1,2,...,n;  $k \ne i$ . Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^{\mathrm{T}}$$
(9)

where  $A_i$  (*i*=1, 2,..., *n*) are *n* elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \dots, d(A_n))^{\mathrm{T}},$$
(10)

where *W* is a non-fuzzy number.

Judgments of decision makers are exposed by using linguistic terms. In this paper, there are six different fuzzy linguistic terms in Table 1 that are implemented for the pair-wise comparison of relative importance.



#### Figure 2: The intersection between M<sub>1</sub> and M<sub>2</sub>

 Table 1: Transformation for TFNs membership functions

Fuzzy number	Linguistic scales	Membership function	Reciprocal	
$\tilde{A}_{I}$	Equally important	(1,1,1)	(1,1,1)	
$ ilde{A}_2$	Slightly important	(1,1,3)	(1/3,1,1)	
$ ilde{A}_{3}$	Moderately important	(1,3,5)	(1/5,1/3,1)	
$ ilde{A}_4$	More important	(3,5,7)	(1/7,1/5,1/3)	
$ ilde{A}_5$	Strongly important	(5,7,9)	(1/9,1/7,1/5)	
$ ilde{A}_6$	Extremely important	(7,9,9)	(1/9,1/9,1/7)	

#### 2.3 The consistency calculation under fuzzy environment

In the literature, consistency control has not been computed to ensure consistency of matrices by using the FAHP method. Bulut et al. (2012) developed the centric consistency index (CCI) which is based on geometric consistency index (GCI) (Crawford & Williams, 1985) to compute the consistency of fuzzy extended decision matrices. The CCI calculation is applied to reveal the consistency in aggregated matrices.

Let  $A = (a_{Lij}, a_{Mij}, a_{Uij})_{n \times n}$  be a fuzzy judgment matrix, and let  $w = [(w_{Ll}, w_{Ml}, w_{Ul}), (w_{L2}, w_{M2}, w_{U2}), \dots, (w_{Ln}, w_{Mn}, w_{Un})]^T$  be the priority vector derived from A using the RGMM. The CCI is computed by

$$CCI(A) = \frac{2}{(n-1)(n-2)} \sum_{i < j} (\log(\frac{a_{Lij} + a_{Mij} + a_{Uij}}{3}) - \log(\frac{w_{Li} + w_{Mi} + w_{Ui}}{3}) + \log(\frac{w_{Lj} + w_{Mj} + w_{Uj}}{3}))^{2}$$
(11)

where n is the number of elements.

CCI(A)=0 means that the matrix are fully consistent. The thresholds of CCI and its scale is based on Aguarón et al. (Aguarón & Moreno-Jiménez, 2003).

2.4 The prioritization of decision maker

Since each decision maker has a different experience and way of thinking, the matrix of each individual decision maker cannot be equal. Several studies in the literature (Cao, Leung, & Law, 2008; Forman &

Peniwati, 1998; Ramanathan & Ganesh, 1994) investigated different methods such as eigenvector (EV) and row geometric mean method (RGMM) to derive priorities for individual decision makers that can be used for aggregating group preferences.

The result of CCI calculation for each matrix is used to determine the weight of the decision maker. The mathematical algorithm of proposed method is as follows:

Let  $D = \{d_1, d_2, ..., d_m\}$  be the set of decision makers, and  $\lambda_k = \{\lambda_1, \lambda_2, ..., \lambda_m\}$  be the weight of decision makers. The weight of decision makers  $(\lambda_k)$  is the normalized  $I_k$  for the group of experts which is calculated as follows:

$$I_k = \frac{1}{CCI_k} \tag{12}$$

where  $I_k$  is the inverse of the CCI,

$$\lambda_k = \frac{I_k}{\sum_{k=1}^m I_k} \tag{13}$$

where  $\lambda_k > 0$ , k = 1, 2, ..., m, and  $\sum_{k=1}^{m} \lambda_k = 1$ .

Let  $A^{(k)} = (a_{ij}^{(k)})_{n \times n}$  be the judgment matrix provided by the decision maker  $d_k$ .  $w_i^{(k)}$  is the priority vector of criteria for each decision maker calculated by

$$w_i^{(k)} = \frac{\left(\prod_{j=1}^n a_{ij}\right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n a_{ij}\right)^{1/n}}$$
(14)

The aggregation of individual priorities is defined by

$$w_i^{(w)} = \frac{\prod_{k=1}^m (w_i^{(k)})^{\lambda_k}}{\sum_{i=1}^n \prod_{k=1}^m (w_i^{(k)})^{\lambda_k}}$$
(15)

where  $w_i^{(w)}$  is the aggregated weight vector.

#### 2.5 The principles of QFD

The Quality Function Deployment (QFD) method is defined as "an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production" (Sullivan, 1986).

In 1986, Ford Motor Company was the first company to apply this technique in the United States. QFD has since been applied successfully by many Japanese companies such as the Toyota Motor Company. Toyota reduced their design costs and product development time by one third after applying QFD in their process (Bergman & Bengt, 1994).

The systematic framework of the QFD method is defined in stepwise form as follows:

- Step 1. Customer needs for service quality must be identified.
- Step 2. Measure the importance degree of each customer requirement by using the Fuzzy-AHP framework.
- **Step 3.** Measure the degree of satisfaction of each customer service attribute to reveal the voice of customer service quality requirements.
- Step 4. Make the evaluation of the priorities of customer needs.
- **Step 5.** Build up service management requirements to represent the service provider management to reveal customer service quality requirements.
- **Step 6.** Create the central relationship matrix to connect the service management requirements to customer needs.

- **Step 7.** Establish the fuzzy relationship strength of each service management requirement and each attribute of customer needs.
- **Step 8.** List the service management requirements' ranking to identify the priority that each service management requirement satisfies the overall customer service quality requirements.

The procedure for constructing the HoQ for implementation of the QFD can be illustrated by the following steps (Hauser & Clausing, 1998):

- Consumer requirements (WHATs): Customer requirements can be defined through a survey or consultation with customers. The weight of customer requirements exposes the importance of each item.
- Technical measures (HOWs): Technical measures are defined according to a firm's product or service by an expert consultation.
- Relationship Matrix: Combining each WHATs and HOWs, the relationship matrix shows the contribution level and the relation of technical measures to each customer requirements. As usual, signs represent four levels of interaction (Strong relationship, ■; Moderate relationship, ▲; Low relationship, ●; and No relationship, "Ø") by using 9-5-1 scale<sup>i</sup>.
- Correlation Matrix: Correlation Matrix is to measure the relationship of each technical measure and how much they affect each other. Correlations are represented with signs that express the degree of relationship between technical measures. Signs are translated into a five-step scale (strong positive correlation, "++"; positive correlation, "+"; no correlation, "\$\Omega"\$," negative correlation, "-"; strong negative correlation, "--").
- Relative weight: Relative weight of a technical measure is calculated by the normalization of the sum of products. The sum of products refers to the sum of multiplication of the weight of customer requirements and relationship value.
- Targets: Targets of the intended project are defined by the expert group by investigation of relative weight of technical measures and the correlation among them. Defining targets is a judgmental process which is figured by the capacity and facilities.

### 2.6 Multi-layer QFD framework

The multi-layer QFD is designed in the three dimensional framework which consists of matrices of the customer oriented HoQ, the provider oriented HoQ and the top surface is allocated for cross-synthesis of requirements. Figure 3 illustrates the structure of the multi-layer QFD. The anterior surface of the cubical indicates the classical customer oriented the HoQ matrix (customer satisfaction face). On the other hand, the right hand side of the cubical represents the service provider oriented HoQ matrix. The technical response indicators of both matrices are identical (edge #3). However, requirements of both parties have differences. The requirements of customer and service provider (or manufacturer) are indicated on edge #1 and edge #2 respectively. The top of the cubical shows the cross-synthesis matrix for the conflict resolution. The size of the cross synthesis matrix is based on the requirements of both parties.

The customer oriented and service provider oriented HoQ matrices are the traditional QFD assessments. In case of service provider satisfaction, the relationship matrix is composed of its intentions and prospects. In the prior analysis, the initial distribution of relative importance of requirements is defined by the expert consultation for both HoQ matrices (fuzzy AHP based assessment). The secondary part is the cross-synthesis analysis between the relative importance and the relationship valuations among the requirements. After the cross-synthesis analysis, the relative weight of the requirements will be revised. Then, further procedures of the HoQ matrices are performed by the revised indications. Both HoQ matrices denote the relative weights for technical measures. The simple average of these indications provides the final compromised weights of the technical responses. Objectives for the service/product improvement are based on the cumulative assessment of the final weights and the correlation between technical measures.



Figure 3: The three dimensional design of the multi-layer QFD method

2.7 The cross-synthesis analysis

The cross-synthesis analysis is a part of the multi-layer QFD framework for resolution of the conflict of interests between the customer and the service provider (or manufacturer). The relative importance of the requirements is rated by the parties according to their own intentions. The relationship matrix between the requirements presents how these intentions are correlated and support/oppose each other. Figure 4 illustrates the procedure of the cross-synthesis analysis. The relative importance of the requirements is defined by the priority assessment of FAHP method. Then, the product of the relationship matrix and the relative importance of the counterparty obtain the estimation of the implied relative importance from the viewpoint of the counterparty. The synthesis is completed by averaging the relative importance of a party and the implied relative importance of the counterparty.



Figure 4: Airport services and passenger transport process

Let  $R_i^s$  and  $R_j^c$  are requirements of service provider and customer respectively. *i* (*i*=1,2,...,*k*) is the number of service provider requirements and *j* (*j*=1,2,...,*l*) is the number of customer requirements. The relative importance of the requirements are  $w_i^s$  and  $w_j^c$  for the service provider and the customer respectively. The relationship value between the requirements is  $r_{ij}$  which equals to 9 for the strong relationship, 5 for the moderate relationship, 1 for the weak relationship and 0 for no relationship. The relationship matrix,  $A_{ij}$ , is presented as follow:

$$A_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1l} \\ r_{21} & r_{22} & \cdots & r_{2l} \\ \vdots & \vdots & \vdots & \vdots \\ r_{k1} & r_{k2} & \cdots & r_{kl} \end{bmatrix}$$
(16)

The revaluation of the relative importance is performed in two steps. First, the cross priority weighted value of relative importance is calculated. Second, the simple average of cross-priority weighted and the raw relative importance rates denote the mid-position between parties.

The sum of the products of the relationship degree and the relative importance is calculated by

$$\sum_{i=1}^{k} W_i^s r_{ij} \tag{17}$$

for customer requirements, j and,

$$\sum_{j=1}^{l} w_j^c r_{ij} \tag{18}$$

for service provider requirements, *i*. The simple average of the normalized cross-priority weighted and the raw relative importance rates indicates the compromised relative weights which is

k

$$\omega_{j}^{c} = \frac{\sum_{i=1}^{i=1} w_{i}^{s} r_{ij}}{\sum_{j=1}^{l} \sum_{i=1}^{k} w_{i}^{s} r_{ij}} + w_{j}^{c}$$
(19)

for the relative importance of customer requirements after the cross-synthesis,  $\omega_i^c$  and

$$\omega_{i}^{s} = \frac{\sum_{j=1}^{l} w_{j}^{c} r_{ij}}{\sum_{i=1}^{k} \sum_{j=1}^{l} w_{j}^{c} r_{ij}} + w_{i}^{s}}{2}$$
(20)

for the relative importance of service provider requirements after the cross-synthesis,  $\omega_i^s$ . The re-valued relative importance of the requirements is moved to the assessment of both HoQs.

In the QFD methodology, the relative weight of the technical measures,  $\Phi_t$ , are calculated by

$$\phi_{t} = \frac{\sum_{i=1}^{k} \omega_{i}^{s} r_{it}^{s}}{\sum_{t=1}^{n} \sum_{i=1}^{k} \omega_{i}^{s} r_{it}^{s}}$$
(21)

for the HoQ of the customer and

$$\phi_{t} = \frac{\sum_{j=1}^{t} \omega_{j}^{c} r_{jt}^{c}}{\sum_{t=1}^{n} \sum_{j=1}^{l} \omega_{j}^{c} r_{jt}^{c}}$$
(22)

for the HoQ of the service provider. t (t=1,2,...,n) is the number of technical measures and the superscripts, c and s, classify the relationship values for the HoQ of the customer and service provider respectively. In case of the fuzzy extended parameters, arithmetic operations are based on Zadeh (1965) and the final crisp results can be calculated either by using the center of gravity or by the PERT (Program evaluation and review technique) estimation method.

## 3. The Case of Kansai International Airport (KIX)

Airport competition and hub-airport incentives in Eastern Asia are discussed in the literature and the Kansai International Airport is principally indicated by its financial challenges and spatial disadvantages. Ishikura *et al.* (2005) investigated the financial status of KIX and the Incheon International Airport (ICN). The financial imbalance of KIX is discussed and the major role of the long term liabilities (*i.e.* interest debt) is found to be the fundamental cause of financial loss. The existing long term liabilities are around 13 billion USD (2010 figures) which is compensated by a joint venture company (including government contributions). However, KIX maintains its operational competitiveness and is rated in the top three airports of the Eastern Asian region (with Singapore Changi Airport and the New Hong Kong Airport).

Under the joint venture structure and privatization prospects, service quality improvement is of growing interest in the case of KIX and it is essential for the sustainability of airport services and business. Figure 4 illustrates the services provided by the airport between the airport transfers in both ends. The major airline company services (in-flight) are highlighted and it should be separated from the airport services. A number of potential passengers (frequent flyers) and company officials who are employed by KIX are asked to define the essential requirements of the passenger and the airline company. The outline of the results of these consultations is presented in Table 2. The airport company requirements are not only based on the existing services but also consider the potential connections and services (assuming that the route approval is eligible). For instance, the technical capacity of an airport is a critical consideration for extending services and connections. New generation aircrafts require wider and longer runways in addition to multiple boarding bridges such as is the case with the Airbus 380 series.

The technical measures of airport services are gathered from several academic and technical papers including airport performance indicators published by the Airport Cooperative Research Program (2011). Table 3 shows the main and sub-titles of technical measures. Eleven main titles are selected while a number of sub-titles are indicated which are usually measurable performance indicators. Some of the measures are based on existence (1: exist, 0: nil).

Table 2. Volce of Customer of spatial flog matrix (Euge "1 and "2)					
Passenger requirements - Edge #1	Symbol				
1. Comfort	С				
2. Facilities	F				
3. Security and Safety	SS				
4. Signposting/ Wayfinding	W				
5. Service Quality and Speed	SQ				
Airline Company requirements - Edge #2	Symbol				
1. Safe and speed airfield operation	SA				
2. Cheaper service fees	CSF				
3. Compatible with Airplane characteristics (e.g. A380 series) (MLW, MTOW)	AC				
4. Convenience of ticketing, boarding, gate management, transfers, duty free floor	TBG				
5. Proper-Safe-Speed Baggage Handling Service	BH				

# Table 2: Voice of Customer of spatial HoQ matrix (Edge #1 and #2)

## Table 3: Technical measures for the airport services

- 1. General particulars
  - 1.1. Design and architectural originality
  - 1.2. Terminal size
  - 1.3. Terminal cleanliness
  - 1.4. Toilet facilities
  - 1.5. Wayfinding illustrations
  - 1.6. Flight information screens
  - 1.7. Announcements
  - 1.8. ATM Cash machines
  - 1.9. Internet/ WI-FI availability
  - 1.10. Smoking lounges
- 2. Means of Mass Transit (Transport to terminal)
  - 2.1. Shuttle bus service 7/24
  - 2.2. Railway Transport
- 2.3. Parking lot capability and service
- Particulars of Check-In services
  - 3.1. No. of counters

3

6.

- 3.2. Size of check-in floor
- 3.3. Waiting time at check-in counter
- 3.4. Courtesy of check-in attendant
- 4. Particulars of Security and Customs
  - 4.1. Waiting duration at security check
  - 4.2. Waiting duration at customs check
  - 4.3. Crimes reported on the airport
- 5. Particulars of Duty Free/ Transit/ Lounge
  - 5.1. Size of duty free floor(s)
  - 5.2. No. of duty free shops
  - 5.3. No. of 7/24 shops in duty free floor
  - 5.4. No. of airport hotels
  - 5.5. No. of lounge facility for private/VIP passengers
  - 5.6. No. of paid-lounge facility for economy class passenger
  - Particulars of Reception and Gate Facilities
- 6.1. No. of Gates
  - 6.2. No. of Gates with boarding bridge
  - 6.3. No. of Gates with dual boarding bridge (separation for seat class)
  - 6.4. Proper boarding bridge for the last generation aircrafts (i.e. A380)
  - 6.5. No. of Arrival Gates with boarding bridge
  - 6.6. Average distance between customs and gates
- 7. Particulars of Baggage Handling/ Claim/ Pick-Up Aids
  - 7.1. No. of baggage carts available
  - 7.2. Baggage Claim desk 7/24 (1/0)
  - 7.3. Baggage claim speed
  - 7.4. Airport trolleys for departure (free of charge) (1/0)

- 7.5. Airport trolleys for transit area (free of charge) (1/0)
- 7.6. Airport trolleys for arrivals (free of charge) (1/0)
- Particulars of Private/VIP Service/ Disabled Services
- 8.1. Existence of entrance-to-flight disabled facilities (1/0)8.2. Size of VIP Lounge
- 9. Particulars of Cost and Pricing (USD)
  - 9.1. Landing fees (over 100,000 lbs, per 1,000 lbs)
  - 9.2. Apron Parking Fee per day

8.

- 9.3. Boarding area fee (per sq meter)
- 9.4. Ticketing area fee (per sq meter)
- 9.5. Fuel flowage fee (per gallon)
- 9.6. Office Rentals (per square meter)
- 9.7. Hangar Fees (large jet, per day/month)
- 10. Particulars of Airfield Operations
  - 10.1. Arrival delay per Flight
    - 10.2. Departure delay per Flight
    - 10.3. Percent of Arriving Flights Delayed
    - 10.4. Percent of Departing Flights Delayed
    - 10.5. No. of Runways
    - 10.6. Length of Runways (meter)
    - 10.7. Existence of Aircraft Hangars and Technical Service
    - 10.8. Existence of Facility for new generation aircrafts
    - 10.9. Runway clearing time
    - 10.10. Taxi time Gate-to-Runway End
  - 10.11. Wildlife/ Bird strikes
- 11. Particulars of Green Airport Framework
  - 11.1. Renewable energy generated by the airport
  - 11.2. Airport vehicles and ground service equipments with energy-efficient type (%)
  - 11.3. Airfield electricity consumption-change over prior period
  - 11.4. Noise No. of homes within 65 dBA DNL contour
  - 11.5. Utilities/ Energy cost per square meter of Terminal building

The initial priority rates of customer requirements (Edge #1 and #2) are defined by the group decision making process under the fuzzy-AHP framework. Both potential passengers and airline company officials (including the regional director, the station manager, etc.) are asked to complete a pairwise comparison survey to elicit the priority rates. The priority perceptions are presented by linguistic terms as in Table 1. Table 4 and 5 are calculated from the existing responses and the reliability of the survey is tested by the CCI value. Since the CCI metrics are under the threshold (0.37) in the first call, no additional adjustments are required from the participants. According to the final outcome, the most important request is cheaper service fees (0.44). In case of passenger's requirements, service quality, security and safety and facilities indicated higher priority rates in a close range (0.24-0.26).

The cross-synthesis of the priority rates is performed (eq. 17 to eq. 21) to compromise expectations from both perspectives. Table 6 presents the conflict resolution matrix which indicates the correlation between requirements, their temporary weights (i.e. priorities) and the post-synthesis priorities. Particularly the convenience of passenger services (ticketing, boarding, transfers, and gate facilities among others) is highly correlated with the passenger's requirements as expected. On the other hand, the correlation between facilities and cheaper service draws attention to the contradiction on the costs and benefits of facilities which should be considered on the goal setting and implementation through the QFD assessment.

-	Tuble in The uggregated tuzzy judgment matrix for the anime company requirements (Duge "")						
	SA	CSF	AC	TBG	BH	Weight	
SA	(1,1,1)	(0.16,0.24,0.52)	(0.63,0.83,1.41)	(0.43,1.04,1.36)	(0.35,0.63,1.14)	(0.09)	
CSF	(1.92,4.18,6.27)	(1,1,1)	(2.35, 4.26, 5.42)	(2.19,4.37,6.43)	(1.14,1.77,3.96)	(0.44)	
AC	(0.71,1.20,1.58)	(0.18,0.23,0.43)	(1,1,1)	(0.57,0.80,1.73)	(0.42,0.66,1.13)	(0.11)	
TBG	(0.73,0.96,2.32)	(0.16,0.23,0.46)	(0.58,1.25,1.76)	(1,1,1)	(0.39,0.88,1.23)	(0.14)	
BH	(0.87,1.60,2.88)	(0.25, 0.56, 0.88)	(0.88,1.53,2.36)	(0.81,1.14,2.58)	(1,1,1)	(0.22)	
CCI = 0.033							

Table 4: The aggregated fuzzy judgment matrix for the airline company requirements (Edge #2)

Table 5: The aggregated fuzzy judgment matrix for the passenger's satisfaction (Edge #1)

	С	F	SS	W	SQ	Weight
С	(1,1,1)	(0.57,1.12,1.18)	(0.36,0.79,1.72)	(1.54,2.11,4,42)	(0.44,0.57,1.12)	(0.21)
F	(0.85,0.89,1.74)	(1,1,1)	(0.44,1.23,1.53)	(1.63,3.36,5.51)	(0.65,1.12,1.18)	(0.24)
SS	(0.58,1.27,2.75)	(0.65,0.82,2.26)	(1,1,1)	(2.91,3.63,622)	(0.71,0.91,1.38)	(0.25)
W	(0.23, 0.47, 0.65)	(0.18,0.30,0.61)	(0.16,0.28,0.34)	(1,1,1)	(0.17,0.26,0.61)	(0.04)
SQ	(0.89,1.74,2.25)	(0.85,0.89,1.55)	(0.73,1.10,1.41)	(1.64,3.78,5.82)	(1,1,1)	(0.26)
CCI = 0.025						

Table 7 and 8 present the HoO matrix for both perspective and the comparative assessment for the regional competition in the Eastern Asia. Table 7 introduces the HoQ for passenger needs and the high priority on particulars of duty free/transits/lounge etc. is significantly indicated. Since the passengers spend most of their time using these services, it is an anticipated conclusion. Kansai Airport is found on the forth position among the competitors and its low ratings on comfort and facilities are well noted. Comfort and facilities are the most important indicators for passenger satisfaction and the major technical indicator is the particulars of duty free/transits/lounge which are mainly dominated by the existence of several shops and related services in the duty-free hall. The working hours of these facilities may also be of particular importance. One of the weak points of KIX is the limited service hours since many of the duty-free shops are closed by around 10 PM and the remaining passengers do not have opportunity for even having dinner. Lack of fast food shops is another concern. Table 8 illustrates how the airline companies' perception is figured out about the KIX and which technical indicators have major importance for possible improvements. The last position of KIX among the competitors is a critical indication since it contributes to the carriers' choice of airport and the frequency of flights (slot allocation such as new schedule-N or schedule revise-R in terms of Schedule Movement Advice-SMA) as well as passenger potential. The major demerits are indicated from the higher service fees and charges in addition to the convenience of passenger related services which is also mentioned in the previous interpretation. The dynamics of airport charges and the price determination will be discussed in the next chapter through the financial and operational nature of KIX. The level of congestion (schedules coordinated airport-Level 2) will be addressed in this circumstance.

Table 9 is the abstract of the final outcome that was determined by synthesizing the entries from both perspectives. The final results indicate four major factors (over 10% of contribution ratio) on customer satisfaction and service improvement: particulars of the duty-free hall (including lounges, shops etc.), particulars of cost and pricing (*i.e.* airport charges and fees), particulars of baggage handling and general particulars of the airport (*i.e.* design, amenities, comfort respectively).

## 4. Discussion on Service Quality Improvement

Although a number of issues are discussed in earlier sections, the recap of practical implementations and their further interpretations are considered to be addressed and elaborated for the future prospects of KIX. Among the previously mentioned challenges, the services provided in the duty-free hall are found to be an existing concern. KIX has a very limited number of shops in the duty-free hall and their working hours are also short since many of them are closed at night. There are no fast food restaurants except a few restaurants serving meals and drinks. Another concern is the size and content of lounges. In contrast to competitors, existing lounges are very limited due to their small size and fewer services. Improvements in extending shopping hours

in the duty-free service area and greater choices in the food court area are indicated. Lounge services also should be redesigned to ensure competitiveness. Such revisions may contribute to both operating revenues and passenger comfort.

From the passenger's perspective, comfort is a weak point in the case of KIX. If we examine the contributing technical measures, means of mass transit is a critical component for this requirement (high correlation). The longer distances and trip times from regional centres to KIX are major converns. Although, a direct railway connection exists between Osaka City and KIX, the remaining major connections such as Kyoto City-KIX and Kobe City-KIX are based on multiple railway trips or shuttle bus services. The current shuttle bus service (named Airport Limousine Bus) is the most popular and cheapest way of transferring to KIX while its travel time is over 40 minutes for many connections. For citizens of Kobe City, an alternative is the ferry service between Kobe Airport and KIX while its travel time is 30 minutes and many citizens use a minimum two additional vehicles (a local train/bus and connection between the city centre and Kobe Airport). Kyoto City is one of top attractive places in Japan and transfers between the city and KIX are a minimum of 90 minutes in addition to its relatively high fares (over 30 USD). A number of improvements should be considered in the transport network:

- Establishment of direct railway connections between Kyoto City, Nara City and Itami-Osaka Airport and KIX
- Increasing the ferry stations to ensure the convenience of direct boarding (single transfer) from a possible berth near the railway connections (such as Iwaya-Nada berths, Nishinomiya Marina etc.). A similar transport network is established for Istanbul Ataturk Airport (IST) by fast ferry connections.

From the airline companies' perspective, higher airport charges are the most important issue. There are three major drivers of airport pricing in the case of KIX. First, the initial investment and remaining interest debt impact the airport charges and fees which also raise the financial imbalance. Second, average prices and labor costs are very high in Japan and influence the operational costs correspondingly. Another important reason is current low utilization. Although, KIX is designed for more passenger and aircraft traffic (also the remaining project is extending the capacity), due to a number of causes the utilization is still low. The Itami-Osaka Airport (ITM) is still in operation and its competitive position for domestic flights is unavoidable. Kobe Airport (UKB) is also a regional competitor for the domestic market. Although, the first national low cost carrier, Peach, will use the KIX as its hub airport by 2012, the existing fleet and aircraft traffic of the company are very limited.

A number of service quality improvements are discussed by the HoQ results and the recent developments in the region. However, many of the improvements also require the contribution of the central government to coordinate regional facilities for maintaining the sustainability of KIX. Rather than Narita Airport (NRT), KIX has many advantages based on its unique geographical position which eliminates possible issues such as noise, air quality and limitations on structural developments.

## 5. Conclusion

The architectural uniqueness of Kansai International airport (KIX) is frequently noted for its engineering excellence as indicated on the Civil Engineering Monument of the Millennium Award of the American Society of Civil Engineers. Although, the originality of design is definite, the operation of KIX is complicated in terms of its financial burden and airport competition. The mainstream literature exclusively deals with the perspectives of airline companies or passengers and does not compromise the perceptions. Therefore, an improvement for airline companies may disimprove the satisfaction of passengers. The prioritization of improvements is another existing issue under the separated assessments.

This paper proposes to employ the multi-variate QFD framework to deal with the multi-agent problem and elicits both priorities and the cumulative importance of a technical indicator. The results of the assessment indicated the role of services provided for passengers and the pricing of airport services. Since the KIX is one of the most expensive airports in the world, the cost related drawbacks are previously discussed. On the other hand, this paper illustrates other factors including the quality of service in duty free sections and airport transfers, among others.

				Satisfaction <sup>2</sup>	ร.ัางรู	Buəss	Pa							•	
				Weight after Cross-Synthesis	0.23	0.33	0.17	0.06	0.22					.Ø,, pue	
				Relative weight	0.24	0.41	0.08	0.08	0.18					onship :	
				Sum of products	3.77	6.32	1.25	1.26	2.80					w relatio	
	ß	ъ	0.22	Proper Baggage Handling	•		•		▼	2.96	0.20	0.21		o, • Lo	
	4	6	0.14	convenience of passenger services			•			7.00	0.46	0:30	1 <sup>3</sup>	ionshi	
ix	3	0	0.11	onstquiA diw olditsqmoD						0.00	0.00	0.06	action	te relat	
Matr	2	6	0.44	Cheaper service fees			•		•	3.72	0.25	0.34	atisfa	Modera	
lution	1	5	0.09	Safe and speed airfield operation	-1					1.46	0.10	0.09	y's S	ip, 🔺 ]	
Conflict Resolu	Column No.	Max. value in column	Relative weight		Comfort	Facilities	Security and Safety	Signposting/ Wayfinding	Courtesy of services and Speed	Sum of products (absolute weight)	Relative weight	Weight after Cross-Synthesis	Airline Compan	ship indicators:  Strong relationsh	
				tdgiəw əvitsləX	0.21	0.24	0.25	0.04	0.26					elations	nship.
				Wor ni sular. value in row	6	6	ъ	6	6					es: <sup>1</sup> R(	relatio. lge #1.
				.oN WOR	7	2	m	4	ъ					$Not\epsilon$	No 1 2 Ed

Table 6: Conflict resolution matrix (Edge #1 vs. #2)

س س	-	<u>/.</u>	7	$\overline{\lambda}$	7				
4		Þ	مجرراً		<u></u>				nship
m 			. *		, • , •				elatior
H									No
	5	4	4	5	3	2	4.07		
Shanghai Airport	m	m	m	4	2	4	2.84		
— — troqriA stogspic	4	ы	ы	S	Ŀ	ъ	4.77		dihi
тосреон Ангрога	4	ы	4	4	4	ъ	4.33		elations
Kansai Airport	m	m	ы	4	5	S	3.83		Low r
Particulars of Green Airport Framework	•	•				1	0.55	0.02	•
Particulars of Airfield Operations						6	1.49	0.04	d
Particulars of Cost and Pricing (USD)					◄	6	4.03	0.11	ationshi
Particulars of Private Services	◀	•			◄	S	2.57	0.07	rate rela
Particulars of Baggage Handling		•	•		◄	6	3.64	0.10	Mode
Particulars of Reception and Gate Facilities	◄	◄		▼		5	3.07	0.09	◀
Particulars of Duty Free/ Transit/ Lounge					◄	6	6.08	0.17	
Particulars of Security and Customs	•				▼	6	2.82	0.08	nship
Particulars of Check-In services					▼	6	3.15	0.09	g relatio
Means of Mass Transit (Transport to terminal)		◀				6	3.67	0.10	Strong
General particulars	◄	◄			▼	6	4.42	0.12	
	Comfort	Facilities	Security and Safety	Signposting/ Wayfinding	Courtesy of services and Speed	Max. value in column	Sum product	Relative weight	Relationship Indicators
Relative weight	0.23	0.33	0.17	0.06	0.22				
wor ni sulux. value in row	6	6	6	5	2				
Row No.	1	2	æ	4	S				

HoQ of Passenger Satisfaction

Table 7: House of quality matrix for passenger's requirements (Edge #1 vs. #3)

<u>س</u>	1	1.	7	1	1				
4	1	7	A	M	/				dihsr
m	2	K		$ \mathbf{H} $	•				elation
, ,		V		۰. ۱	_				No re
mori AgnoH	2	3	ß	4	ß	5	3.73		
tıoqniA isrignardZ	4	5	4	1	1	5	2.82		
— — tıoqıiA sıoqısgniZ	2	2	S	5	2	5	2.98		qih
последия последние по	4	4	4	4	m	4	3.79		elations
Kansai Airport	ъ	1	4	2	4	ß	2.46		Low r
Particulars of Green Airport Framework						6	3.09	0.08	•
Particulars of Airtifeld Operations		•		◄		6	3.18	0.09	d
Particulars of Cost and Pricing (USD)					◄	6	4.96	0.13	ationshi
Particulars of Private Services		•		◄		5	1.85	0.05	erate rel
Particulars of Baggage Handling		◀		◄		6	5.09	0.14	Mode
Particulars of Reception and Gate Facilities	◄	•				6	3.52	0.09	◀
Particulars of Duty Free/ Transit/ Lounge						6	5.80	0.15	
Particulars of Security and Customs				◀		2	1.51	0.04	nship
Particulars of Check-In services		•		◀		2	1.85	0.05	g relatic
Means of Mass Transit (Transport to terminal)		•				6	3.05	0.08	Stron
Сепетаl рагтісиlars	◄	•				6	3.52	0.09	
	Safe and speed airfield operation	Cheaper service fees	Compatible with Airplane	Convenience of passenger services	Proper Baggage Handling	Max. value in column	Sum product	Relative weight	Relationship Indicators
Relative weight	0.09	0.34	0.06	0.30	0.21				
Max. value in row	6	6	6	6	6				
.0 МоЯ	7	7	m	4	ъ				

HoQ of Airline Company Satisfaction

Table 8: House of quality matrix for airline company's requirements (Edge #2 vs. #3)

	Sum	35.49	1.00	Sum	37.41	1.00	Sum	1.00		
Particulars of Green Airport Framework	1	0.55	0.02	9	3.09	0.08	9	0.05		7
Particulars of Airfield Operations	6	1.49	0.04	9	3.18	0.09	9	0.06		9
Particulars of Cost and Pricing (USD)	6	4.03	0.11	6	4.96	0.13	6	0.12		0
Particulars of Private Services	5	2.57	0.07	5	1.85	0.05	5	90.06		9
Particulars of Baggage Handling	6	3.64	0.10	6	60.2	0.14	6	0.12		0
Particulars of Reception and Gate Facilities	5	3.07	0.09	6	3.52	0.09	6	0.09		4
Particulars of Duty Free/ Transit/ Lounge	6	6.08	0.17	6	5.80	0.15	6	0.16		Θ
Particulars of Security and Customs	6	2.82	0.08	5	1.51	0.04	6	0.06		9
Particulars of Check-In services	6	3.15	0.09	5	1.85	0.05	6	0.07		ß
Means of Mass Transit (Transport to terminal)	6	3.67	0.10	6	3.05	0.08	6	60.0		4
General particulars	6	4.42	0.12	6	3.52	0.09	6	0.11		6
	Max. value in column	Sum product	Relative weight	Max. value in column	Sum product	Relative weight	Max. value in column		Mean relative weight	Priority Rank
		Passenger		A inline	Company				Synthesis	

Table 9: Design/ Selection objectives (Assessment of Edge #3)

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<sup>i</sup> Although, we prefer 9-5-1 scale for the empirical work, further studies can be performed under 9-3-1 scale or any other scales according to the intended context.

# **Factors Attracting Foreign Low Cost Carrier's Choice of Airports**

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## Abstract

Low cost operation has been a popular business model that is dramatically different with traditional full services in the airline industry. However, Taiwan has no national low cost carriers (LCCs) yet, even though the first foreign LCC had operated into Taiwan in 2004. Currently, creating an ideal environment to attract foreign LCCs is vital for air transport markets in Taiwan, but most LCCs serve at the Taoyuan International Airport (TPE). This phenomenon varies with the development of using secondary airports in other area cases. This study aims to explore the determinants that influence the airport choice of foreign LCCs. Through an expert investigation, this paper proposes a hierarchic framework to examine the critical criteria and affiliated sub-criteria. This study exploits a Fuzzy Analytic Hierarchy Process (FAHP) to evaluate the relative weights of all sub-criteria and the potential of three main airports, i.e., TPE, Taipei Songshan Airport (TSA) and Kaohsiung International Airport (KHH), in Taiwan. A rank pair-wise comparison (RPC) is used to measure the relative weights for the expert questionnaires. This approach can totally satisfy the requirement of consistent expression. The analysis results reveal that airport authority promotion policy is the most important criteria and TPE is still the most contestable airport in Taiwan.

*Keywords: Low Cost Carrier (LCC), Fuzzy Analytic Hierarchy Process (FAHP), Rank Pair-wise Comparison (RPC)* 

## 1. Introduction

Low cost carriers (LCCs) have reshaped the competitive environment within liberalized markets and some domestic passenger markets (O'Connell and Williams, 2005). The product features of LCCs are entirely different with that of traditional full service carriers (FSCs). A direct brand impression of LCCs is lower fares than the full-service airlines on the same market. This advantage bases on many different strategies for reducing airline's costs (Vasigh et al., 2008).

As the mature of LCC business and the increase of passenger acceptance, some studies express anxiety for the growth of LCCs (Aydemir, 2012; Klophaus et al., 2012; Wit and Zuidberg, 2012). However, the business of LCC is just booming in Taiwan, like the progress in some Asian countries (O'Connell and Williams, 2005; Lawton and Solomko, 2005). Taiwan has no national LCCs yet, even though the first foreign LCC had operated into Taiwan in 2004. The government assessment and local academic studies all reveal that Taiwan still lacks sufficient conditions to set up Taiwanese LCCs, but can create a successful environment to attract foreign LCCs.

In 2012, 10 airlines in total 12 foreign LCCs served at the Taoyuan International Airport (TPE) for 8 scheduled international routes. The rest LCCs operated flights at the Taipei Songshan Airport (TSA) for one route. Table 1 shows the seat provision of LCCs and FSCs in all routes, i.e., TPE-SIN, TPE-MNL, TPE-KUL, TPE-KIX, TPE-BKI, TPE-PUS, TSA-GMP, TPE-CJU, and TPE-NRT. The percentages of LCC seat capacities in these services are different, the highest over 50% and the lowest below 10%. Although LCCs provide fewer seats than FSCs in the most of routes, LCC's passenger load factors are higher than that of FSCs except new opening services as shown in Table 2. LCC's passenger load factors of 7 in 9 routes are all over 70%, even over 80% on 4 routes. Using the number of embarkation passengers, the LCC's market shares in TPE-BKI and TPE-PUS are more than 50%. Market shares in TSA-GMP and TPE-CJU can reach above

40%. However, the LCC contestability in TPE-NRT, TPE-SIN, TPE-MNL, and TPE-KIX is not strong than other routes as shown in Figure 1.

Route	TPE-SIN	TPE-MNL	TPE-KUL	TPE-KIX	TPE-BKI	TPE-PUS	TSA–GMP <sup>1</sup>	$TPE-CJU^2$	TPE-NRT <sup>3</sup>			
LCC	453,634	134,685	354,982	263,880	87,120	129,696	83,076	34,912	51,456			
LCC	(26.5%)	(13.5%)	(39.5%)	(15.6%)	(43.3%)	(63.3%)	(52.4%)	(47.1%)	(8.2%)			
ESC	1,256,360	866,022	543,835	1,430,526	114,186	75,046	75,526	39,176	573,397			
FSC	(73.5%)	(86.5%)	(60.5%)	(84.4%)	(56.7%)	(36.7%)	(47.6%)	(52.9%)	(91.8%)			
Total	1.709.994	1.000.707	898.817	1.694.406	201.306	204.742	158.602	74.088	624.853			

Table 1: Seat provision of routes with LCC services in 2012

<sup>1, 2, 3</sup> LCC services start from Apr., Jun. and Oct. 2012, respectively.

Source: Civil Aeronautics Administration, Taiwan

Table 2: Average	load factors	of routes with	LCC	services in	2012
------------------	--------------	----------------	-----	-------------	------

TPE-SIN	TPE-MNL	TPE-KUL	TPE-KIX	TPE-BKI	TPE-PUS	TSA-GMP	TPE-CJU	TPE-NI
81.66%	82.18%	83.49%	75.44%	76.37%	82.43%	55.43%	72.90%	44.53%
70.28%	62.85%	78.13%	71.25%	71.35%	59.92%	68.79%	75.17%	73.96%
74.55%	67.01%	79.24%	72.00%	75.53%	74.33%	60.02%	74.27%	70.00%

Source: Civil Aeronautics Administration, Taiwan

Figure 1: Market shares for Taiwanese LCC markets in 2012



The analysis for Taiwanese LCC markets reveals the TSA airport has a potential to attract passengers taking LCC services in spite of only one operated route. The TPE airport is not totally of advantage in the entire market. Currently, the Kaohsiung International Airport (KHH) has not any LCC operating into it yet. The phenomenon varies with the development of using secondary airports in the cases of other areas.

This study aims to explore the determinants that influence the airport choice of foreign LCCs. Through an investigation of experts, a hierarchic framework is built to examine the critical criteria and affiliated sub-criteria. This study exploits a Fuzzy Analytic Hierarchy Process (FAHP) to evaluate the relative weights of all sub-criteria and the potentials of three main Taiwan airports, i.e., TPE, TSA, and KHH.

## 2. Methodologies

Route LCC FSC Total

## 2.1 Analytic Hierarchy Process (AHP)

The AHP is one of the popular multi-criteria decision-making methods and has been successfully applied to different fields (Kumar and Vaidya, 2006; Ho, 2008). In problem modeling, the AHP permits decision-makers to construct a hierarchical structure, traditionally composed of goal, criteria, sub-criteria and alternatives. This process can logically allocate the relative weights of specific criteria and sub-criteria, and then to assess the better alternatives. Saaty (1977) proposed to employ a pair-wise comparison matrix for the evaluation of relative weights.

Suppose a pair-wise comparison matrix P, an  $n \times n$  matrix, is formed by  $p_{ij}$  and  $p_{ji} = p_{ij}^{-1}$ . For estimating the weight vector, w, we can solve the equation, Pw = Iw, where I is an identity matrix. Saaty (1977) applied the eigenvector approach to solve  $Pw = \lambda_{\max}w = nw$ , where  $\lambda_{\max}$  is the maximal eigenvalue. An average of normalized columns (ANC) approach, as shown in Equation (1), is a simple method to estimate the eigenvector (Saaty, 1980), i.e., the relative weight vector w.

$$w_{i} = \frac{1}{n} \sum_{j=1}^{n} \frac{p_{ij}}{\sum_{i=1}^{n} p_{ij}} \quad \forall i$$
 (1)

A perfectly consistent pair-wise matrix has to satisfy the transitivity rule,  $p_{ij} = p_{ik} \times p_{kj}$ , for every element in the matrix, just like P in Equation (1). However, Saaty (1977) notes that a slight inconsistency is possible, as people's judgments may not be transitive. Therefore, a consistency check is required to ensure an acceptable level. A consistency ratio (*CR*) is defined as the ratio of a consistency index (*CI*) and a random index (*RI*), *CI* =  $(\lambda_{max} - n)/(n - 1)$  and *CR* = *CI/RI*. The *RI* is a series of values with different orders and scales, as proposed by Saaty (1977). If the *CR* value is lower than 0.1, the matrix can then be considered as having an acceptable consistency. Following these processes, one can estimate a stable eigenvector for relative weights of involved objectives. The remaining step is to aggregate the scores of surveyed alternatives for ranking their priorities.

#### 2.2 Rank Pair-wise Comparison (RPC)

The pair-wise comparison is a building block in conducting the AHP. However, this technique is also a time-consuming process while having too many comparative elements. This necessary process generally makes decision makers unable to discriminate the relative weights that are needed to reach the acceptably consistent level. In particular, when decision makers encounter elements with closer perceived relationships, the inconsistency in responses easily takes place. To ask them adjusting the responses for reaching the minimum consistency level is so complicated that their original intention might be distorted. The reason for this phenomenon might be that decision makers do not rank the element priorities in advance for further comparison.

This study proposes an RPC approach that asks respondents to express the priorities of involved elements, then to assess the relative weights for two consecutive ranks. Using multiples of relative weights and the reciprocal principle, we obtain the pair-wise comparison matrix. There are *n* elements to be evaluated to determine their relative weights. If a respondent has revealed his priorities, ranked from  $r_1$  to  $r_n$ , he can further express the comparative weights for consecutive ranks, i.e., the values of  $p_{\eta_1, \tau_2} = w_{\eta_1}/w_{\tau_2}$ ,  $p_{\tau_2, \tau_3} = w_{\tau_2}/w_{\tau_3}$ , ...,  $p_{\tau_2, \tau_3} = w_{\tau_1}/w_{\tau_2}$ . Other comparative weights for inconsecutive ranks can then be calculated as follows.

$$p_{r_{1},r_{3}} = \frac{w_{r_{1}}}{w_{r_{3}}} = \frac{w_{r_{1}}}{w_{r_{2}}} \times \frac{w_{r_{2}}}{w_{r_{3}}} = p_{r_{1},r_{2}} \times p_{r_{2},r_{3}}, p_{r_{1},r_{4}} = p_{r_{1},r_{3}} \times p_{r_{3},r_{4}}, \dots, p_{r_{1},r_{n}} = p_{r_{1},r_{n-1}} \times p_{r_{n-1},r_{n}},$$

$$p_{r_{2},r_{4}} = \frac{w_{r_{2}}}{w_{r_{4}}} = \frac{w_{r_{2}}}{w_{r_{3}}} \times \frac{w_{r_{3}}}{w_{r_{4}}} = p_{r_{2},r_{3}} \times p_{r_{3},r_{4}}, p_{r_{2},r_{5}} = p_{r_{2},r_{4}} \times p_{r_{4},r_{5}}, \dots, p_{r_{2},r_{n}} = p_{r_{2},r_{n-1}} \times p_{r_{n-1},r_{n}},$$

$$\dots, p_{r_{n-2},r_{n}} = \frac{w_{r_{n-2}}}{w_{r_{n}}} = \frac{w_{r_{n-2}}}{w_{r_{n-1}}} \times \frac{w_{r_{n-1}}}{w_{r_{n}}} = p_{r_{n-2},r_{n-1}} \times p_{r_{n-1},r_{n}}$$

As the calculation above is the definition of the transitivity rule, other elements in the matrix can be filled in accordance with the reciprocal property. This matrix will be perfectly consistent. However, this process will enlarge the difference between  $p_{r_1,r_2}$  and  $p_{r_{n-1},r_n}$ . If the scales used are *s*-point measures, their maximal difference is  $s^{n-1}$ . Normally, one would like and to yield all relative weights falling between 1 and *s*. The range between consecutive linguistic variables must be adjusted. Let *d* be the adjusted range, so that  $d \times (s^{n-1} - 1) = s - 1$ , or  $d = (s - 1)/(s^{n-1} - 1)$ . It is noted that the minimum of the new scales is still 1.
The RCP can satisfy the requirement of consistent expression. The opinion collection and calculation process of weight estimation are relatively less complex than in traditional pair-wise comparison. The number of comparisons is n - 1 for n elements, while the number of comparisons using the tradition method is n(n - 1)/2. This study uses the RPC and Equation (1) to obtain the relative weights of the determinants and alternatives in the designed AHP framework.

#### 2.3 Fuzzy Numbers

A fuzzy set is a class of objects with a continuum of membership grades. Such sets characterized by a membership function assign each object a membership grade ranging from zero to one (Zadeh, 1965). Let X be a universal set. Fuzzy set A in X is characterized by a membership function  $f_A(x)$ , which associates a real number in the interval between 0 and 1 with each point in X. The value of  $f_A(x)$  at x represents the membership grade of x in A.

Using a triangular fuzzy number to express decision maker's fuzziness is one of the popular methods of defining the membership function. The membership grades for a triangular fuzzy number *A* in real line  $\Re$  referring to  $f_A: \Re \to (0, 1)$  can be expressed as shown in Equation (2), where  $-\infty < c \le a \le b < \infty$  (Dubois and Prade, 1978). The grade of *a* represents a maximal grade of membership in *A*. This grade has the most probable value in the evaluation data, *i.e.*  $f_A(a) = 1$ . The interval (c, b) is the range of the lower and upper bounds of this set. The length of this range can represent the fuzziness of the evaluation data. The shorter the length of the interval (c, b) is, the lower the fuzziness of the evaluation data will be. Thus, a triangular fuzzy number *A* can be represented by A = (c, a, b).

$$f_{A}(x) = \begin{cases} (x-c)/(a-c), \ c \le x \le a \\ (x-b)/(a-b), \ a \le x \le b \\ 0, \ otherwise \end{cases}$$
(2)

With this notation, let  $A_1 = (c_1, a_1, b_1)$  and  $A_2 = (c_2, a_2, b_2)$  be two fuzzy numbers. According to the extension principles (Zadeh, 1965), the algebraic operations of two fuzzy numbers can be expressed as follows.

- (1) Addition of triangular fuzzy numbers:  $A_1 \oplus A_2 = (c_1 + c_2, a_1 + a_2, b_1 + b_2)$
- (2) Subtraction of triangular fuzzy numbers:  $A_1 \Theta A_2 = (c_1 b_2, a_1 a_2, b_1 c_2)$
- (3) Multiplication of triangular fuzzy numbers:  $k \otimes A_1 = (kc_1, ka_1, kb_1), k \ge 0, k \in \Re$  and  $A_1 \otimes A_2 \cong (c_1c_2, a_1a_2, b_1b_2), c_1 \ge 0, c_2 \ge 0$
- (4) Division of triangular fuzzy numbers:  $A_1 \oslash A_2 \cong (c_1/b_2, a_1/a_2, b_1/c_2), c_1 \ge 0, c_2 \ge 0$

#### 3. Analysis Model

The fundamental to conduct AHP or FAHP is to construct an analysis hierarchy framework. This section first introduces the factors that have discussed in previous literature. Adding some other potential factors, this study then present the proposed analysis hierarchy framework for airports attracting foreign LCCs to operate. Finally, we propose a FAHP procedure to conduct our analysis.

#### 3.1 Selected Factors

Several studies have contributed to the exploration of airport selection for airlines, not only for LCCs but also for full-service airlines and cargo business. In the LCC's field, Adler and Berechman (2001) indicate that the airport quality is getting more and more important when airlines choosing hub location. In their designed questionnaire, some variables, such as peak short, medium haul charges, minimum connecting times, airport turn-around times, slot availability, the reliable of ATC, local labor costs, airports charges, and potential demand, are mentioned for measures.

Francis et al. (2003) interview airport managers to conduct case studies for the LCC impact to two secondary European airports. They found that secondary airports usually rely on aeronautical revenues to maintain their

livelihood. Barrett (2004) also indicates that secondary airports are usually far away from the urban area, which will increase the average utilization rate of near the airport car rental. The practice of no-frill service makes passengers spend much money in airports. Airports might, thus, reduce the charges to attract LCCs to operate, due to the increase of non-aeronautical revenues. Gillen and Lall (2004) have the same observation on airport charges between the relationships of LCCs and airports. Moreover, they particularly indicate that the value of airports is location. That is why Southwest and Ryanair consider the location of airports is one of important factors in choosing airports. Location advantages imply a large economic and population base that might be attractive to travelers.

Lawton and Solomko (2005) highlight operating conditions of the secondary airports are necessary to ensure rapid turnaround times that is critical for LCCs to increase the average daily utilization of their aircraft. Although, many passengers, including business travelers, are willing to endure the inconvenience of airport locations in exchange for a lower fare, LCCs must consider the maximum distance that travelers can endure in the selection of airports.

Warnock-Smith and Porter (2005) survey 15 airport choice factors of the eight European LCCs. The results reveal that high demand for LCC services is the fundamental factor, followed by quick and efficient turnaround facilities, convenient slot times, good aeronautical discounts, etc. Small size LCCs, because of weak capitals, may pay more attention on non-aeronautical revenue of airports than large size LCCs. They worry about airports might increase the charge to LCCs when lacking non-aeronautical revenue.

Chang et al. (2008) model a framework that LCCs select China's airports for the flights across the Taiwan Strait. Airport competitiveness, infrastructures and potential demand are the survey criteria. The involved factors include airport charge, airport operation hours, distance between airport and downtown, airport surface transport, terminal floor area, runway classification, navigation aids, and estimated demand of destination.

The opinions of full service airlines in airport selection are quite different with LCCs. Berechman and de Wit (1996) find that airport charges, demand and airport capacity are significant factors on airlines' choice of airports. However, Graham (2001) indicates that airport charges account for a small portion of the total operating costs for the traditional airlines, so it may not be the most important factor. The factors affecting the choices of airports include catchment area and potential demand, slot availability, competition, network compatibility, airport fees and availability of discounts, other airport costs (e.g. fuel, handling), marketing support, range and quality of facilities, ease of transfer connections, maintenance facilities, and environment restrictions. Gardiner et al. (2005) performed an international survey of airport selection for cargo airlines. They find some factors are special for the freighter operations, such as night curfews and freight forwarders, in addition to some common factors like airport charges.

Table 1 lists the detailed factors affecting airport choices of airlines discussed in the mentioned studies. However, we aim to evaluate the main competitive conditions of airports for attracting foreign LCCs to operate. It is assumed that the potential traffic demand for opening services has been verified. We delete some factors that are not concerned with this study, such as labor costs, non-aeronautical revenues, ambitious expansion plans, airport competition, and network compatibility. Based on the possible factors filtered from the mentioned studies, this paper systematically illustrates the detailed critical factors for investigation. For example, the condition of quick turnaround time is caused by many reasons, such as ramp operation, fueling support, aircraft maintenance etc. We also append possible factors with every linkage relative to our topic.

## 3.2 Evaluation Hierarchy

We designed a questionnaire to list possible factors to ask the expert to express their importance with a Likert's 5-point scales. The threshold of acceptance is 3 points in average. We distributed questionnaires to thirteen academic experts who all ever published their works regarding LCC business on local or international journals. Eight copies, 62% of return rate, were received. Three factors, i.e. airport with civilization administration organization or not, the number of LCCs operating at airport, and the consuming level of service cities, were deleted. The factor of airport authority's support attitude was suggested to add in.

The ultimate aim of the analysis model is to evaluate the airport determinates of attracting foreign LCCs. All factors are categorized into 5 criteria, 4 sub-criteria in each. The AHP framework is shown in Figure 1 for assessing the potential of three main airports in Taiwan.

Factors	Berechman & De Wit (1996)	Adler & Berechman (2001)	Graham (2001)	Francis et al. (2003)	Barrett (2004)	Gillen & Lall (2004)	Lawton & Solomko (2005)	Warnock- Smith & Porter (2005)	Chang et al. (2008)	This study
Airport location			~			~	~	~	*	*
Airport or terminal capacity	*		*					*	*	*
Labor costs		Ť								
Single-storey airport terminals					>					>
Quick check-in procedure					*					*
Passenger demand	~	Ť	~			~		~	*	*
Airport charges	*	~		*	*	~	*	*	*	*
Airlines competition			*					*		*
Transport connections			*		*					*
Convenient slot times		~	¥			~		¥		*
Turnaround time		~			~		×	×	~	~
Good experience of LCCs								*		*
Non-aeronautical revenues				<b>,</b>	*			~		
Airport privatization								*		*
Ambitious expansion plans								¥		
Environment restrictions			*					*		*
Cost conscious airport management								*		*
Surface access and transport								*	*	*
Runway and navigation aids									*	*
Airport competition								¥		
Maintenance facilities			~							~
Reliable air traffic control		×								~
Network compatibility			~							

Table 1: Factors of airport choice in previous literature and this study

#### 3.3 FAHP Procedure

A systematic procedure to conduct our analysis is proposed as follows. Steps 1 to 3 have been introduced.

Step 1: Select possible factors attracting foreign LCCs' choices of airports.

- Step 2: Conduct an expert survey to ensure the investigation factors.
- **Step 3**: Construct the AHP framework.
- Step 4: Design the investigation questionnaire following the requirement of the RPC approach.
- Step 5: Distributed questionnaires to experts.
- **Step 6**: Collect experts' opinions and calculate the weights of all sub-criteria and the evaluation scores of alternatives in every sub-criterion, replacing the pair-wise comparison by the RPC approach.
- Step 7: Define the fuzzy numbers for the weight of every sub-criterion, and every evaluation score for each alternative. Let the weight of sub-criterion *i* be a triangular fuzzy number A<sub>i</sub>. A<sub>i</sub> is defined as Equation (3) for *k* experts' opinions. Let the evaluation score of sub-criterion *i* for alternative *j* be a triangular fuzzy number A<sub>ii</sub>. A<sub>ii</sub> is defined as Equation (4) for *k* experts' opinions.

$$A_i = (c_i, a_i, b_i)$$
, where  $c_i = Min. \{A_i^k\}, a_i = Mean \text{ of } \{A_i^k\}$ , and  $b_i = Max. \{A_i^k\}$  (3)

$$A_{ij} = (c_{ij}, a_{ij}, b_{ij})$$
, where  $c_{ij} = Min.\{A_{ij}^{k}\}, a_{i} = Mean \text{ of } \{A_{ij}^{k}\}, and b_{i} = Max.\{A_{ij}^{k}\}\}$  (4)

- **Step 8**: Integrate the fuzzy performance for alternatives on each sub-criterion using the multiplication operation of triangular fuzzy numbers.
- **Step 9**: Conduct the defuzzification process for the quantified performance of each sub-criterion for each alternative using the center of gravity method as Equation (5). Then, we sum the defuzzification values of all criteria for each alternative and use it to rank their potentials.  $DF = c_i + [(a_i - c_i) + (b_i - c_i)]/3$ (5)



Figure 1: The framework for evaluating airport determinates of attracting foreign LCCs

#### Rank Pair-wise Comparison & Fuzzy Number Operation

#### 4. **Results and Discussions**

The investigation group for LCC's airport selection is supposed to be the LCC airlines managers. However,

the headquarters of target LCCs all locate at the foreign counties. It might be a difficult and time consuming process to investigate the foreign airline managers for this study. We invited some managers of airlines which have ever expressed the interests to set up LCCs and academics who ever published relative papers in international or local journals. The expert group consists of 16 academic professors, 6 senior airline managers, and 2 senior airport managers. Detailed results with the proposed FAHP procedure are discussed as follows.

## 4.1 Critical Factors

The weights of criteria in each questionnaire are distributed as the relative importance of sub-criteria. We can obtain the final weights of all sub-criteria for all experts. Following the definition of triangular fuzzy numbers and the defuzzification method, the range of lower and upper bounds of fuzzy sets and defuzzification results for each sub-criterion are displayed in Table 2.

Table 2. Fully weights and relative ranks for sub-criteria							
Criteria	Sub-criteria	Min.	Average	Max.	DF	Rank	
Land side	Traffic convenience between airport & service cities	0.0443	0.0523	0.0700	0.0555	4	
connection &	Distances between airport & service cities	0.0438	0.0497	0.0606	0.0514	12	
development	Populations of service cities	0.0410	0.0483	0.0581	0.0492	16	
(0.1984)	Exclusive terminal for low cost carriers	0.0406	0.0489	0.0605	0.0500	15	
Down operation	Support ability for aircraft maintenance operation	0.0422	0.0483	0.0521	0.0475	18	
conditions	Operation efficiency of ramp services	0.0455	0.0542	0.0739	0.0579	2	
(0.2027)	Supply convenience of aircraft fueling	0.0411	0.0476	0.0514	0.0467	20	
(0.2027)	Assignment policy of boarding gates & relative facilities	0.0406	0.0491	0.0691	0.0530	6	
Flight infrastructure & management	Air traffic congestion level	0.0408	0.0497	0.0709	0.0538	5	
	Ability of air traffic control	0.0413	0.0488	0.0638	0.0513	13	
	Compatibility between used aircraft type & runway conditions & navigation aids	0.0412	0.0484	0.0553	0.0483	17	
(0.2001)	Flexibility of time slot provision	0.0444	0.0519	0.0621	0.0528	7	
Passenger traffic	Efficiency of baggage handling	0.0412	0.0482	0.0525	0.0473	19	
operation	Convenience & efficiency of CIQ procedure	0.0408	0.0501	0.0645	0.0518	10	
conditions	Availability of ground agent selection for passenger handling	0.0434	0.0498	0.0615	0.0516	11	
(0.1978)	Check-in facilities & flight information systems	0.0434	0.0502	0.0623	0.0519	8	
A import outhouitu's	Allowance for the number of flights in the same route	0.0411	0.0492	0.0607	0.0503	14	
promotion policy	Incentive alternatives for low cost carriers	0.0415	0.0504	0.0635	0.0518	9	
(0.2122)	The level of airport's tariff	0.0448	0.0542	0.0748	0.0579	1	
(0.2132)	Airport authority's support attitude	0.0449	0.0506	0.0761	0.0572	3	

Table 2: Fuzzy weights and relative ranks for sub-criteria

The level of airport's tariff is the most important condition for an airport to attract foreign LCCs operation, followed by operation efficiency of ramp services. Airport authority's support attitude is also a critical factor. In the landside connection and development, traffic convenience between airport and service cities, rather than distances or populations. The exclusive terminal for low cost carriers is not so important than the assignment policy of boarding gates and relative facilities. Congestion incurred from air traffic and time slots for planning flight are vital for LCCs. Airport authority's promotion policy seems the most important criteria. If the airport can provide the incentive alternatives for LCCs, it will generate some attractions for LCCs considering.

#### 4.2 Airport Evaluation

Table 3 shows experts' ratings in the triangular fuzzy definition of each sub-criterion for three evaluated airports, i.e., TSA, TPE, and KHH. Using the defuzzification process, we can obtain the evaluation results as shown in Table 4. The results of summing the values of all criteria for airports reveal that Taipei Taoyuan airport (TPE) is the airport with the potential to attract foreign LCCs. This airport has highest score on airport authority's support attitude because it is unique civilization airport in Taiwan. Taoyuan airport obtain higher assessment on ramp operation conditions and passenger traffic operation conditions.

The potential of KHH airport is higher than TSA airport. Although KHH airport has no LCC operating into, its development may be expected, such as building the exclusive terminal for LCCs and flexible time slots. Air traffic without congestion and flexible provision of time slots and lower tariff are the most attracting conditions of KHH airports. Although TSA airport has lower competitiveness to attract LCCs, it still has an advantage on the location with the service cities. It is so close with Taipei city that many passengers like to access this airport for available flights.

Table 5: Fuzzy performance values for evaluated airports									
Sub criteria		TSA		TPE				KHH	
Sub-entena	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Traffic convenience between airport & service cities	0.2612	0.4019	0.4937	0.2375	0.3131	0.5068	0.2320	0.2850	0.3273
Distances between airport & service cities	0.2921	0.4279	0.5133	0.2278	0.2784	0.3273	0.2372	0.2937	0.4442
Populations of service cities	0.2721	0.3848	0.4910	0.2355	0.3358	0.4751	0.2430	0.2794	0.3296
Exclusive terminal for low cost carriers	0.2320	0.2884	0.3333	0.2278	0.3828	0.4751	0.2494	0.3289	0.5133
Support ability for aircraft maintenance operation	0.2321	0.2847	0.3273	0.3636	0.4368	0.5105	0.2372	0.2786	0.3091
Operation efficiency of ramp services	0.2430	0.3104	0.4751	0.2332	0.3802	0.4855	0.2499	0.3094	0.5003
Supply convenience of aircraft fueling	0.2564	0.3223	0.4789	0.2438	0.3667	0.4606	0.2727	0.3111	0.4540
Assignment policy of boarding gates & relative facilities	0.2430	0.2955	0.3999	0.2375	0.3854	0.4855	0.2532	0.3191	0.4937
Air traffic congestion level	0.2321	0.3061	0.4684	0.2462	0.3421	0.4855	0.2430	0.3517	0.5105
Ability of air traffic control	0.2278	0.2998	0.3333	0.3041	0.3977	0.5133	0.2441	0.3025	0.3919
Compatibility between used aircraft type & runway conditions & navigation aids	0.2321	0.2934	0.3406	0.2656	0.3929	0.5105	0.2271	0.3136	0.4855
Flexibility of time slot provision	0.2430	0.2912	0.3333	0.2375	0.3293	0.4855	0.2494	0.3796	0.4937
Efficiency of baggage handling	0.2375	0.3157	0.4245	0.2375	0.3596	0.4937	0.2636	0.3247	0.4937
Convenience & efficiency of CIQ procedure	0.2430	0.3213	0.4606	0.2320	0.3524	0.4855	0.2565	0.3263	0.5068
Availability of ground agent selection for passenger handling	0.2320	0.3073	0.3948	0.2565	0.3860	0.5068	0.2564	0.3067	0.4540
Check-in facilities & flight information systems	0.2375	0.3066	0.4122	0.2565	0.3869	0.4937	0.2591	0.3065	0.4540
Allowance for the number of flights in the same route	0.2430	0.3190	0.4540	0.2565	0.3274	0.4855	0.2438	0.3536	0.4540
Incentive alternatives for low cost carriers	0.2332	0.3080	0.4034	0.2852	0.3521	0.5003	0.2430	0.3399	0.4619
The level of airport's tariff	0.2494	0.2994	0.3333	0.2332	0.3281	0.4751	0.2749	0.3726	0.5003
Traffic convenience between airport & service cities	0.2494	0.3169	0.3948	0.2721	0.3407	0.4708	0.2799	0.3424	0.4474

Table 3: Fuzzy performance values for evaluated airports

Sub-criteria	TSA	TPE	KHH
Traffic convenience between airport & service cities	0.0224	0.0208	0.0160
Distances between airport & service cities	0.0217	0.0146	0.0173
Populations of service cities	0.0194	0.0178	0.0142
Exclusive terminal for low cost carriers	0.0146	0.0189	0.0191
Support ability for aircraft maintenance operation	0.0135	0.0210	0.0132
Operation efficiency of ramp services	0.0210	0.0224	0.0217
Supply convenience of aircraft fueling	0.0168	0.0170	0.0164
Assignment policy of boarding gates & relative facilities	0.0173	0.0207	0.0200
Air traffic congestion level	0.0193	0.0205	0.0212
Ability of air traffic control	0.0151	0.0216	0.0166
Compatibility between used aircraft type & runway conditions & navigation aids	0.0142	0.0194	0.0171
Flexibility of time slot provision	0.0155	0.0193	0.0205
Efficiency of baggage handling	0.0158	0.0177	0.0175
Convenience & efficiency of CIQ procedure	0.0186	0.0195	0.0198
Availability of ground agent selection for passenger handling	0.0166	0.0205	0.0181
Check-in facilities & flight information systems	0.0171	0.0204	0.0183
Allowance for the number of flights in the same route	0.0177	0.0187	0.0183
Incentive alternatives for low cost carriers	0.0169	0.0205	0.0189
The level of airport's tariff	0.0174	0.0213	0.0233
Airport authority's support attitude	0.0191	0.0218	0.0213
Total performance	0.3502	0.3942	0.3689
Rank	3	1	2

Table 4: Evaluation results for three airports

#### 5. Conclusion and Suggestion

LCC businesses are gradually flourishing in Asian markets. Although there has no national LCCs in Taiwan, the effort of airports to attract foreign operators is never neglected. This study contributes to collect the factors of airport choices in airlines to survey the potential of three main airports in Taiwan. Through a proposed FAHP procedure, it is found that the level of airport's tariff is the most important factor, followed by operation efficiency of ramp services and airport authority's support attitude. Airport authority's promotion policy is the most critical criterion. Taipei Taoyuan airport (TPE) is the airport with highest potential to attract foreign LCCs operation standing on a general perspective.

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# Evaluating the Relationship between Service Attributes, Customer Performance and Financial Performance for Air Cargo Forwarders in Taiwan

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## Abstract

Asian air cargo industry has witnessed consistent growth over the past few years and far outpaced the broader world economy. But not all Asian cargo airports are growing so quickly; for example, this is not the case for Taiwan Taoyuan International Airport (TPE). One of the reasons given for TPE's lower cargo traffic is the state of surrounding industries. In this difficult business environment, providing the best service to consignees in order to gain superior competitive advantage has become an important issue for Taiwan's air cargo forwarders. This study sets out to address the gap in knowledge by testing whether there is a relationship between the service attributes and the performance of these companies.

A survey of 500 air cargo forwarders in Taiwan was carried out in order to examine their service attributes, using factor analysis and mediator multiple regression analysis. Results identified four critical service factors, namely, basic service attributes, pricing attributes, value-added, and basic transport attributes. A direct positive relationship between a synthesis of the four service factors and finance performance was established. Specifically, it was confirmed that critical service factors affected customer performance. Overall, findings suggest that air cargo forwarders' top managers should constantly seek to enhance and refine their firms' four key service factors and customer performance over and above those of their competitors in order to gain superior financial performance.

Keywords: Air cargo forwarders, Service attributes, Performance

## 1. Introduction

Asian air cargo industry has witnessed consistent growth over the past few years and far outpaced the broader world economy. Moreover, Asian air cargo markets will continue to lead the world air cargo industry in average annual growth rates, with domestic China and intra-Asia markets expanding 8.0% and 6.9% per year, respectively (Boeing World Air Cargo Forecast Team, 2012).

But not all Asian cargo airports grow so quickly; for example, this is not the case for Taiwan Taoyuan International Airport (TPE), as show in Figure 1. This airport had seen negative growth in cargo traffic for four consecutive years from 2006 to 2009, which was the lowest grow rate in average on the main Asia' cargo airport (-21.9/4=-5.5%), followed by Tokyo (-20.3/4=-5.1%) and Singapore (-10.2/4=-2.6%). Moreover, Taiwan Taoyuan International Airport also lost traffic at an average rate of -6.1% ((-7.9-4.2)/2) from 2011 to 2012, returning to the bottom of Asia's main cargo airports again in terms of growth. One of the reasons given for the lack of success in terms of cargo traffic is the state of surrounding industries. Some of Taiwan's

manufacturing, such as laptops and electronics components, has been moved to China in recent years (Sun et al., 2010).

In this difficult business environment, providing the best service to consignees to gain superior competitive advantage has become an important issue for Taiwan's air cargo forwarders. Previous research studies have examined the factors affecting logistics provider performance and the extent of 3PL use (e.g., Liu and Lyons, 2011). However, there has been relatively little attention given to empirical studies of air cargo forwarders. This study sets out to address this gap in knowledge from resource-based view (RBV) by testing whether there is a relationship between service attributes, customer performance, and financial performance for these companies. "Customer performance" in this context indicates the measurable points of the outcomes of customer behaviors, such as customer satisfaction and customer loyalty (Fink et al., 2008).

Key questions posed by the research are:

1. Do different forms of service attributes lead to different profitable contributions for air cargo forwarders?

2. Does customer performance have a significant effect on the financial performance of air cargo forwarders?



Figure 1: Total Cargo Traffic in Main Asian Airport, 2006-Oct 2012 (change %)

## 2. Literature Review

#### 2.1. Resource-based view of the firm

The resource-based view (RBV) of the firm "attempted to look at firms in terms of their resources rather than in terms of their products" (Wernerfelt, 1984). Over the last ten years, the RBV has been employed in logistics-related research to assess the contribution of service attributes on logistics firm performance (Lai, 2004; Liu and Lyons, 2011; Shang, 2009). For example, Lai (2004) indicated that full service providers had the best firm performance. Liu and Lyons (2011) concluded that through better operational performance, 3PLs will gain superior financial performance both in Taiwan and the UK. Researchers found logistics-related attributes, such as service attributes, to be significantly positively related to firm performance. Therefore, the RBV can establish a theoretical base for this study that seeks to explore the relationships between service attributes and firm performance for air cargo forwarders.

Total Cargo: loaded and unloaded freight and mail in metric tonnes. Data resource: Airports Council International (2012, 2013)

## 2.2. Service attributes

Service attributes of the 3PLs represent the process of delivering products, such as information system and logistics value-added services. Numerous previous studies have identified a number of examples of logistics service attributes (e.g., Abshire and Premeaux, 1991; Bardi et al., 1989; Cheng and Yeh, 2007; Kent et al., 2001; Lai, 2004; Liu and Lyons, 2011; Lu, 2000; Lu, 2003, 2007; Lu and Dinwoodie, 2002; Voss et al., 2006). In terms of air cargo forwarder-related studies, Cheng and Yeh (2007) analyzed the effect of core competencies on sustainable competitive advantage in air-cargo forwarding and indicated that resources, capabilities, and logistics services all affect sustainable competitive advantage of air cargo forwarders in the Taiwan logistics industry.

Based on the RBV theory, service attributes "can be seen to be a key source of leading superior performance" (Lu and Yang, 2009). Better service attributes may have a positive impact on the financial performance of air cargo forwarders. In addition, air cargo forwarders with better service attributes may be in a better position to meet the requirements of customers and, therefore, achieve better customer performance than competitors. The above considerations led to the following two hypotheses:

H1. The service attributes offered by air cargo forwarders are positively related to their financial performance. H2. The service attributes offered by air cargo forwarders are positively related to their customer performance.

## 2.3. *Customer performance*

Customer performance concerns the measurable points of the outcomes of customer behaviors, such as customer satisfaction and customer loyalty (Fink et al., 2008). Based on the RBV theory, customer performance also can be seen to be a key source of leading superior financial performance. For instance, Anderson et al. (1997) asserted that customer performance "should be a more fundamental indicator of the firm's performance." In addition, some studies indicated that customer performance had a positive influence on financial performance (e.g., Fornell, 1992; Rust and Zahorik, 1993). Thus, customer performance may have a positive impact on financial performance for air cargo forwarders. Therefore, we propose the following additional hypothesis:

H3. Air cargo forwarders whose customer performance is high have better financial performance compared to those with lower customer performance.

#### 2.4. The relationship between service attributes, customer performance, and financial performance.

A review of the literature in the area reveals the conceptual model shown in Figure 2. The model suggests that service attributes affect both customer performance and financial performance. Customer performance is cast in a mediating role between service attributes and financial performance. Stated in hypothesis form,

H4. For air cargo forwarders, the relationship between service attributes and financial performance is mediated by customer performance.



#### **Figure 2: The conceptual model**

#### 3. Methodology

3.1. Research methods

The analytical steps of the methodology are shown in Figure 3. The first step was the selection of service attributes by reviewing service attributes and air cargo forwarders research presented in the literature, followed by the design of the questionnaire, conducting personal interviews with air cargo forwarder practitioners, and a content validity test. Factor analysis was conducted to summarize and reduce the large number of service attributes into a smaller set of service factors. A reliability test was conducted to assess whether the service factors were reliable. The third step sought to identify perceived differences in key service factors based on firms' size and sales. One-way analysis of variance (ANOVA) was used to test whether significant differences existed between air cargo forwarder industries. Simple regression analysis was utilized to evaluate the relationship between service factors, customer performance, and financial performance for air cargo forwarders (H1~H3). A combination of simple and multiple regression analysis was conducted to determine whether customer performance plays an intermediary role between service factors and financial performance for air cargo forwarders (H4). All analyses were carried out using the SPSS 12.0 for Windows package.

Figure 3: Analytical steps of t	his	study	
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Selection of service attributes
Literature review
• Interview
Questionnaire design
Content validity test
$\downarrow$
Determining the key service factors
Factor analysis
Reliability test
$\downarrow$
Evaluating perceived differences in service factors according to films' characteristics
• ANOVA
$\downarrow$
Evaluation of the relationship between service factors, customer performance and financial
performance for air freight forwarders
<ul> <li>Simple regression analysis</li> </ul>
<ul> <li>Multiple regression analysis</li> </ul>

#### 3.2. Questionnaire design

A postal questionnaire was employed as the main method of data collection for this study. The questionnaire design stages followed the seven stages outlined by Churchill (1991). The questionnaire consisted of four parts: service attributes, financial and customer performance, business background information and respondent characteristics. The items selected as measures of service attributes presented in Table 1 were based upon past studies (Abshire and Premeaux, 1991; Bardi et al., 1989; Cheng and Yeh, 2007; Kent et al., 2001; Lai, 2004; Liu and Lyons, 2011; Lu, 2000; Lu, 2003, 2007; Lu and Dinwoodie, 2002; Voss et al., 2006). Seven-point Likert-type scale anchors were used. Respondents were asked to provide a rating of a company's satisfaction level with the service attributes using a seven-point Likert scale anchored by "1= very poor" and "7= excellent".

Financial performance was measured on a four-item scale (i.e., sales growth, ROI, profit, and market share) which had been employed in previous logistics literature (Lai et al., 2007; Liu and Lyons, 2011; Panayides, 2007; Wang et al., 2008). Customer performance was measured on a six-item scale (Fynes and Voss, 2001; Gupta and Zeithaml, 2006; Kumar and Shah, 2004):

- 1. Over the past few years, customer complaints have been reduced significantly.
- 2. Our customers never stopped using our service.
- 3. Over the past few years, our overall customer satisfaction is rising steadily.
- 4. Customers are satisfied with our overall service quality.
- 5. Customers would continue to use our service.

6. Customers would recommend our services to their friends or peers.

Respondents were asked to provide a rating of the company's customer and financial performance relative to their major competitors using a seven-point Likert scale anchored by "1= much worse" and "7= much better". The questionnaire was translated into Chinese and a pilot study was carried out by interviewing 14 experts working for air cargo forwarders (average length of service in the industry = 16.86 years) in order to obtain their valuable suggestions for questionnaire improvement.

## *3.3. Defining the population and sample*

The samples for this study focus on Taiwanese air cargo forwarders specific to international service routes. The population of these air cargo forwarders was drawn from the directory of the Association of Air-cargo Forwarding & Logistics in Taiwan.

## 3.4. Response rate analysis

The survey instrument was mailed to 500 respondents. The initial mailing elicited 44 usable responses. Twenty-three questionnaires were returned as non-deliverable. After two weeks, follow-up mailings were sent to those respondents who had not returned questionnaires in the first wave survey. An additional 37 usable responses were subsequently returned. The total response rate was therefore 17%, [(44+37)/(500-23)].

## 3.5. Non-response bias test

The 81 survey respondents were divided into two groups based on their response wave (first and second). Ttest analysis results revealed no significant differences (at p<0.05) as regards all service attributes variables analyzed and non-response bias was therefore not a problem (Armstrong and Overton, 1977; Lambert and Harrington, 1990).

#### 4. **Results of empirical analyses**

## 4.1. Factor analysis and reliability test

Factor analysis was used to reduce the 33 service attributes of air cargo forwarders to smaller sets of underlying factors. To aid interpretation, only variables with a factor loading greater than 0.5 were extracted (Hair et al., 2006). Principal components analysis with VARIMAX rotation was employed to identify key attributes factors as shown in Table 1. The data were deemed appropriate for analysis, according to the Kaiser-Meyer-Olkin measure of sampling adequacy value of 0.865 (Hair et al., 2006). The Bartlett Test of Sphericity was significant [ $\chi 2 = 2077.8$ , p < 0.001], indicating that correlations existed among some of the response categories. Eigenvalues greater than 1 were used to determine the number of factors in each data set (Hair et al., 2006). In addition, variables with two factor loading scores greater than 0.50 should be eliminated (Kim and Mueller, 1978). Thus, variables S6, S11, S16, S19, and S29 were deleted. The four key services factors identified accounted for approximately 71% of the total variance. Key service factors extracted were labeled and are described below: Factor 1, a basic service attributes factor; Factor 2, a pricing attributes factor; Factor 3, a value-added attributes factor; Factor 4, a basic transport attributes factor. All of the reliability scores for the four factors exceeded the minimum reliability standard of 0.70 (0.79 to 0.95).

#### 4.2. One-way analysis of variance on respondents' firm characteristics

To evaluate the relationship between key service factors and respondents' firm characteristics, i.e. number of employees and sales, one-way analysis of variance (ANOVA) was performed. Respondent groups' perceptions of the importance of key attributes factors did not significantly differ at the 5% significance level for number of employees and sales.

## 4.3. An analysis of the relationship between customer and financial performance

An average of item scores was used to calculate customer and financial performance. The results of the regression analysis are shown in Table 2. The overall model F-values is 31.365, which is significant at the p=.01 level. Moreover, the parameter estimate for customer performance is significant at p=.01. These results provide significant support for H3 that developing a strong customer performance for air cargo forwarders can lead to enhanced financial performance.

Table 1: Factor analysis to extract key service factors							
Items	Factor 1 F	actor 2 F	actor 3 F	'actor 4			
S10 Courtesy of sales representatives and operation staff	0.87	0.13	0.03	0.26			
S9 Prompt response to shipper complaints	0.86	0.17	0.11	0.16			
S18 Informed about the goods' conditions actively.	0.80	0.24	0.05	0.23			
S8 Professional knowledge of sales and operation staff	0.78	0.27	0.12	0.13			
S7 Prompt and accurate to issue shipment documents	0.77	0.17	-0.06	0.05			
S15 Prompt loading and unloading customer's cargos	0.77	0.18	0.21	0.24			
S24 Tailored services beyond standards	0.76	0.18	0.29	0.06			
S12 Accomplished various services to clients on time.	0.76	0.11	0.13	0.36			
S1 On-time delivery of goods	0.70	0.11	0.19	0.06			
S25 Ability to meet shippers' need	0.69	0.25	0.41	0.09			
S22 Frequency of sales representative's calls to shippers	0.68	0.40	0.28	-0.07			
S17 Online real-time information tracking/tracing	0.61	0.49	-0.07	0.18			
S30 Prompt response to quoting	0.52	0.41	0.08	0.32			
S2 Reduced flight rate and discount negotiation capability	0.12	0.88	0.12	0.04			
S3 Availability of competitive cargo space	0.24	0.86	0.04	0.06			
S21 Integration with warehouse partners in the logistics information system	0.13	0.85	0.13	0.04			
S20 Integration with air cargo partners in the logistics information system	0.18	0.82	0.10	0.01			
S4 Pricing flexibility in meeting competitors rates	0.26	0.79	0.15	-0.01			
S5 A space and flight rate agreement with the other air cargo forwarder operators	0.31	0.74	0.11	0.09			
S23 Accurate flight information	0.48	0.68	0.34	0.15			
S32 Logistics value-added services	0.11	0.07	0.84	0.15			
S33 Good ability to provide consolidation service	0.26	0.27	0.78	-0.09			
S28 Recommendation of logistics facilities	0.28	0.04	0.75	0.35			
S26 Assembling/re-assembling	0.03	0.11	0.64	0.44			
S31 Number of subsidiary companies and agents	0.03	0.48	0.61	0.14			
S13 Periodically providing latest forwarder information and customs regulations.	0.37	0.23	0.21	0.75			
S14 Ability to provide customs clearance or inland transport service	0.47	0.15	0.12	0.68			
S27Ability to provide door-to-door service	0.18	-0.14	0.33	0.67			
Eigenvalues	12.8	3.33	2.62	1.18			
Percentage variance	45.7	11.91	9.37	4.21			

# Table 2: Regression results for the effect of customer performance on air cargo forwarders' financial performance

	Dependent variables: Financial performance
Independent variable: Customer performance (p)	0.533 (0.000)
F (p)	31.365 (0.000)
$\mathbb{R}^2$	0.284

Standardized beta-coefficients are reported with p-values in parentheses.

## 4.4. Results of mediator multiple regression analysis

A combination of simple and multiple regression analysis was conducted to determine whether customer performance plays an intermediary role between service factors and financial performance. A three-step regression analysis was used to assess the potential mediating influence of customer performance on the service factors-financial performance relationship, as suggested by Baron and Kenny (1986).

Customer performance and financial performance are the same variables used in the previous regression. Four key service factors (i.e., basic service attributes, pricing attributes, value-added attributes, and basic transport attributes in Tables 3, 4, 5, and 6) were calculated using an average of item values according to Table 1.

$\mathbf{r} = \mathbf{r} + $						
	Dependent variables					
	Model 1	Model 2	Model 3			
Independent variable	Customer	Financial	Financial			
	performance	performance	performance			
Basic service attributes (p)	0.758 (0.000)	0.436 (0.000)	0.075 (0.613)			
Customer performance (p)	-	-	0.477 (0.002)			
F (p)	106.832 (0.000)	18.533 (0.000)	15.665 (0.000)			
$\mathbb{R}^2$	0.575	0.190	0.287			

 Table 3: Results of mediator multiple regression analysis (basic service attributes)

Standardized beta-coefficients are reported with p-values in parentheses.

#### Table 4: Results of mediator multiple regression analysis (pricing attributes)

		Dependent variables					
	Model 1	Model 2	Model 3				
Independent variable	Customer	Financial	Financial				
	performance	performance	performance				
Pricing attributes (p)	0.451 (0.000)	0.519 (0.000)	0.349 (0.001)				
Customer performance (p)	-	-	0.376 (0.000)				
F (p)	20.182 (0.000)	29.062 (0.000)	24.036 (0.000)				
$R^2$	0.203	0.269	0.381				

Standardized beta-coefficients are reported with p-values in parentheses.

#### Table 5: Results of mediator multiple regression analysis (value-added attributes)

	Dependent variables					
	Model 1	Model 2	Model 3			
Independent variable	Customer	Financial	Financial			
	performance	performance	performance			
Value-added attributes (p)	0.522 (0.000)	0.498 (0.000)	0.303 (0.006)			
Customer performance (p)	-	-	0.375 (0.001)			
F (p)	29.594 (0.000)	26.121 (0.000)	21.077 (0.000)			
$\mathbb{R}^2$	0.273	0.248	0.351			

Standardized beta-coefficients are reported with p-values in parentheses.

#### Table 6: Results of mediator multiple regression analysis (basic transport attributes)

	Dependent variables					
	Model 1	Model 2	Model 3			
Independent variable	Customer	Financial	Financial			
	performance	performance	performance			
Basic transport attributes (p)	0.506 (0.000)	0.485 (0.000)	0.290 (0.008)			
Customer performance (p)	-	-	0.386 (0.000)			
F (p)	27.146 (0.000)	24.355 (0.000)	20.705 (0.000)			
$R^2$	0.256	0.236	0.347			

Standardized beta-coefficients are reported with p-values in parentheses.

Tables 3, 4, 5, and 6 present the results of the three-step regression. For all of the key service factors, the independent variable affected the mediator in the first model, while the independent variable also affected the dependent variable in the second model. Moreover, all of the mediators affected the dependent variable in the third model. For all of the key service factors, "the effect of the independent variable on the dependent variable was less in the third model than in the second" (Baron and Kenny, 1986). Thus, customer performance plays an intermediary role between service factors and financial performance. Specifically, perfect mediation exists on basic service attributes because the insignificant effect of basic service attributes on financial performance when customer performance is included. In sum, this shows a strong relationship

between air cargo forwarders' abilities to establish a better service factors and their abilities to achieve high levels of financial performance. Moreover, air cargo forwarders that foster service factors can influence the financial performance of air cargo forwarders through enhanced customer performance. Thus, the results support H1, H2, and H4.

## 5. Conclusions and Discussion

The resource-based view (RBV) was used to establish a theoretical base for this study that seeks to assess the relationships between service attributes and firm performance. The objective of this study was to evaluate the relationship between performance and service attributes in order to provide useful policy information for such companies. The main findings and response to hypotheses can be seen in Table 7. A positive and significant relationship was found between customer performance and the air cargo forwarders' financial performance (H3). This finding suggests that if air cargo forwarders administrators can improve their customer performance, they will increase the financial performance of the firm. The findings are consistent with a previous study (e.g., Fornell, 1992; Rust and Zahorik, 1993). The influences of service attributes on air cargo forwarders financial performance (H1) and customer performance (H2) were also supported. This means that air cargo forwarders with better service attributes generally have better financial and customer performance for air cargo forwarders (H4). Through better customer performance, air cargo forwarders with better service attributes and financial performance, air cargo forwarders with better service attributes and financial performance, air cargo forwarders with better service attributes and financial performance, air cargo forwarders with better service attributes and financial performance, air cargo forwarders with better service attributes will gain superior financial performance. Thus, overall, findings suggest that air cargo forwarders' top managers should constantly seek to enhance and refine their firms' four key service factors and customer performance over and above those of their competitors in order to gain superior financial performance.

Table 7: Summary of Results				
	Hypotheses	Supported/Not-support		
H1.	The service attributes offered by air cargo forwarders is positively related to their financial	Supported		
	performance.			
H2.	The service attributes offered by air cargo forwarders is positively related to their customer	Supported		
	performance.			
H3.	Air cargo forwarders whose customer performance is high have better financial	Supported		
	performance compared to those with a lower customer performance.			
H4.	For air cargo forwarders, the relationship between service attributes and financial	Supported		
	performance is mediated by customer performance.			

Several contributions have been made by this study to both the theory and practice of air cargo forwarder management. Firstly, this study provides a theoretical framework to link service attributes, financial performance, and customer performance for the air cargo forwarders. Secondly, the customer performance offered by air cargo forwarders was found to have a positive relationship with their financial performance. Thirdly, the service attributes offered by air cargo forwarders can directly influence air cargo forwarders' financial and customer performance. Moreover, through better customer performance, air cargo forwarders with better service attributes will gain superior financial performance.

The study findings have implications for practice and research. First, research findings reveal that service attributes are the crucial source of superior financial performance. It is therefore necessary for air cargo forwarders' managers to evaluate strengths and weaknesses in their service attributes relative to their competitors and to gain competitive advantages. Secondly, this study provides a general framework for identifying key service factors for air cargo forwarders. Such a framework can help air cargo forwarders' managers to improve their understanding of service attributes and customer performance and identify how such service attributes and customer performance may affect firm financial performance.

However, the research findings suffer from several limitations. First, this study was limited to air forwarder markets in Taiwan. Secondly, all participants responded within a particular time frame. It therefore does not necessarily reflect the current dynamic business environments. Thirdly, although a low response rate has been reported in similar studies (Cheng and Yeh, 2007), and non-respondent bias was not a problem, nevertheless, inferences from this data need to be drawn cautiously.

This study also raises several important issues for further research. First of all, future studies could combine this research with a survey to actual customers of the forwarders, to see how satisfied the customers really are. Secondly, structural equation modeling (SEM) may be helpful for understanding cause and effect relationships between key service factors and performance. Thirdly, more qualitative-based methodologies such as case study are alternatives to assist in more deeply understanding firms' key service factors.

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# Air Freight, Economic Growth and Emissions in Asia-Pacific Region: Is There A Stable Balance?

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## Abstract

This paper provides an overview of China and Singapore's economic growth, air freight growth and transport carbon emissions in the past twenty years. Relationships among economic growth, international trade and air freight growth are examined. It shows that international trade is an important force driving the growth of economy and air freight industry. While it is concerned that economic growth comes at the expense of the environment, however, our analysis does not support such view in terms of transportation carbon footprint in the two countries' cases. Relevant research issues that are pertinent to air freight industry's carbon footprint is raised for future study.

Keywords: Economic Growth, Air Freight, Carbon Footprint, China, Singapore

## 1. Background

## 1.1 Air Freight and Global Economy

As the economy develops and globalization strengthens, the efficiency and effectiveness of supply chain are drawing greater attention. Many new technologies and systems, such as RFID (Radio Frequency Identification) and ERP (Enterprise Resource Planning) have been developed, and more strategic collaborations formed to build more efficient and robust global supply chains. The intent is to provide visibility without compromising on speed to market. Though expensive, air freight is growing rapidly due to its fast speed thus shorter lead time, which is especially important for the electronics industry, medicine and some agricultural products. The air cargo industry is now a crucial part of the global economy. In 2011, this sector handled more than 35% in the value of goods traded internationally, while accounting for only 0.5% in volume (IATA, 2012).



While the growth of the air freight industry drives economic development, the global economy also affects the growth of the air freight industry. As suggested by various professional services houses, the air freight traffic serves as a clear indicator of the macroeconomic environment (IATA, 2009). As indicated in Figure 1, it shrank quickly during a recession, bounced back when the economy recovered, and started to drop again when the economic expectations became pessimistic.

## 1.2 Economy Growth and Sustainability

According to the World Bank, economic and social sustainability, and social and environmental sustainability have been found to be compatible and complementary. However, it is not so for economic and environmental sustainability as indicated by the dotted line in Figure 2. The long held argument is that economic growth comes at the expense of the environment (World Bank, 2012).



## Figure 2: Sustainable Development (World Bank, 2012)

According to the Ecologic Institute, for example, energy input and transport contribute most to greenhouse gas (hereafter we use  $CO_2$ ) emissions for the EU from 2000 to 2007 as shown in Figure 3. Also transport is reported to be the only source where greenhouse gas emissions will continue to increase (Melanie, 2010).



As more and more people realize the importance of sustainable growth, governments, international organizations and many corporations have started the initiative to go green. Carbon footprint control is one common step towards environmental sustainability. To examine the effect of carbon emissions control on economic growth, the concept of 'decoupling' is introduced. According to the OECD, decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force (e.g. GDP) over a given period and this can be either *absolute* or *relative*. Absolute decoupling is said to occur when the environmentally relevant variable is stable or decreasing while the economic driving force is growing. Decoupling is said to be relative when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the economic variable (OECD, 2001). Figure 4 shows the relative locations of the EU member countries with respect to the **CO**<sub>2</sub> emissions from transport and their GDP from 2000 – 2007.





In this paper, we will focus on analyzing the relationship between air freight and economic growth in Asia as well as the impact on environment. Specifically, we will examine the situation of Singapore and China using GDP as proxy for economic development, air freight ton-km as proxy for air freight development, and indicate environmental sustainability by  $CO_2$  emissions. Section 2 presents the data analysis, Section 3 provides discussions of the results and Section 4 concludes the paper.

## 2. Data and Analysis

This section will present basic economic and environmental indicators of China and Singapore.

2.1 China

## 2.1.1 Economic Growth

China has achieved amazing economic growth since its economic reform, especially during the past two decades when its annual GDP growth rate stayed above 8% (World Bank). This mainly attributes to its low-cost manufacturing which attracted huge FDI and in turn drove the growth of the whole value chain.



As indicated in Figure 5, trade has been playing an increasingly important role in driving the economy, as the percentage of total trade to GDP has grown from less than 30% to as high as more than 80%. A correlation of 0.988 is a proof of the close relationship between GDP growth and the international trade, probably showing that boom of international trade is driving the growth of economy.

As its international trade develops, this leads to growth in both ocean freight and air freight, where air freight is crucial in transporting time-sensitive product such electronics, medicine and agriculture product.

## 2.1.2 Air Freight Industry

Air freight industry, however, only achieved tremendous growth in the new century. This is mainly because the underdeveloped infrastructure impeded the development of the air freight industry.



According to Fung et al. (2005), air cargo is primarily shipped in passenger aircraft in China. Despite the high growth in air cargo business, the logistics industry is still under-developed, fragmented and with local protectionism. Even the largest Chinese carriers have not developed real hub-and-spoke networks as stated by Fu et la. (2012). The situation has only improved recently in the new century. As shown in Figure 6, the growth is nearly exponential for both trade and air freight transport.

## 2.1.3 Environmental Effects

Due to lack of data directly related to detailed air freight travelling distance, we will use total  $CO_2$  emissions from transport as the indicator of pressure on environment from transportation.



Figure 7: China's GDP and CO<sub>2</sub> emissions from transport, 1991-2010 (World Bank)

The correlation between GDP and  $CO_2$  emissions from transport for China is 0.991, showing that carbon emissions are increasing while economy is developing. As indicated in Figure 7, while GDP achieved exponential growth,  $CO_2$  emissions also increased exponentially during the twenty-year period.

While GDP growth stays relatively stable,  $CO_2$  emission growth is much more volatile. There is no clear indication of relationship between GDP growth and  $CO_2$  emissions growth rate. However, we can observe that growth rate of  $CO_2$  emissions from transport stays below the growth rate of GDP most of the time.

## 2.2 Singapore

## 2.2.1 Economic Growth

Singapore being a small country lack of natural resources depends heavily on external environment for economic growth, thus international trade plays a crucial role in driving GDP.





As indicated in Figure 9 above, Singapore's international trade has been growing at a higher rate than its GDP. The correlation between GDP and international trade is 0.994, which is very obvious as Singapore's economy relies much on imports and exports. What is particularly special is that its total trade value is much higher than its GDP value, implying that its economy can be easily affected by outside environment. Thus, air freight and ocean freight are both crucial to economy development.

## 2.2.2 Air Freight Industry

Singapore, due to its geographic location, is a transportation hub in Asia. Changi airport, which is the aviation hub, has been a leading airport in capacity and efficiency for decades.



It is very obvious as indicated in Figure 10 that both trade value and air freight volume dropped in 1997, 2001 and 2008, which is a result of macro-economic environment change. To analyze the growth, we exclude the sharp drop after 2009 for total trade, and 2008 for air transport before performing the regression. It can be seen from Figure 10 that its trade value followed nearly exponential growth, while air freight transport has been experiencing linear growth.



Figure 11: Singapore's GDP and CO<sub>2</sub> emissions from transport, 1991-2010 (World Bank)

2.2.3

Environmental Effects

The correlation between GDP and  $CO_2$  emissions is 0.976, a similar result to that of China. This indicates that carbon emissions from transport have been growing while economy develops rapidly. Both GDP and  $CO_2$  emissions followed nearly exponential growth during the twenty-year period.



Figure 12: Singapore's GDP and CO<sub>2</sub> emissions growth rates, 1991-2010 (World Bank)

One important observation is that Singapore's GDP growth is much more volatile. This may attribute to its dependence on international trade, making GDP very sensitive to global economic condition.  $CO_2$  emission doesn't present any regularity either. However, it is also observed that  $CO_2$  emissions growth rate stays below GDP growth rate most of the time during the past twenty years.

## 3. Results and Discussions

## 3.1 Economy and air freight

International trade is an important part of economic development for both China and Singapore, as indicated in Section 2. Air freight is thus a key to future development as customers increase their expectations on efficiency and flexibility. However, air freight, being more costly, is also more sensitive to macro-economy environment, indicated by the slow-down or drop in growth following *1997 Asia Financial Crisis*, *2001 911 Crisis* and *2008 Global Financial Crisis* in both countries.

In contrast to China's relatively stable economy growth, Singapore's GDP growth is much more volatile, and fell negative during the crisis. This is mainly because Singapore's economy relies a lot on international trade, for example, total trade value is almost 4.6 times the value of GDP in 2010.

In both countries' cases, trade is more resistant to macro-economy environment change than air freight is. This phenomenon may attribute to the switch of transportation mode from air freight to cheaper ocean freight in expectation of a weakening economy by purchasing managers, since they may want to consume storage of goods on hand and slow down the incoming order during economy downturns instead of simply cutting orders. Correspondingly, they will increase the order on air freight transportation to build up inventory quickly when expecting an economy boom and increase in customer demand. This is also the reason why air freight industry is often seen as an indicator of economy conditions.

GDP, which comprises trade and factors like consumption and investment, is even more resistant to macroeconomy change than international trade. China, especially, has the power to stimulate the economy by huge injection of investment into infrastructure development, thus maintained a high level of GDP growth rate. Singapore's GDP, on the other hand, is less controllable as a result of the limitation of resources the government has and the structure of economy that depends heavily on trade, tourism and finance, all of which were severely affected during financial crisis.

#### 3.2 Economic growth and pressure on environment

 $CO_2$  emissions from transport in both countries showed great volatility as indicated in Figure 8 and Figure 12. Though both countries show a high correlation between GDP and  $CO_2$  emissions, it is clear that both China and Singapore are experiencing either relative or absolute decoupling most of the time, as indicated by the negative or smaller growth rate of  $CO_2$  emissions as compared to GDP growth rate. This result indicates that both countries are doing well in controlling transport carbon footprint during economic growth. Though the actual performance of the air freight industry is yet to be determined, we believe that both countries should maintain the efforts in controlling  $CO_2$  emissions.

## 4. Conclusion

This paper examines the relationship between economic development and air freight industry growth, and economic growth and  $CO_2$  emissions for both China and Singapore from 1991 to 2010. It can be concluded that GDP is less sensitive to economic downturn than air freight, as the transportation mode can be switched from air freight to ocean freight to reduce cost while maintaining the trade volume. China takes more control in its economy development as it relies less on international trade than Singapore does. It is also observed that both countries are experiencing either absolute or relative decoupling most of the time during the past 20 years in terms of  $CO_2$  emissions from transport industry.

Due to the limitation of data availability, it remains a future research direction to fully test the relationship between GDP and  $CO_2$  emissions from air freight industry in both countries. In addition, the effects of packing efficiency, fill rate and routing schemes on carbon footprint are also interesting to look at if detailed study is to be conducted on air freight industry's impact on environment.

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## Market Power and Its Determinants of the Chinese Airline Industry

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#### Abstract

This paper uses the Lerner index to analyze the market power of Chinese airlines and investigates its main determinants. Our empirical results show that a certain degree of market power exists in the Chinese airline industry. Of the three largest carriers, Air China has the strongest market power whereas China Eastern Airlines has the weakest, with China Southern Airlines in the middle. Furthermore, the northeast region of China sees the least competition within the domestic market, whereas the central area is the most competitive. We also find that route distance, population size, income level of the origin-destination city pairs, market share of airlines, and the existence of low-cost carriers and high-speed rail are the main determinants for how competitive the Chinese airline industry is.

Keywords: Market power, Chinese airline industry, Lerner index

## 1. Introduction

The Chinese airline industry has experienced tremendous growth owing to China's rapid economic development and a series of airline policy reforms (Zhang, 1998; Zhang and Chen, 2003; Zhang and Round, 2009). Annual air passenger traffic has grown by approximately 17% over the last 30 years. Since 2005, China has become the second largest aviation market in the world (after the United States). Based on the International Air Transport Association (IATA) and several other forecasts, the Chinese civil aviation market will continue its rapid, albeit at a slower rate, growth in the next 20 years. Air transportation is the fastest growing mode among the three most popular inter-city transport modes in China (road, railway, and air), with its proportion rising steadily every year (*China Statistical Yearbook*, 2012). To accommodate and further stimulate the industry's rapid development, Chinese governments are contemplating whether, and how, in-depth policy reforms should be carried out.

There are two different views on the market-oriented policy reforms and their effectiveness in promoting airline competition in China. One view is that the Chinese airline industry has achieved a certain degree of competitive vigor as a result of a steady, in-depth marketization process and proper policy formulation and implementation. The other view is that the market-oriented reforms have not effectively weakened the market power of state-owned airlines; consequently, they have not promoted effective competition in the market. This paper provides an analysis of the market power of the Chinese airline sector in order to understand whether airline market power exists and if so, what its determinants are.

More specifically, the paper will first estimate the Lerner indices, which will be used to measure the extent of airline market competition in China. Then in the second stage, we investigate the explanatory factors of market power so as to determine the sources of market power. We use the panel data of the "Big 3" - CA (for Air China), CZ (for China Southern Airlines), and MU (for China Eastern Airlines) - and focus on the routes from Beijing, Shanghai, and Guangzhou to all China's provincial capital cities (except Lhasa, the capital city of Tibet) and sub-provincial cities. The "Big 3" carriers have occupied dominant positions in the Chinese civil aviation market since their establishment in 2002, with their domestic market share approximately 80%. Furthermore, the three mega-cities (Beijing, Shanghai, and Guangzhou) have the country's top-4 hub airports,

namely, Beijing Capital International Airport, Shanghai Pudong International Airport, Shanghai Hongqiao International Airport, and Guangzhou Baiyun International Airport. These three aviation centers and the other capital cities are important in terms of their dominant share of overall domestic air travel, and these cities are spread throughout the country. Competition among airlines on these routes can reflect the competition situation of the entire Chinese aviation market and thus determines to a large extent the welfare impact on carriers and passengers.

Our results indicate that a certain degree of market power exists in the Chinese airline industry. Among the three largest state-owned carriers, the market power of Air China is the strongest and the market power of China Eastern is the weakest, with China Southern positioned in between. From a geographical perspective, China's Northeast region is shown to have the strongest market power, whereas the Central region has the weakest. Furthermore, route distance, population size, income level of the origin-destination city pairs, market share of airlines, and the existence of low-cost carriers and high-speed rail are found to be the main determinants of market power of the Chinese airline industry. Other important factors include the number of passengers, number of competing airlines, tourism, seasonality, and the macroeconomic environment. Our analysis also shows that the determinants of air fares are not entirely consistent with those of market power.

The paper is organized as follows. Section 2 provides a review of the literature, and Section 3 presents the theoretical model used for the measurement of market power. Section 4 provides the estimation results and analyzes the explanatory factors of market power. Finally, Section 5 offers concluding remarks.

## 2. Literature Review

Empirical industrial organization (IO) economists have been concerned with measuring the degree of market competition. Concentration indicators such as concentration ratio (CR) and the Herfindahl-Hirschman Index (HHI) are often used to measure the market power of airlines in the early days. From the perspectives of market concentration, product differentiation and barriers to entry, Ma (2004) showed that the airline industry is an oligopoly in China. By analyzing average fare changes, Zhang and Round (2009) determined that market power is possibly exercised in the hub-to-hub networks of MU after the mergers in 2002. However, these methods for measuring the degree of competition in the Chinese market have several deficiencies. First, concentration indices were used to describe the values of the entire industry, but these authors were not able to measure the market power of an individual firm. They also ignored potential competition from other modes of transportation. Since profits and market positions of different airlines are found to be different in China, the market power of the industry does not necessarily reflect the power of each firm. Second, China has one of the most advanced high-speed rail (HSR) networks in the world. HSR poses a significant challenge to the survival and development of civil aviation. Third, changes in price are not fully consistent with those in market power. Therefore, the level of prices cannot completely reflect market power strength. Zhang and Round (2009) did not analyze CA, one of the most important airlines in the country; as such, their work cannot fully reflect the whole Chinese civil aviation market.

Lerner (1934) proposed a measure of "the degree of monopoly power in force," which is referred to as the *Lerner index*. This index shows the deviation of price from the marginal cost, which is the natural measure of market power or market competition level. Feinberg (1980) found that the Lerner index is a better guide to market power allocation than seller concentration. Kim and Esmeralda (1986) reported that the Lerner index contributes significantly in explaining the excess market value of multinational corporations. The Lerner index has been widely used in many fields, such as the banking and financial industries (Oliver et al., 2006; Nguyen et al., 2012), power industry (Kamerschen et al., 2005; Bosco et al., 2012), old newspaper market (Hervani, 2005), aluminum industry (Lindquist, 2001), railroad market (Ivaldi and McCullough, 2007), communications industry (Kahai, 1996), and gas markets (Newbery, 2008).

However, there are only a few studies that apply Lerner index to analyze the market power of the airline industry. Fischer and Kamerschen (2003b) estimated the Lerner indices of 29 airport pairs, emphasizing particularly airlines with a considerable degree of market power in every airport-pair market. Kutlu and Sickles (2012) estimated the market power of US airlines in two city-pairs using the Lerner index and the dynamic efficiency-adjusted Lerner index to analyze the market power even with firm-level inefficiencies. To

the best of our knowledge, there is no work that applies the Lerner index method to study the market power of the Chinese airline industry. We aim to fill this gap through the present paper.

#### 3. Theory Model

#### 3.1 Definition of Lerner index

The Lerner index (L) in general can be expressed as

$$L = \frac{p - MC}{p},\tag{1}$$

where p is the price of the product, and MC is the marginal cost. For the airline industry, the Lerner index can be defined as

$$L_{ikt} = \frac{p_{ikt} - MC_{ikt}}{p_{ikt}},\tag{2}$$

where  $L_{ikt}$  is the Lerner index of carrier *i* on route *k* in period *t*,  $p_{ikt}$  is the per-passenger price of airline *i* on route *k* in period *t*, and  $MC_{ikt}$  is the per-passenger cost of airline *i* on route *k* in period *t*.  $L_{ikt}$  ranges from 0 to 1. Larger values of  $L_{ikt}$  indicate stronger market power of firm *i* on route *k* in period *t*, whereas 0 represents perfect competition. Under the assumption that the elasticity of demand is a constant ( $\eta$ ), it is straightforward to show that the Lerner index is given by: (i)  $L = \frac{1}{\eta}$  for a monopolist; (ii)  $L_{ikt} = \frac{s_{ikt}}{\eta}$  under Cournot competition, where  $s_{ikt}$  is the market share of firm *i* on route *k* in period *t*; and (iii)  $L_{ikt} = 0$  under perfect competition.

#### 3.2 Measurement of the Lerner index

#### 3.2.1 Price

The Lerner index can be estimated by the price and marginal costs. The fare data can be complicated as every flight of each carrier has seating classes, namely, first class, business class, and economy class, with the last category having a variety of price discounts. Many scholars (Melville, 1998; Alderighi et al., 2012) have used the average price as the price on a route; this price is calculated from the weighted averages of the number of passengers. The definition is

$$AveP = \sum_{i=1}^{n} P_i \cdot Num_i / \sum_{i=1}^{n} Num_i , \qquad (3)$$

where AveP is the average price to account for the Lerner index,  $P_i$  is the price of cabin *i*, and  $Num_i$  is the number of passengers in cabin *i*.

#### 3.2.2 Marginal cost

There are two ways to estimate the route-specific marginal cost for each carrier in the literature. One method, with the aid of econometrics, is implemented in two steps: first, by building a translog total cost function, and second, by estimating the route-specific marginal cost for each carrier. Fischer and Kamerschen (2003b) and Mizutani (2011) estimated the marginal costs of different airlines using this method. One of the prerequisites for using this method is a definition of the cost function under consideration. However, for different authors, the choice of the main factors affecting the total cost may be different, owing to their individual preferences for the choice of an econometric model. Since essential data (such as the average annual salary per employee) are not available to the public in China, the approach cannot be applied in this study. Brander and Zhang

(1990, 1993) proposed another estimation methodology of route-specific marginal cost for each carrier. They defined the marginal cost of carrier i on route k in period t as

$$MC_{kt}^{i} = cpk_{t}^{i}(D_{k} / AFL_{t}^{i})^{-\theta}D_{k}, \qquad (4)$$

where  $D_k$  is the distance of route k,  $AFL_t^i$  is the average distance flown by carrier *i* in period *t*,  $cpk_t^i$  is the cost per passenger-km of carrier *i* in period *t*, and  $\theta$  is an unknown parameter in the cost function that ranges from 0 to 1. Data required by this methodology are relatively easier to obtain in China, and the marginal costs of airlines can be calculated by this approach at the route level. Furthermore, the uncertainty of the cost-function specification can be avoided, and there is a consistent way of computing the marginal cost for all the sample airlines. Several studies (Brander and Zhang, 1993; Oum et al., 1993; Murakami, 2011; and Zhang et al., 2012) used this method to estimate the route-specific marginal cost for each carrier. We will use the same approach to estimate the marginal costs.

#### 4. Empirical Results and Analysis

## 4.1 Data

The data used for this paper is a quarterly, route level panel data of the "Big 3" in China from January 1, 2010 to December 31, 2011. A total of 93 routes are analyzed, including the routes among Beijing, Shanghai, and Guangzhou, as well as the non-stop city-pair routes from the three big cities to all provincial capital cities (except Lhasa, the capital city of Tibet) and sub-provincial cities. Carriers are likely to possess market power only when they occupy a certain market share. Similar to Borenstein (1989), data are rejected when the share of the airline on the route is no more than 10%. As a result, a total of 1,384 observations are obtained. The data on the routes operated by Spring Airlines and their opening times are collected from the airline's website. The information on whether HSR services are provided on the routes is obtained from the booking site of the Ministry of Railway of China.

Data on airlines' capacity and the market shares of the Big-3 airlines on each route are collected from the Civil Aviation Resource Net of China. Information on the number of passengers in different fare classes carried by a given airline on each route is obtained from the computer reservation system of TravelSky Technology Limited. Passenger demand data are restricted to non-stop services. Fare information is obtained from the Chinese Airfare Information Network (www.airtis.net) and the Web sites of the three airlines. Data on the main costs of carriers are obtained from quarterly and annual reports of the Big-3 airlines. Total flight length, total number of flights, and revenue passenger-km 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 can be calculated for every quarter. The distances of the routes are collected from the *Statistical Data on Civil Aviation of China* published by CAAC (2012). Data on the per capita income, population, and GDP of each city are obtained from the National Bureau of Statistics of China.

## 4.2 *Market power in the Chinese airline industry*

The average prices and marginal costs of the "Big 3" on each route in each quarter are calculated to obtain the Lerner indices. The average price on each route for each carrier can be estimated by using Eq. 3. Further, according to Zhang et al. (2012),  $\theta$  equals 0.4 in the Chinese airline industry. The marginal costs of the three carriers on each route for eight quarters can be estimated by using Eq. 4.

The values of the prices and the marginal costs are used to estimate the Lerner index of the "Big 3" on related routes in Eq. 2 and obtain 1,384 observations. Only 140 observations are less than 0, and approximately 90% of the observed values are greater than 0, indicating the some degree of market power of the "Big 3" for most of the routes. These values are then used to calculate the means of the Lerner indices in each quarter for the industry as a whole. The average values of Lerner indices for the "Big 3" in each quarter are also calculated. The trends of these average values are shown in Figure 1.



Figure 1: Average values of the Lerner indices





(b) Lerner indices of the "Big 3" carriers

The means of the Lerner indices and their upper and lower bounds of the 95% confidence interval are shown in Figure 1(a). Among the Lerner indices for eight quarters, the minimum is 0.09, whereas the maximum is 0.25. The mean of all estimated Lerner indices values is calculated as 0.18. The highest upper limit of the 95% confidence interval is less than 0.3, which indicates that the Chinese airline industry is not a monopoly or a cartel. However, the lower limits of the 95% confidence interval are greater than 0 in each quarter, suggesting that the Chinese airline industry is not perfectly competitive either. Sheldon and Sperling (2003, Table 1) and Kamerschen (2005, Table 6) summarized the Lerner indices for various industries in different countries. In comparing the Lerner indices for these industries, the degree of competition in the Chinese civil aviation market is fiercer than that of most of the industries. The Lerner indices of the "Big 3" in each quarter are shown in Figure 1(b). All values are greater than 0, and the "Big 3" have a certain degree of market power. Figure 1(b) also shows that the market power of CA is the strongest among the "Big 3". Finally, Figure 1 shows a downward trend, indicating the industry has become more competitive during the two-year period.

Geographically, there exist regional differences in the Chinese civil aviation market. Based on the 2010 Civil Aviation Development Statistics Bulletin issued by the CAAC, the area covered by Chinese aviation is divided into four regions: eastern, central, western, and northeastern. As Beijing, Shanghai, and Guangzhou are situated in the eastern region, the 93 routes are divided into the respective region by the other end of the routes. The degrees of market power in the four regions are analyzed by ANOVA, whereby the difference is statistically significant at the 1% level. Independent samples t-test helps further define the differences among the regions.

Table 1. Results of independent samples t-test						
	Moon	t value and the le	evel of significance	;		
	Wiean	Eastern region	Central region	Western region	no Northeastern region	
Eastern region	0.177128		3.306 (0.001)	-0.038 (0.969)	-8.585 (0.000)	
Central region	0.140417	3.306 (0.001) <sup>a</sup>		-3.390 (0.001)	-10.320 (0.000)	
Western region	0.177469	-0.038 (0.969)	-3.390 (0.001)		-9.739 (0.000)	
Northeastern region	0.258137	-8.585 (0.000)	-10.320 (0.000)	-9.739 (0.000)		
a: significance levels in parentheses						

Table 1 shows the results of the independent samples t-test. Almost all differences among the regions are significant at the 1% level. Only the difference between the eastern and western regions is not significant. The means of the Lerner indices on the four regions indicate that the market power of the eastern region is the strongest and that of the central region is the weakest. The Lerner indices of the eastern and western regions are very close, which implies similar market power for the two regions.

We estimate the confidence interval of the market power for the "Big 3" on each route. In all the estimations, the confidence levels are set to 95%. First, for only 9 out of the 93 routes, the Lerner indices include the perfect competition value of 0 in their 95% confidence intervals. Second, the lower limits of the 95% confidence intervals are greater than 0 on all the other routes, indicating that these routes are imperfectly competitive. However, all the upper bounds of the 95% confidence intervals on these routes are less than 0.5. Therefore, we may conclude that the market power is between monopoly and perfect competition on these routes; thus, it is still far from perfect competition. ANOVA is conducted to test whether a significant difference exists in the market power among the OD city pairs. The results are given in Table 2, which shows that the difference in the market power among the routes is significant at the 1% level. The regulators are particularly concerned about the determinants of market power, given that these are essential in formulating effective reform policies. We will analyze the determining factors of market power in the next subsection.

ANOVA						
	Sum of Squares	Df	Mean Square	F	Sig.	
Between Groups	16.05	92.00	0.17	22.15	0.00	
Within Groups	10.17	1291.00	0.01			
Total	26.21	1383.00				

Table 2: Difference test on the market powers among the routes

#### 4.3 Analysis of the determinants of market power

From the perspective of policy formulation, an important concern is the identification of the sources of market power. Several studies have explored the determinants of market power in the airline market. Melville (1998) concluded that market share, the average number of stops per flight, and market concentration have significant impacts on market power for international routes. However, studies that specifically analyze the determinant factors of market power in the airline industry are rare. Borenstein (1989) analyzed the determinant factors on air fares in the U.S. airline industry by using a reduced-form regression equation model. Other studies used the actual situation of the market and availability of data to adjust the model for the explanatory factors on air fares in different areas. Fischer and Kamerschen (2003a) selected the number of passengers, distance, average cost, income, market share, vacation, and existence of LCCs as independent variables for analyzing their effects on fares in the US airline industry. Oliveira and Huse (2009) analyzed the effects of several factors, such as flight distance and share of newcomers, on prices in the Brazilian civil aviation market.

The prices for different routes vary according to the influence of several factors. However, the costs may also vary depending on the different routes as well, whereas several factors affect both the price and the cost for the same route. As mentioned above, market power is defined as the ability of the company to raise the price above the cost of a product. Following this definition, both price and cost affect the strength of market power, and the price may not rise or fall when market power is enhanced or diminished. Hence, research on explanatory factors on prices cannot completely replace studies on determinant factors on market power.

#### 4.3.1 Factor specification

Numerous studies aimed at identifying the factors affecting the civil aviation industry (Borenstein, 1989; Barla, 2000; Fischer and Kamerschen, 2003a; Oliveira and Huse, 2009; Dobruszke et al., 2011). The factors in these studies can be classified into four groups, namely, attributes of the routes, characteristics of the cities, substitute modes of transportation, and time differences. From these four aspects, we analyze the determinant factors of the market power in the Chinese airline industry and then find the sources of the strength of market power. 1) Route attributes: the distance of the route, air passenger traffic, number of carriers, and market shares of each airline are the most used factors in the literature (e.g., Borenstein, 1989; Lijesen et al., 2002; Fischer and Kamerschen, 2003a; Fageda et al., 2012). 2) Characteristics of the cities: The degree of air service is related to the characteristics of urban regions (Dobruszkes et al., 2011). Several studies analyzed the impact of the features of the cities on air transport (e.g., Borenstein, 1989; Dobruszkes et al., 2011; Fageda et al., 2012). Income level, size, and tourism are most popular in these studies. 3) Substitutes: For full service carriers (FSCs), LCCs and HSR are obvious substitutes, and these alternative transport modes have a cost

advantage (Alderighi et al., 2012). The impact of LCCs and HSR on the Chinese airline industry is significant (Fu et al., 2012; Yang and Zhang, 2012). 4) Time differences: Several time-related factors are determinants on market power of the airline industry, e.g., both macroeconomic conditions and seasonality will affect the demand of air transport (Chirinko and Fazzari, 1994; Fageda and Villadangos, 2009). And GDP growth rate is a basic variable for evaluating the trend of macroeconomic development (Samuelson and Nordhaus, 2008).

#### 4.3.2 Panel data regression model

To determine how these factors affect the strength of market power, we adopt a regression model for the estimation. This method is similar to the analysis for factors that influence price behavior used by Borenstein (1989). The regression equation is

$$Lerner_{kt} = \alpha + \beta_{1} \ln Distance_{k} + \beta_{2} \ln Passenger_{kt} + \beta_{3}Share_{kt} + \beta_{4}Number_{kt} + \delta_{1} \ln Population_{kt} + \delta_{2} \ln Income_{kt} + \delta_{3} \ln Tourism_{k} + \varphi_{1}LCC_{k}$$
(5)  
+  $\varphi_{2}HSR_{k} + \gamma GDPins_{i} + \lambda_{1}Spring + \lambda_{2}Summer + \lambda_{3}Autumn,$ 

where k = 1,...,93 indicates route identification; t = 1,...,8 pertains to the eight seasons starting from 2010; i = 1,2 is the year in lieu of 2010 and 2011, respectively; *Lerner<sub>kt</sub>* is the average of the Lerner index of the "Big 3" on routes k; *Distance<sub>k</sub>* is the distance (unit: km) of route k; *Passenger<sub>kt</sub>* is the number of passenger on route k in period t; *Share<sub>kt</sub>* denotes the share structure variables (HHT) on route k in period t with value in [0,1]; *Number<sub>kt</sub>* is the number of airlines on route k in period t; *Population<sub>kt</sub>* is the total population of the two cities linked by route k; *Income<sub>kt</sub>* is the per capita income of the two linked cities on route k in period t; *Tourism<sub>k</sub>* is a dummy variable representing whether the tourism of the city is developed, which equals 1 if the two cities linked by route k both belong to the top 25 Chinese cities with most developed tourism by Forbes; *LCC<sub>k</sub>* is a dummy variable, which equals 1 if Spring Airlines operates on route k; *HSR<sub>k</sub>* is a dummy variable, which equals 1 if Spring Airlines operates on route k; *HSR<sub>k</sub>* is a dummy variable, which equals 1 if HSR is parallel with route k; *GDPins<sub>i</sub>* is the growth rate of GDP, which is the value for the *i*-year GDP growth at constant prices; and *Spring, Summer*, and *Autumn* are dummy variables for the seasons.

Variables	Coefficients	Standard
	ن ن ن	Deviations
Distance	0. 0303201***	0.006263
Passenger	$0.\ 0075941^{*}$	0.0043318
Share	0. 1902983***	0.03173
Number	- 0. 011256***	0.0041747
Population	0. 164154***	0.164154
Income	0. 3200674 ***	0.0422511
Tourism	$0.\ 0107824^{*}$	0.0063612
LCC	- 0. 0449385***	0.0078863
HSR	- 0. 1652571***	0.0174719
GDPins	0. 0461616***	0.0052295
Spring	- 0. 0327555****	0.0085686
Summer	0. 0567365***	0.0082226
Autumn	0. 0815465 ***	0.0079674
cons	- 3.176104***	0.2348059
Wald chi2(13)	680.18	3

Table 3: Parameter estimation in the regression model of influencing factors

Note: \*\*\*, \*\*, and \* represent significance levels of 1%, 5%, and 10%, respectively.

The parameters in the model are estimated with panel data of 8 quarters on the 93 routes by feasible generalized least squares. The coefficient estimation for model (5) regarding the factors affecting market power is reported in Table 3.

As expected, a longer-distance route corresponds to a stronger market power. The market powers of the "Big 3" on long-distance routes are higher than those on short-distance routes. However, the different effects on competition between long- and short-distance routes are not considerable. Particularly, when the volume of passengers doubles, the increase in market power is less than 0.01. As shown in Table 3, airlines with higher market shares have significantly stronger market power. This result shows that the "Big 3", with absolutely dominant shares in national civil aviation market, occupy a dominant position in the competition with other carriers. Although the "Big 3" dominate the routes, the estimated coefficient of Number, that is, the number of airlines, is negative at the 1% significance level. Intuitively, an increase in the number of airlines results in more competition.

Population size, economic level, and tourism status are factors that reflect the characteristics of a city, and these factors have significant impacts on the market power of the civil aviation industry; among which, population size and economic level show significance at the 1% level. Based on the value of coefficients in the regression model, airlines operated in city pairs, with large population and rich economy, have significantly stronger market powers. Particularly, when the population size is doubled, the value of the Lerner index increases by 0.16. Resident income has a greater influence, that is, when it doubles, the value of the Lerner index increases by 0.32. As the average value of market powers of China's civil aviation is 0.18, increases in population and income can bring about a large degree of increase in monopolistic market power. Tourism development can also lead to the improvement of the market power of civil aviation. However, the influence degree of tourism development is less than that of population size and economic level. Specifically, the value of the Lerner index for airlines in city pairs with prosperous tourism is only 0.01 higher than that in city pairs with less developed tourism.

As FSCs, the "Big 3" face fierce competition from LCCs and HSR. Competition rises significantly on routes with LCCs or parallel HSR services. The Lerner index declines by approximately 0.05 on routes where Spring Airlines fly. Parallel HSR services intensify the competition, as shown by a 0.17 decrease in the Lerner index value. The impact of the parallel HSR services is stronger than that of LCCs on the "Big 3". This is not surprising since the LCCs in China are still in the initial stage and undeveloped (Zhang et al., 2008), whilst China has the world's largest and most modern (with a maximum speed of 350 km/h) HSR network.

Based on the table above, when economic growth accelerates, the market power of the civil aviation industry enhances as well; when economic growth slows down, competition in the civil aviation market intensifies accordingly, which is consistent with the conclusions of Brander and Zhang (1993) and Chirinko and Fazzari (1994). In addition, competition among airlines is more intense in off-seasons and is decreased in peak seasons. For example, as the fall is the peak season of China's civil aviation market, the three coefficients of dummy variables representing seasons imply that the dominant airline has the strongest market power in the fall, which is consistent with the trend in Figure 1.

In exploring the similarities of and differences among factors influencing market power and fares, the impacts of the factors on the yield are estimated. We find that several variables affect fares and market power in the same direction. Variables including a larger share of the airline, OD city pairs with larger population size and higher level of income, peak season, and higher macroeconomic growth rate can increase both fares and market power. On the other hand, variables such as more airlines on the route, existence of LCCs and HSR, and off-peak season decrease both fares and market power. However, several variables have opposite influences on fares and market power, such as the distance of routes and the number of passengers. For longer routes and dominant routes, aviation unit fares decline significantly; such finding is the same as the conclusion of Borenstein (1989) and Fischer and Kamerschen (2003a). Conversely, longer distance and more passengers increase market power on the routes. Moreover, prosperous tourism has a significant impact on the market power of China's civil aviation; however, such an impact is not significant on fares. The above results show that the determinants of fares are not entirely consistent with those of market power.

#### 5. Concluding Remarks

In measuring the market power of China's airline market by the Lerner index, we have shown that the industry exhibits a certain degree of market power. Therefore, the regulators should develop targeted policies and measures to further stimulate the competition among airlines. The "Big 3" have a certain degree of market power in China's civil aviation market; among which, the market power of CA is the strongest, and that of MU is the weakest. Furthermore, the results indicate that there appears a seasonal effect on airline price-cost margins. In addition, the degrees of market power vary significantly among regional markets, with the northeast region as the strongest, followed by the eastern and western regions, and the western region as the weakest.

Regarding the determinants of the market power, we have the following results. First, based on the analysis of the determinants of the civil aviation market power, city pairs with long route distance, large number of passengers, large population, developed economy, and prosperous tourism will have stronger market powers. Among these determinants, population size and income level are the most significant factors; higher market shares on the route correspond to a stronger market power. Second, civil aviation market power is obviously stronger during peak seasons than during off-seasons. As a result, when economic growth declines, competition in China's civil aviation industry intensifies because the market power of the "Big 3" decreases accordingly. Furthermore, when the number of airlines operating on the route increases, the market power of the dominant airline weakens. Third, LCCs and parallel HSR are the most powerful factors that reduce the market power of FSCs. Therefore, the competition degree in the civil aviation market will increase greatly along with the completion of the HSR line network in China. Finally, based on the empirical results, the factors causing fare changes are not necessarily the source of market power. As a result, although useful for better understanding of the airline market, the analysis on the determinants of fares cannot replace the analysis on the determinants of market power.

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# Multi Criteria Supplier Selection for Aircraft Maintenance in Thailand

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#### Abstract

With severe competition under global uncertainty demands, airlines have to generate new strategies in order to enhance their competitive advantages in the current marketplace. Currently, an individual airline mainly focuses on its existing business function, while impacts from supply chain efficiency have been neglected. Thus, the effective management of aviation supply chain must be considered. Supply chain in aircraft maintenance includes the flow of materials or services from many suppliers through airline maintenance. The airline must fulfill air travelling demand as committed flight schedule. The aircraft maintenance in Thailand is different than airlines in US or Europe. In the US or Europe, several suppliers and repair shops are located near airlines. Part purchasing and repairing lead-time is shorter as well as costs are lower. In Thailand, the procurement lead time is longer while manpower costs are cheaper. Consequently, important factors which impact aircraft maintenance performance are identified as well as a proper supplier selection model is Initially, requirement for spare parts are generated using flight schedule to obtain aircraft developed. maintenance tasks. Later, a multi - criteria portfolio for supplier selection by considering cost, lead-time, and the quality is calculated. The maintenance managers can apply this technique to help them effectively deal with suppliers. Finally, the multi-criteria portfolio for supplier selection as a decision support tool is implemented in the actual airline case.

Keywords: Aircraft Maintenance, Portfolio Management, Supplier Selection, Supply Chain Management

#### 1. Introduction

Supply chain in aircraft maintenance includes the flow of materials or services from many suppliers through airline maintenance regarding to Choy et al. (2007). The airline must fulfill air travelling demand as committed flight schedule. Supply Chain in Thai Aviation starts from the aircraft owner requesting services to commercial maintenance centers or internal maintenance department. The maintenance manager buys the materials or outsources services from overseas suppliers. There are more than 1,000 aircrafts in Thailand which are operated by commercial airlines, government, commercial flying training schools, and private owners (Department of Civil Aviation, 2011). The supply chain of aircraft operators in Thailand is different than airlines in US. In the US, several suppliers and repair shops are located near airlines. Buying and repairing lead-time is shorter as well as costs are lower. Whereas, the procurement lead time in Thailand is longer as well as manpower costs in Thailand are lower.

Government agencies fly their aircraft under self-quality assurance system with supports from manufacturers. Royal Thai Air Force, Royal Thai Navy, Royal Thai Army, Ministry of Agriculture, and the Ministry of Natural Resource are operating the aircraft fleet under different maintenance systems. They usually buy spare parts overseas. Most of them believe that aircraft parts which are manufactured or repaired by the OEM (Original Equipment Manufacturer) are top quality products, Federal Aviation Administration (FAA) or European Aviation Safety Agency (EASA) is the second class quality aircraft parts. These government agencies prefer the OEM parts. However, prices and lead times are other trade-off issues in a decision making. They frequently find long lead time problem in purchasing and repairing. Sometimes, the repair in US takes 18 month lead-time. The operator must cannibalize aircraft parts from the other unserviceable aircraft which use double manpower and is risky for unexpected malfunction during removing. Moreover, some aircrafts must stop flying and waiting for the spare parts. This problem results in cancelling some government missions.

On the other hand, commercial airlines and commercial flying training schools are operating in Thailand under the Department of Civil Aviation (DCA) regulations according to Milde and Kumpeera (2012). They prefer the lowest costs with minimum quality required by DCA regulation. The lead-time is also the important factor in the airline, especially the high utilization airline such as Thai Air Asia airline. They lost much income per day of unserviceable aircraft. Moreover, they have other extra expenses e.g. parking fees, recovering costs, and etc.

The private own aircrafts in Thailand are operating under DCA regulations. They mostly fly for leisure and seek the cheapest aircraft maintenance cost. Since they are flying as hobbies, they can wait for a longer purchasing lead-time in return for lower material price.

This paper reviews important factors which impact aircraft maintenance performance. Later, this paper establishes the multi-criteria portfolio for supplier selection which benefits aircraft maintenance managers in making decision of material procurement. Finally, this method is implemented in the actual airline case in Thailand.

# 2. Literature Review

There are several studies in performance measurement methods in the aviation supply chain according to Choy et al. (2007); (Langford, 2006). Most of them used a single factor to measure their systems. However, in a practical environment, the system components of several important factors relate to enterprises' key success factors. The authors specify key factors in aircraft maintenance into cost, time, quality, reliability, maintainability, availability, and flexibility or replaceability.

# 2.1 Cost

The cost is the prime factor of firms, especially in a highly competitive industry. Airline operations directly affect the costs of the products or services and their purchase prices. Platts and Song, (2010) mentioned unsatisfied global sourcing costs. Higher costs and prices decrease airline competitiveness regarding to Beckman and Rosenfield (2008). Choy et al. (2007) had studied the costs of aircraft parts and developed a performance measurement system to monitor the effectiveness of the logistics flow in handling various components for rework, maintenance, or replacement and benchmark with the best-in-class practice. Moreover, Kumar et al. (2009) suggested that the process analysis or cost reduction strategy provides insights into the inefficiencies which exist within current processes and place more emphasis on demand pull type processes which require forecasting operational schedules.

# 2.2 Time

Time refers to maintenance time and material procurement lead time. Yang et al. (2011) defined maintenance time is the job processing times since service requested by a customer to completely fulfill that requirement. According to Chandra and Grabis, (2008), procurement lead time begins from an order issued until the part's arrival at the promised location. Lead times include transportation time, custom clearance time, and other unexpected delay. Moreover, Jones et al. (2010) suggested the supplier relationship possibly affects to procurement lead time. Chen and Chu (2010) studied in minimizing completion time subject to maintenance and proposed integer linear programming. This model only applies to serial dependent setup time jobs, but in aircraft maintenance practical operations continuously perform in parallel and sequentially.

# 2.3 Quality

Aircraft parts must be manufactured by factories which officially approved by civil aviation organization of the state. Also, inspection, repair, altering, or overhauls of aircraft parts must performed by approved factory

(Kinnison, 2004). The worldwide accredited auditors are Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA). Department of Civil Aviation (DCA) of Thailand is also approved as the auditor of repairing factories which located in Thailand (Yadav, 2010). On the other hand, quality of aircraft maintenance is related to approval organization. Airlines trust FAA/EASA certified repair stations as top quality and DCA certified repair station as lower quality. However, both FAA/EASA and DCA are acceptable as explained in ICAO annex 6 (International Civil Aviation Organization, 2012).

# 2.4 Reliability

John Langford (2006) explained the meaning of reliability as "*The probability that a system will perform its intended function for a specified interval under stated conditions*" and expressed as:

$$R_t = e^{-\lambda t} \tag{1}$$

Where;

 $R_t$  = probability that the system will successfully preform as required over the interval of time t.

- $\lambda$  = failure rate.
- t = specified operation interval.
- *€* = 2.7182818.

From Eq.1, the longer mean time between failure (MTBF) results in higher reliability. In order to increase aircraft reliability, maintenance managers must reduce aircraft downtime for maintenance which related to aircraft parts procurement lead time and repairing time (Langford, 2006). The failure rate dictates the frequency of unscheduled corrective maintenance (or repair) of a system affected by random malfunction. Low reliability indicates frequent failures, which trigger more frequent corrective maintenance.

# 2.5 *Maintainability*

The maintainability measures ability of a system to be restored to a specified level of operational readiness within defined intervals with the use of prescribed, facility, and equipment resources (Dhillon, 2006); (Langford, 2006). The maintainability is related to scheduled and unscheduled maintenance. The minimization of related factors time, procurement lead time, and corrective/preventive time results to maximize maintainability. According to Smith and Mobley (2007), maintainability refers to ease and speed which any maintenance activity can be carried out on an equipment. Maintainability may be measured by Mean Time to Repair (MTTR). Gulati and Smith (2008) referred maintainability as a function of equipment design, and maintenance task design including use of appropriate tools, jigs, work platforms, and etc. Once a piece of equipment has failed, it must be possible to get it back into an operating condition as soon as possible.

2.6 Availability

Regarding to Samet et al. (2010), availability measures the readiness of a system to fulfill its assigned function. Airlines try to obtain high utilization to maximize their income. Ferguson et al. (2012) suggested the aircraft must be available before next scheduled flight. Otherwise, the flight delay can be costly. According to Hennequin et al. (2009) and Su and Tsai (2010), maintenance managers must predict unforeseen troubles and pre-plan materials, skilled technician, and facilities. They seek possible solutions for minimizing aircraft maintenance times which result to maximize availability.

# 2.7 *Flexibility/Replaceability*

Operation managers frequently experience problems of material shortage or malfunction of equipment. Flexibility is an ability of production plant or service provider switches the planned operation to another process or solution to meet the customer expectation (Oke, 2005). Soon and Udin (2011) defined supply chain flexibility as an ability to reconfigure the supply chain and alter the supply of product in line with customer

demand.

In this research, the three factors of aircraft maintenance-cost, aircraft downtime, and quality are considered since the reliability, maintainability and availability relate to aircraft downtimes in an adverse direction. On the other hand, flexibility and replaceability relates to choice of alteration material sources or outsource maintenance centers.

## 3. Multi- Criteria Supplier Selection Model

According to Pleumpirom and Amornsawadwatana (2010), the supply chain of aviation is established and can be illustrated in Figure 1. The suppliers deliver materials or maintenance services to airline. Later, the airline delivers services to passengers, tour agency, and air cargo agency with promises quantity and specified time. The airline must prepare its aircrafts with effective and efficient maintenance. Back office has to plan future maintenances which conform to flight plan. The manager must make a decision whether to in-source or outsource maintenance services as well as materials suppliers in advance.



Figure 1: Supply Chain of Airlines with Maintenance Support

Source: Pleumpirom and Amornsawadwatana (2010)

These activities need powerful and impact decision tools to aircraft maintenance and relevant supply chain. The planner has to survey aircraft flying requirements and transform them to flight plan which indicate exactly aircraft registration number and flight schedule. Then, the planner reviews aircraft maintenance planning data along with aircraft use. The results are maintenance scope of works and individual maintenance schedule. The next process is the resource preparation for future inspection. There are different types of inspection e.g. A-

check (aircraft inspection 600 flight hours interval) and C-Check (aircraft inspection 6,000 flight hours interval). The aircraft maintenance plan can be depicted in Figure 2.



Figure 2: Aircraft Maintenance Planning Process

The quality of aircraft parts must be high realized which conform to aviation organization certificate. In this research, quality is classified as follows: (1) OEM (Original Equipment Manufacturer) = 4; (2) FAA (Federal Aviation Administration) or EASA (European aviation safety agency) = 3; (3) Thai DCA (Department of Civil Aviation) = 2; (4) Other state aviation organization approval = 1; (5) Bogus part = 0. Airlines should accept at least Thai DCA approval quality.

The maintenance manager plans future aircraft inspection and necessary resources. First, he reviews the scope of works in aircraft manufacturer's manual, in which he obtains A-check and C-check as shown in Figure 2. Second, he identifies each check into N tasks that illustrates procedures, level of manpower, tools, and

materials. Lastly, he makes the list of materials of each check which need advance procurement before the check starting. There are several occurrences that the lack of material result of the exceed aircraft ground time plan. It is important to generate an effective maintenance planning, a professional plan, which results lower cost, the shorter aircraft ground time, the higher aircraft availability, more reliability, and higher maintainability.

As shown in Figure 3, the portfolio of decision making for a source of material procurements. The process starts in loading material data of buying, repair, and loan which includes price, lead time, and quality level. There are three criteria, cost, lead time, and quality level. The cost of repair must less than 85 percent of buying cost. The lead time of both buying and repairing must less than the safety time which means that item must be received before the starting of the check. Nevertheless, the manager may loan the item from other sources as he waits for material from buying or repairing. To make the lowest cost, the manager must compare between loan cost plus buy cost and loan cost plus repair cost. Moreover, the quality of materials is important because the source of the materials must be certified by state authority. In Thailand, the repair item must be certified by the FAA, or EASA. There are four choices of final decision by this diagram which are buying, repair, loan plus buying, and loan plus repair.

		I Igui e et i oi	tiono or muterr	ui boui ee beieee	1011	
	Q-Buy≥	Q-Repair ≥ DCA	Buy	Buy	Repair	Loan and Buy
Repair Price $\geq$	FAA/EASA	Q-Repair < DCA	Buy	Buy	Loan and Buy	Loan and Buy
85% Buy Price	Q-Buy <	Q-Repair≥ DCA	Repair	Loan and Repair	Repair	Loan and Repair
	FAA/EASA	Q-Repair < DCA	Loan and find more sources	Loan and find more sources	Loan and find more sources	Loan and find more sources
	Q-Buy≥	Q-Repair≥ DCA	Repair	Loan and Repair	Repair	Loan and Repair
Repair Price <	FAA/EASA	Q-Repair < DCA	Buy	Buy	Loan and Buy	Loan and Buy
85% Buy Price	Q-Buy <	Q-Repair≥ DCA	BuyBuyLoarRepairLoan and RepairH	Repair	Loan and Repair	
	Q-Buy < FAA/EASA     DCA     Repair     Loan and Repair       Q-Repair < DCA     Q-Repair < DCA     Loan and find more sources     Loan and find more sources		Loan and find more sources	Loan and find more sources		
** It is assumed that a lead-time on loan item is in		Buy LT: in time	Buy LT: in time	Buy LT: out of time	Buy LT: out of time	
time a	nd always availa	ble.	Repair LT: in time	Repair LT: out of time	Repair LT: in time	Repair LT: out of time

**Figure 3: Portfolio of Material Source Selection** 

# 4. The Case of AA airline in Thailand

The AA Airline is budget airline which is registered in Thailand. They have flown Airbus A320 aircraft for more than five years, with continuous growth. They are looking for tools which guide them to enhance their competitive advantage in the Asia market. In this paper, the Multi Criteria Supplier Selection for Aircraft Maintenance model is developed to maintenance system of AA airline. The two steps, aircraft maintenance process and material source selection, are used.

The engineers start reviewing A320 Maintenance Planning Data manual. The manual indicates that the AA airline must perform the E-check every 750 flight hours as well as the C-check every 7500 flight hours. Hence, they follow the instructions in manual and generate sixty E-checks and eight C-checks as illustrated in Table 1. Each check applies to all A320 aircraft in their fleet.

<b>E</b> 1	E2	E3	E4	E5	E6	E7	E8	E9	E10+C1
750	1500	2250	3000	3750	4500	5250	6000	6750	7500
E11	E12	E13	E14	E15	E16	E17	E18	E19	E20+C2
8250	9000	9750	10500	11250	12000	12750	13500	14250	15000
E21	E22	E23	E24	E25	E26	E27	E28	E29	E30 + C3
15750	16500	17250	18000	18750	19500	20250	21000	21750	22500
E31	E32	E33	E34	E35	E36	E37	E38	E39	E40+C4
23250	24000	24750	25500	26250	27000	27750	28500	29250	30000
E41	E42	E43	E44	E45	E46	E47	E48	E49	E50+C5
30750	31500	32250	33000	33750	34500	35250	36000	36750	37500
E51	E52	E53	E54	E55	E56	E57	E58	E59	E60+C6
38250	39000	39750	40500	41250	42000	42750	43500	44250	45000
E1	E2	E3	E4	E5	E6	E7	E8	E9	E10+C7
45750	46500	47250	48000	48750	49500	50250	51000	51750	52500
E11	E12	E13	E14	E15	E16	E17	E18	E19	E20+C8
53250	54000	54750	55500	56250	57000	57750	58500	59250	60000

Table 1: E-Check and C- Check with indicated flight hour

The Table 1 calculates the intervals of all A-check and C-check, then it indicates the specific flight hours which AA airline must perform suitable check e.g. AA Airline must perform the Check E10 and Check C1 when the aircraft reach 7500 flight hours. The expected utilization is 300 flight hours per aircraft per month. The engineers calculate the flight hour of aircraft on each month, then he generates maintenance schedule.

The maintenance manager should not start aircraft check until all necessary resources are ready on the working site. Otherwise, it may be problematic in a stoppage of working with long waiting for material from other resources. Especially, the aircraft-parts procurement mostly buys from overseas and generally takes a long lead time with a difficult control.

			Buy			Repair			Loan	
Item	Part Number	Price (US\$)	Lead Time (days)	Quality	Price (US\$)	Lead Time (days)	Quality	Price (US\$)	Lead Time (days)	Quality
1	E7-001	2,365.00	13	FAA	798.00	7	DCA	354.75	2	DCA
2	E7-002	540.00	20	EASA	400.00	25	FAA	81.00	1	DCA
3	E7-003	1,894.50	50	FAA	750.00	4	BOGUS	284.18	1	DCA
4	E7-004	2,750.00	30	EASA	2,500.00	18	EASA	412.50	1	EASA
5	E7-005	15,700.00	47	EASA	7,530.00	50	FAA	2,355.00	1	EASA
6	E7-006	150.00	45	FAA	130.00	30	DCA	22.50	1	DCA
7	E7-007	3,785.00	30	EASA	1,275.00	25	BOGUS	567.75	1	DCA
8	E7-008	5,534.00	40	EASA	3,500.00	35	EASA	830.10	1	EASA
9	E7-009	7,539.00	35	EASA	6,300.00	30	FAA	1,130.85	2	EASA
10	E7-010	1,890.00	38	EASA	1,450.00	28	FAA	283.50	1	EASA
11	E7-011	250.00	29	FAA	200.00	18	DCA	37.50	1	DCA
12	E7-012	368.00	30	FAA	300.00	25	DCA	55.20	1	DCA
13	E7-013	7,490.00	30	EASA	6,000.00	20	EASA	1,123.50	1	EASA
14	E7-014	1,296.00	30	EASA	1,050.00	25	DCA	194.40	1	DCA
15	E7-015	7,706.00	48	EASA	7,008.00	30	EASA	1,155.90	1	DCA
16	E7-016	5,483.00	25	EASA	4,850.00	15	EASA	822.45	1	DCA
17	E7-017	2,845.00	20	EASA	1,550.00	15	FAA	426.75	1	DCA
18	E7-018	1,650.00	20	EASA	1,450.00	15	FAA	247.50	1	DCA
19	E7-019	27,544.00	25	EASA	15,000.00	40	EASA	4,131.60	1	EASA
20	E7-020	5,430.00	27	EASA	3,560.00	52	FAA	814.50	1	DCA
21	E7-021	4,365.00	25	FAA	2,150.00	52	EASA	654.75	1	DCA
22	E7-022	745.00	25	FAA	620.00	30	DCA	111.75	1	DCA
23	E7-023	3,564.00	20	FAA	2,890.00	30	FAA	534.60	1	DCA

Table 2: Material list for E7 check and data on procurement

Note: safety day = 45 days

The portfolio of a material source selection is developed in the material plan process of AA airline. The engineers generate a material list for E-checks and C-checks. For simple explanation, this paper use data from the list of material from only one E7 check as shown in Table 2.

This research uses sample data of E7 check which requires 23 items of materials. Each line in Table 2 is composed of buy price, repair price, loan price, lead-time of each source, and quality of each source. The results are illustrated as in Table 3.

	Dout Mousehou	Ma	terial Source Sel	ection
пет	Part Number	Buy	Repair	Loan
1	E7-001		Х	
2	E7-002		Х	
3	E7-003	Х		X
4	E7-004	Х		
5	E7-005	Х		X
6	E7-006	Х		
7	E7-007	Х		
8	E7-008		Х	
9	E7-009		Х	
10	E7-010		Х	
11	E7-011		Х	
12	E7-012		Х	
13	E7-013		Х	
14	E7-014		Х	
15	E7-015		Х	
16	E7-016	Х		
17	E7-017		Х	
18	E7-018	Х		
19	E7-019		Х	
20	E7-020		X	X
21	E7-021		X	X
22	E7-022		X	
23	E7-023		X	

 Table 3: Result of Supplier Source Selection

The results of the evaluation are identified four alternatives - buy, repair, buy with a loan, and repair with a loan. These 23 items are only few decision making process in an actual material requirement planning. For long term plans, there are sixty E-checks and eight C-checks as illustrated in Table 1 which require over 1,000,000 items of materials. Moreover, the flight hours of each aircraft are possibly fluctuated from 300 flight hours per month plan. Hence, the engineers have to monitor the requirement of materials monthly.

#### 5. Conclusions

In this research, the Multi Criteria Supplier Selection for Aircraft Maintenance is particularly useful to aircraft maintenance organizations in simultaneous reduction of cost and aircraft downtime as well as increase quality. Also, it values to an improvement of supplier flexibility/replaceability, aircraft availability, and aircraft reliability. For airlines in Thailand, the results of the portfolio with the AA airline's data can be implemented as a decision support strategy of multi-factor in aircraft maintenance.

There are six contributions of this paper. First, the portfolio of a material source selection supports commercial airlines and the military aircraft fleet in survival under limited budget. Second, this research illustrates the critical factors regarding to aviation performance measurement. Third, the portfolio assists the aircraft maintenance manager as a decision support of resources selection. Forth, the airline maintenance manager could develop their specific portfolio in their maintenance to increase relative benchmarking and continue their best operation to enhance their competitive advantage. Fifth, the outcome of this research can also apply in aircraft operational risk management. Finally, it provides foundation for the future research in performance analysis of other industries e.g. ship, train, truck, etc.

Moreover, aircraft fuel price is a vital factor which related to operating cost and need to be carefully monitored. Thus the future research may consider fuel cost factor in the selection model.

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# Low-cost Carriers in China: Spring Airline's Effect on Market Competition and its Entry Pattern

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# Abstract

Although China lags behind other liberalized aviation markets on Low Cost Carrier (LCC) development, its first and only recognized LCC, Spring airline, demonstrates rapid growth and great profitability since its inauguration in year 2005. Our study finds that Spring airline adopts "cream skimming" strategy to enter high priced routes. In those routes, FSC's (full service carrier) prices are high. Spring airline thus can easily attract enough demand with slightly lower price instead of triggering a price war. This strategy allows Spring airline to distinguish from other FSCs at lower cost and can enjoy high profitability by charging reasonably high price. But it is also found that Spring airline's market entry has forced other FSCs to reduce fares in response. However, different from what observed in other countries' markets, Chinese FSCs do not respond that aggressively by reducing too much of prices. This is probably because FSCs does not treat Spring airline as a real threat due to its limited market capacity. An entry study is also conducted for Spring airline. It is found Spring airline prefers to enter long-haul route, probably to avoid head-to-head competition with Chinese high speed rail (HSR) in medium and short haul market. Similar to other LCCs around the world, Spring airline puts higher priority on dense routes although permits are difficult to get from CAAC. Last, FSC's airport hub status in Beijing and Guangzhou deters Spring airline's presence in those airports. Instead, Spring airline is very likely to extend network from its own hubs in Shanghai.

Keywords: Chinese aviation industry, LCC, Spring airline, cream-skimming, entry pattern

#### 1. Introduction

Chinese aviation industry has experienced explosive growth during past decades, making it the world second largest aviation market in terms of scheduled capacity. Despite phenomenal market prosperity, aviation market development in China lags behind those in western developed countries. While U.S. has completely deregulated its aviation market from year 1978, and European countries initiated market reforms to promote market deregulation since year 1980s, China only started to relax its tight regulation on civil aviation in a cautious and experimental manner from late 1990s. Regarding LCC sector, deregulations in U.S and Europe considerably stimulated their LCC development, creating world renowned LCC brands, including Southwest, Ryanair and Easyjet. In China, the first and only recognized LCC, Spring airline, was not inaugurated until year 2005. This is a result of CAAC's (Civil Aviation Administration of China) lift of restriction on private ownership in airline.

Chinese LCC has to overcome several obstacles to thrive. On policy side, airlines do not have total autonomy on route entry, pilot recruitment and aircraft purchase decisions All these decisions have to be examined CAAC. On cost side, airline cost is highly uncontrollable in China. For example, fuel supply in China is controlled by state owned enterprise, making the jet fuel price very high. In addition, the airport service charge is also regulated by CAAC. It is thus difficult for private to negotiate favorable terms with airports. In

spite of existing regulations and unfriendly environment, Spring airline has still achieved rapid growth in firm size and profitability. Its success illustrates that LCC still can be a feasible business model in China.

Among previous LCC literature in western countries, effect of LCC presence on FSC pricing has been well examined. Studies back to 1990s confirmed that LCC entrant lowers market prices and stimulates traffic volume. Whinston and Collins (1992) studied the People Express, pioneer LCC in U.S., and concluded that People Express's entry forces the air tickets to fall by average 34%. Windle and Dresner (1995) studied Southwest and America and also found similar fare reducing effect due to LCC competition. Dresner et al.(1996), Richards (1996), US Department of Transportation (1996) and Windle and Dresner (1999) concluded that LCC has even larger impact on fares if adjacent markets are also considered. By examining Southwest airline, Morrison (2001) summarized that the LCC's effect on airline market consists of three parts, namely actual, adjacent and potential competition. The author estimated that the Southwest airline aggregately brings about 12.9 billion USD saving for U.S. air passengers in year 1998. The amount of savings accounts for 20% of total domestic scheduled passenger revenue.

Another interest in LCC study is LCC market entry pattern. It is observed that LCC is more willing to enter short haul and dense markets. This can help LCCs to achieve high load factor and quick turn-around time. In addition, most LCCs prefer to choose secondary city airports with less congestion and more favorable service charge terms. Above entry strategies were first practiced by Southwest airline and then widely imitated by LCC followers all around the world. Other uncommon LCCs' entry strategy, however, can be exemplified by Jetblue airways and Oasis airlines that focus on long-haul routes.

Discrete choice models are set up to formally examine LCC market entry choices. Boguslaski et al. (2004) investigated Southwest entry pattern during year 1990 and 2000. They confirmed that Southwest airline is more likely to enter short haul dense routes and to target at those low income and leisure passengers. In addition, Southwest airline avoids to operate in other FSCs' hub airports and to expand network from airports where it has already provided services. Another study by Oliveira (2008) shed light on the entry pattern of Gol airline, Brazilian most successful LCC. The evolution of LCC entry pattern is considered in this study. It suggests that at early stage, Gol adopts similar entry strategies as Southwest to enter short haul and dense markets, while with constant growth Gol added more long-haul routes into the network.

Despite above rich LCC studies, it is still unclear whether these findings can be directly cited to explain Spring airline's success in China. A dedicated study on Spring airline should be conducted given Chinese distinct policy and market structure conditions. This study on Spring airline, therefore, may supplement current LCC literature by identifying LCC development and competition futures in markets like China which is growing rapidly but is still tightly regulated.

This paper is organized as follows. Section 2 provides background information on Spring airline. In section 3, a reduced form fare equation is estimated to identify Spring airline's impact on Chinese FSC's pricing behavior. Section 4 examines Spring airline's entry pattern by estimating a Probit model. Last section summarizes and concludes this study.

#### 2. Background of Spring Airline

Spring airline, the first LCC and the second private airline in China, was founded by Shanghai Spring International Travel Services (Spring Tour) in year 2005. Despite short history, Spring airline has shown a quick growth in firm size, traffic throughput and fleet build-up. As summarized in Table 1, passengers carried by Spring airline reached over 5.8 million in year 2010, increased by over four times since year 2006. In terms of market size, Spring airline expanded from only 13 routes with 4 aircrafts in year 2006 to 38 routes with 20 aircrafts in year 2010 (see Table 2 and Table 3). Apart from the continuous expansion in domestic markets, Spring airline also extents service to more international destinations. In year 2010 and 2011, Spring airline opened flights to Japan, Hong Kong and Macao. Meanwhile Spring airline is planning to exploit service to ASEAN countries.

		_				-
Year		2006	2007	2008	2009	2010
Traffic	Pax	1137062	2353059	2943775	4312889	5859697
	RPK	135167.6	308869.4	375293.7	587943.3	810863.6
	Freight	8137	13641	18073	21944.6	34931.1
	RFTK	947.4	1578.7	2130.1	2822.2	4853.2
	RTK	12925.8	28958.7	35535.2	55174.4	76735.4
Share	Pax	0.78%	1.39%	1.66%	2.00%	2.36%
	RPK	0.73%	1.42%	1.63%	2.09%	2.47%
	Freight	0.32%	0.48%	0.63%	0.69%	0.94%
	RFTK	0.25%	0.38%	0.50%	0.60%	0.91%
	RTK	0.64%	1.23%	1.43%	1.86%	2.22%

Table 1: Summary of Spring airline's traffic volume and market share over years

Source: Statistical Data on Civil Aviation of China

Unit: Pax (person), RPK (10,000), Freight (tonne), RFTK & RTK (10,000 tonne kilometer)

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Year End	2006	2007	2008	2009	2010
Total	4	8	10	14	20
A320	4	8	10	14	20

Source: Statistical Data on Civil Aviation of China

Tat	ble 3: Spring a	irline's opera	ting statistic	s on route le	vel	
Year	2006	2007	2008	2009	2010	2011
No. of routes	13	13	13	22	38	60
A.V.E Density (yearly)	60092.3	89529.2	89750.8	105169.1	113153.7	120195.0
A.V.E route Share	35.3%	40.6%	42.0%	25.5%	29.3%	30.2%
A.V.E route Share *	23.5%	22.7%	24.6%	18.1%	21.0%	19.5%

Source: OAG data.

Remark: a route is regarded to be served only when airline's scheduled seats exceed 12,000 per year (1,000 per month); The route defined here is airport-pair; A.V.E route Share \* is the average market share excluding Spring airline's monopoly routes where it holds 100% market share.

Apart from considerably growing firm size and quick market expansion, Spring airline's extraordinary profitability makes it the most successful private airline in China. Since inauguration in year 2005, Spring air reports six-year consecutive profits. In year 2010 alone, it achieved net profit of 470 million Chinese yuan. Despite global financial crisis, Spring airline had a profit increase over five times in year 2009. This continuous profitability is really a phenomenal achievement in the light of Chinese unfriendly operating environment to private and LCC carrier. Li and Zheng (2008) concluded that 80% of Chinese airlines' cost is uncontrollable, since fuel supply, airport charges and taxes are all regulated, thus the room for Spring airline to lower its operating cost is essentially limited. With this phenomenal profitability record, Spring airline is trying to get listed on major stock exchanges so as to fulfill its ambition to expand.

It is admitted that the overall economic prosperity in China provides great impetus for Spring airline's phenomenal growth. Spring airline's achievement, however, should mainly be attributable to its correct market positioning and successful strategies. On cost side, Spring airline lowers operating cost as much as possible through strict measures such as no-frill services, intense seats arrangement, use of single type aircraft (see Table 2) and self developed computer ticket reservation system. According to Zhang et al (2008), Spring airline manages to achieve 18% lower unit operating cost than industry average level and keeps its load factor as high as 95%. On demand side, Spring airline provides cheaper fares to attract leisure and price sensitive passengers. This proves to be successful due to Chinese populous low income travelers and business people who pay themselves for leisure travel.

Spring airline's success is more apparent when compared to other Chinese private airlines. Okay airline originally followed LCC model similar to Spring airline, but after only seven months, it gave up. Okay airline management owes their failure to the high proportion of uncontrollable cost and tight CAAC regulations. Another private airline, EastStar, after two years unsuccessful operation, went bankrupted and was taken over by Air China. Figure 1 summarizes the RPK for Chinese private airlines established since year 2005. It clearly shows that Spring airline outperforms other counterpart private airlines in both market size and expansion speed.



Figure 1: RPK for Chinese private airlines from year 2006 to year 2010

Source: Statistical Data on Civil Aviation of China

Despite Spring airline's rapid growth and widely recognized success, its market share in Chinese domestic market is still very low. For aggregate Chinese domestic market, Spring airline only accounted for less than 3% in year 2010. On route specific level, Spring airline's average share is around 20%.<sup>1</sup> Chinese domestic market is still dominated by four legacy FSCs, including "Big Three", namely, Air China, China Eastern and China Southern, and Hainan airline. For example, in year 2010, the above four airlines' aggregate RPK reached 259,303 million, representing 64% in entire Chinese market. This market share distribution among LCC and FSCs is quite different from what observed in U.S. and Europe because Southwest has been the largest airline in U.S. aviation market since the last decade.

#### 3. Spring Airline's Impact on FSC's Ticket Price

#### 3.1 The reduced form fare equation and data description

Previous literature found that LCC presence significantly reduced fares, known as "Southwest effect". Windle and Dersner (1995) estimated a single fare equation and concluded that the Southwest airline significantly reduced ticket price. However, their independent variable "passenger volume" might be endogenous. Morrison and Winston (1995) and Morrison (2001) estimated a single reduced form fare equation by excluding the "passenger volume" variable. Later studies simultaneously estimate a fare and a demand function, including Richard (1996), Dresner *et al* (1996) and Windle and Dresner (1999). All these studies reached same conclusion that the market average ticket prices drop significantly with LCC entry.

Due to the lack of fare data, our study adopts similar econometric model to Morrison and Winston (1995). This regression model may help us to examine how Spring airline's market presence affect other legacy FSCs' pricing behavior. The explicit model specification is as following equation (1).

(1). 
$$\ln Yield_{j,t} = \alpha_0 + \alpha_1 \ln Dist_{j,t} + \alpha_2 AirportCap_{j,t} + \alpha_3 \ln HH_{j,t} + \alpha_4 \ln AirShareM_{j,t} + \alpha_5 Tour_{j,t} + \alpha_6 Spring_{j,t} + \gamma Quarter_{j,t} + \mu Year_{j,t} + \varepsilon_{j,t}$$

where

<sup>&</sup>lt;sup>1</sup> This is the average route share excluding those only operated by Spring airline.

 $Yield_{j,t} = FSC's$  average yield on route *j* in time *t*; yield is obtained by dividing ticket price by flying distance (US dollar per kilometer)

*Dist<sub>j,t</sub>* = flying distance for route *j*;

*AirportCap<sub>i,t</sub>* = Product of the endpoint airports' scheduled passenger capacity for route *j* in time *t*;

 $HHI_{j,t}$  = the Herfindahl Hirschman Index for route *j* in time *t*;

 $AirShareM_{j,t}$  = Product of FSC's mean airport share of the endpoint airports for route j in time t;

 $Tour_{j,t}$  = Dummy variable equaling to one if one or both of the end point airports for route *j* is a tourist destination; Here, we define "Kunming, Guilin, Lijiang, Xi'an, Lhasa, Haikou, Sanya and Hailar" as tourist destinations;

 $Spring_{j,t}$  = Spring airline's presence dummy for route *j* in time *t*;

**Quarter**<sub>*j*,*t*</sub> is a vector of quarter dummy; **Year**<sub>*j*,*t*</sub> is a vector of year dummy.

Dependent variable *Yield<sub>j,t</sub>* is FSCs' average yield on one route. Here, FSCs in our study include China's "Big Three" state owned airlines (Air China, China Eastern and China Southern) and Hainan airlines. These four airlines dominate Chinese domestic aviation market. Various exogenous variables control different factors determining FSCs' yield on one route. Route distance  $Dist_{j,t}$  is included because yield generally decreases with average stage length. Variable  $AirportCap_{j,t}$  measures the potential demand on the route with similar effect as controlling population and citizen income level for one route. Variable  $HHI_{j,t}$  measures route market competition intensity. It is expected that fares are higher on more concentrated routes. Variable  $AirShareM_{j,t}$  measures airline's airport dominance. Intuitively, when airlines possess larger market share in endpoint airports, they may enjoy "Hub Premium" to charge higher ticket price (Borenstein, 1990). Variable  $Tour_{j,t}$  controls routes involving tourism destinations. Our most important variable is Spring airline's presence dummy variable  $Spring_{i,j,t}$ . This variable captures the fare difference between routes with and without Spring airline's presence. Last, time series effects are controlled by including both quarter and year dummies.

We compiled monthly panel data covering total 514 Chinese domestic routes (top 500 routes plus all the routes operated by Spring airline) spanning from August 2008 to July 2012. Air ticket price data is from PaxIS database that reports monthly airline route specific ticket price<sup>2</sup>. Flying distance, airline's route scheduled seats for calculating the HHI index, airline's airport specific scheduled capacity for calculating airline's airport share are all complied from OAG database. Spring airline is regarded to serve one route (*Spring*<sub>j,t</sub>=1) when its scheduled capacity exceed 1,000 seats per month. To keep the consistency between PaxIS and OAG database, respective FSC's ticket price in PaxIS database is counted only when this airline serves this route. Descriptive statistics for our sample data is summarized in Table 4.

# *3.2 Fare equation estimation method and results*

Assume that  $\varepsilon_{i,t}$  has the following form.

(2). 
$$\varepsilon_{j,t} = \tau_j + \sigma_{j,t}$$

 $\sigma_{j,t}$  follows the iid normally distribution and independent with explanatory variables.  $\tau_j$  is route-specific unobservable factors determining fares.

If we assumes that  $\tau_j$  is independent to explanatory variables, an OLS estimation would be unbiased and consistent. In this case the variable  $Spring_{i,j,t}$  also captures part of the unobservable route specific factors in  $\tau_j$  for those Spring airline entered routes. In this case, the  $Spring_{i,j,t}$  measures the combination two effects: 1) Spring airline's entry on FSC's effect and 2) unobservable route specific factors for Spring airline entered

<sup>&</sup>lt;sup>2</sup> Here, the ticket price is the average ticket prices for all the classes.

routes. Utilizing the panel data nature, fixed effect model can be used to control the unobservable factor  $\tau_j$  even when it is correlated with explanatory variables. Random effect model can also control  $\tau_j$  when we keep the assumption that  $\tau_j$  is independent. The reduced fare equation is estimated for average FSC's fare and is also for each individual FSC (see Appendix 1).

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1 able 4: 1	Descriptive Statist	ics for the s	ample data us	sed in fare regre	ssion
Variable	No. of Obs	Mean	Std. Dev.	Min	Max
Yield	20008	0.121	0.048	0.037	0.642
Dist	20008	1108	541	159	3309
HHI	20008	4589	2165	1411	10000
AirShareM	20008	0.067	0.069	0.00067	0.57850
AirportCap	20008	520090	675224	290	7434853
Spring	20008	0.053	0.223	0	1
Tour	20008	0.262	0.440	0	1

Table 5 summarizes estimation results for average FSC's fare. The standard error is robust after adjusting heteroskedasticiy. Estimation results for  $\ln HHI_{j,t}$  and  $\ln AirShareM_{j,t}$  are consistent among three methods. The signs are intuitively correct that fares are higher in more concentrated routes. And full service carriers charge "hub premiums". In fixed effect model, coefficients for time invariant variables  $\ln Dist_{j,t}$  and  $Tour_{j,t}$  cannot be estimated. But their signs are intuitively correct in the pooled data OLS regression and random effect model. It is shown that fares decreases with average stage length, and tourism routes have lower ticket price.

The major difference among three estimation methods is the coefficient  $\alpha_6$  for variable  $Spring_{j,t}$ . In pooled OLS regression,  $\alpha_6$  is significantly positive, which somewhat counters our expectation. But as heterogeneous route-specific effect  $\tau_j$  is not totally controlled, and the variable  $Spring_{j,t}$  controls route-specific unobservable factor for Spring airline entered routes, we get positive  $\alpha_6$  probably because the routes entered by Spring airline themselves have significantly higher price than those not entered by Spring airline. It implies that Spring airline probably intentionally selects those high priced routes to enter. Spring airline can benefit from such choices because by charging slightly lower fares, Spring airline can attract enormous demand than other routes to fill in its deployed market capacity. This also explains why Spring airline can achieve over 90% load factor. Similar strategy is widely observed in other business practice known as "cream-skimming" strategy.

Our hypothesis is reinforced with fixed and random effect model results. When unobservable route-specific factor  $\tau_j$  is totally controlled, sign of  $\alpha_6$  turns negative. In other words when eliminating the unobservable factors making Spring airline entered routes to have higher yield, the Spring airline forces FSCs to reduce fares. However, this fare reduction due to Spring airline competition is not statistically significant, although in other markets such as United States and European countries, the fares reduced dramatically due to LCC presence. To explain such pattern in China, Spring airline's route level capacity shares are examined (shown in Figure 2). Spring airline's route capacity shares are relatively lower at around 20% on dense routes with FSCs operation. Despite the rapid expansion of firm and network size, the route level capacity shares are relatively stable. This limited expansion in route market capacity might be a result of tight capacity control by CAAC. But it is also a strategic consideration that Spring airline intentionally acts as "Puppy Dog" to voluntarily restrict its route capacity on those high priced routes, so as not to trigger retaliation from incumbent legacy carriers. Because FSCs does not lose too much traffic to Spring airline due to its limited capacity, a price war is an irrational strategy for FSCs to deal with Spring airline's entry.

results
estimation
regression
Fare
Table 5:

	Pooled (	SIC		F	ixed-Effect					Random-F	ffect	
		Robust				Robust				Robust		
lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	Z	P>z
InDist	-0.463	0.003	0.00	InDist				InDist	-0.501	0.019	-26.69	0.00
InAirportCap	-0.001	0.002	0.34	InAirportCap	0.064	0.012	0.00	InAirportCap	0.038	0.008	4.57	0.00
IHHII	0.179	0.004	0.00	InHHI	0.180	0.012	0.00	IHHII	0.176	0.012	15.01	0.00
InAirShareM	0.035	0.002	0.00	InAirShareM	0.043	0.008	0.00	InAirShareM	0.041	0.007	5.72	0.00
Spring	0.035	0.005	0.00	Spring	-0.019	0.014	0.20	Spring	-0.015	0.014	-1.09	0.28
Tour	-0.045	0.003	0.00	Tour				Tour	-0.047	0.017	-2.69	0.01
q2	0.024	0.004	0.00	q2	0.017	0.004	0.00	q2	0.019	0.004	4.41	0.00
q3	0.146	0.004	0.00	q3	0.127	0.006	0.00	q3	0.135	0.005	25.66	0.00
q4	0.060	0.004	0.00	q4	0.049	0.005	0.00	q4	0.054	0.005	11.43	0.00
y2009	0.119	0.005	0.00	y2009	0.099	0.008	0.00	y2009	0.109	0.007	15.97	0.00
y2010	0.220	0.006	0.00	y2010	0.191	0.011	0.00	y2010	0.205	0.009	22.45	0.00
y2011	0.308	0.006	0.00	y2011	0.272	0.012	0.00	y2011	0.290	0.010	27.87	0.00
y2012	0.353	0.006	0.00	y2012	0.307	0.015	0.00	y2012	0.329	0.012	26.93	0.00
	-0.617	0.046	0.00		-4.573	0.167	0.00	_cons	-0.776	0.167	-4.66	0.00
				sigma_u	0.317			sigma_u	0.140			
				sigma_e	0.123			sigma_e	0.123			
No. of Obs	11	20008		No. of Obs	11	20008		No. of Obs	11	20008		
<b>R-Squared</b>		0.694		<b>R-Squared</b>	11	0.498		<b>R-Squared</b>	11	0.674		



Figure 2: Spring airline route scheduled capacity share

Source: OAG data

(b). Second Quarter in 2012

Remark: the horizontal axis indicates the rank of the route. For example, "5" means the 5<sup>th</sup> densest route in China.

To confirm our findings, FSCs' average yields before and after Spring airline's entry are compared for 35 sample routes that Spring airline entered with FSCs operation. A paired-test is conducted with result collated in Table 6. It is apparent that FSCs' average yield decreased after Spring airline's entry. But the reduction magnitude is limited to only 0.6 US cents per km. The 35 sample routes have average stage length of 1,268 kms. Thus an approximate FSC fare reduction due to Spring airline competition is around 7.7 USD (53 RMB) per ticket, which is only moderate in magnitude. Although FSC's fares slightly decreased on Spring airline entered routes, average ticket prices for those 35 sample routes are still higher than other routes without Spring airline entry.

# Table 6: Paired-t test for FSCs' yields before and after Spring airline entry

		i alleu Sa	ampiea	S Statistics	
-		Mean	Ν	Std. Deviation	Std. Error Mean
Pair 1	Before	.08615408223	35	.025445853278	.004301134233
	After	.08013747014	35	.024858018290	.004201771984

# **Paired Samples Statistics**

## **Paired Samples Correlations**

	Ν	Correlation	Sig.
Pair 1 Before & After	35	.821	.000

## **Paired Samples Test**

				Paired Difference	S				
					95% Confider the Diff	nce Interval of			Sig
									Sig.
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	(2-tailed)
Pair 1	Before -	.006016612086	.015067120648	.002546808224	.000840875055	.011192349116	2.362	34	.024
	After								

## 4. Entry Pattern of Spring Airline

## 4.1. Probit model for entry pattern study

In order to study the Spring airline's entry pattern, a simple discrete choice model similar to Boguslaski et al. (2004) and Oliveira (2008) is utilized. Because of the short history of Spring airline and its relatively few market entries since year 2005, we set our study period since its inauguration up to year 2012 to maximize the our market entry observations.

In above section 3, it has already been pointed out that Spring airline adopts "cream skimming" strategy to enter those high priced routes. This observation has been one important aspect concerning Spring airline's market entry pattern. In our discrete choice model setting, however, route price variable is not included because of the endogenity concern.

Similar to Boguslaski et al. (2004) and Oliveira (2008), Spring airline's latent post-entry profit  $\pi^*$  can be expressed in stochastic form as following equation (3).

(3) 
$$\ln \pi^* = \ln x' \varphi + \mu$$

We believe that Spring airline's post-entry profit is determined by a vector of variables  $\mathbf{x}'$ . More specifically we consider the  $\mathbf{x}'$  in the following expression (4),

(4) 
$$\ln \pi_i^* = \varphi_0 + \varphi_1 \ln Dist_i + \varphi_2 \ln AirportCap_i + \varphi_3 \ln HHI_i + \varphi_4 Density1_i + \varphi_5 Density2_i + \varphi_6 Density3_i + \varphi_7 OwnHub_i + \varphi_8 OtherHub_i + \mu_i$$

where

 $\pi_i^*$  = the latent profit for Spring airline when entering route *i*;

 $Dist_i$  = the flying distance of route *i*;

*AirportCap<sub>i</sub>* =the product of endpoint airports' passenger throughputs for route *i*;

 $HHI_i$  = the HHI index for route *i*;

 $Density1_i$  = equals to 1 for the top 20 densest Chinese routes;

 $Density2_i = equals$  to 1 for the 21 to 50 densest Chinese routes;

 $Density3_i$  = equals to 1 for the 51 to 150 densest Chinese routes;

 $OwnHub_i$  = a dummy variable equals to 1 if one of the endpoint city for route *i* is Shanghai. Shanghai has been the headquarter and hub airport for Spring airline;

 $OtherHub_i$  = a dummy variable equaling to 1 if one/ both of the endpoint airports on route *i* is Beijing or Guangzhou.

Variable  $Dist_i$  is commonly included in airline entry studies.  $AirportCap_i$  measures the potential demand on one route.  $HHI_i$  is used to capture the impacts of route concentration on Spring airline's post-entry profit. Dummy variables  $Density_i$  are included to measure the effect of market density on Spring airline's entry decision. In previous LCC studies, it is proved that LCCs are more likely to enter dense routes. Here, density dummies instead of continuous variable are used because in China the entry permits for top routes are tightly controlled by CAAC, especially the top 20 routes in China. Therefore, using dummies to distinguish the route density categories can help us also identify the route entry regulation effect on Spring airline's market entry decisions. Shanghai hub dummy  $OwnHub_i$  is important to identify the network effect of Spring airline's market expansion design. Previous studies suggest that LCCs prefer to add routes from airports where they have already served. However, as our study period starts from Spring airline's inauguration year, there are no previous services out of any airport. Since Spring airline has hub in Shanghai, it is then expected that Spring airline operates more routes originating from Shanghai. Last,  $OtherHub_i$  examines whether Spring airline avoid to involve direct competition with Air China, China Southern by operating at Beijing and Guangzhou airport.

The profit model (4) is a latent variable model, so what we can only observe is only Spring airline's entry decision variable Y. Let C be the fixed cost (sunk cost) or a profit threshold <sup>3</sup> for Spring airline to start business on one new route.

(5) 
$$Y_{i} = \begin{cases} 1, & \text{if } \pi^{*} - C > 0 \\ 0, & \text{if } \pi^{*} - C \le 0 \end{cases}$$
$$(5) \quad \operatorname{Prob}(Y_{i} = 1) = \operatorname{Prob}\left(\frac{\pi^{*}}{C} > 1\right) = \operatorname{Prob}(\ln x' \varphi - \ln C + \mu > 0)$$

It is also assumed that  $\mu_i \sim iid N(0,1)$ , thus a Probit model can be estimated with MLE (maximum likelihood estimation).

Data for this Probit model is from OAG database. We define Spring airline's entry on one route only if Spring airline's scheduled capacity exceeds 1,000 seats for at least three consecutive months. In order to avoid endogeneity problem<sup>4</sup>, our exogenous variables values are all based on year 2005 data. This is equal to assume that when Spring airline started business in year 2005, it has already made all the entry decisions up to year 2012. There are total 514 routes selected, including top 500 Chinese domestic routes and all the routes entered by Spring airline during the study period. Because explanatory variables  $HHI_i$  is in log form, thus for those routes only operated by Spring airline, HHI index before Spring airline's entry is zero, and the log zero cannot be defined, thus these observations are eliminated. After our necessary adjustments, total 496 market observations remain for this probit model estimation. Descriptive statistics for our sample data is shown in Table 7.

<sup>&</sup>lt;sup>3</sup> Only when Spring airlines can earn the profit larger than the threshold profit, will Spring airlines enter the route. This can also be understood as the opportunity cost for Spring airlines to make entry decision.

<sup>&</sup>lt;sup>4</sup> Similar to Boguslaski et al. (2004), we have to use the variable values in the beginning of the study period. Because, if using entry year variable values for different entries, these values may be affected by Spring airline's previous entries. As a result, endogeneity problem emerges.

Variable	Obs	Mean	Std. Dev.	Min	Max
Entry	496	0.123	0.329	0	1
HHI	496	6452	2583	2099	10000
Airportcap	496	29100000	55000000	44182	561000000
Dist	496	1044.93	529.91	159	3388
Tour	496	0.228	0.420	0	1
Density1	496	0.040	0.197	0	1
Density2	496	0.060	0.239	0	1
Density3	496	0.198	0.399	0	1
Ownhub	496	0.133	0.340	0	1
Otherhub	496	0.222	0.416	0	1

 Table 7: The descriptive statistics for Probit model sample data

#### 4.2 Probit model estimation results

The Probit model estimation results are reported in Table 8. First, it is noted that Spring airline is more likely to enter longer stage length route. This observation differes traditional "Southwest pattern" that LCCs choose short haul routes. The longest route length for Spring airline in domestic market is from Shanghai to Urmuqi, with flying distance as long as 3,295 kilometers, comparable to some long-haul international flights from Shanghai to Eastern or Southeastern Asia. In our data sample, mean stage length for Spring airline's entered routes is 1,247.7 kilometers, longer than the entire sample mean 1,091.7 kilometers (Table7). Spring airline is willing to choose long haul routes might be a result of more and more fierce competition imposed by high speed rail (HSR). According to Fu, Zhang and Lei (2012), HSR in China has significant advantage in connectivity and cost efficiency especially in medium and short haul routes. For example, for flights less than 600 kilometers from Whuhan Tianhe airport, 70% have been cancelled since the introduction of HSR. With fierce competition from HSR, for example, Spring airline exited from the Shanghai to Hangzhou market with stage length only 138 kilometers. Thus, selecting long-haul routes can help Spring airline avoid head-to-head competition with HSR, making it to have more advantage to attract leisure and price sensitive travelers.

		Robust		
Entry	Coef.	Std. Err.	Z	P>z
lnDist	0.90	0.21	4.26	0.00
InAirportcap	-0.20	0.09	-2.20	0.03
lnHHI	-0.07	0.29	-0.25	0.80
Density1	0.98	0.54	1.81	0.07
Density2	0.68	0.35	1.92	0.06
Density3	-0.11	0.25	-0.45	0.65
Ownhub	1.98	0.22	8.90	0.00
Otherhub	-0.89	0.37	-2.39	0.02
_Cons	-4.06	3.33	-1.22	0.22
Number of obs		=	496	
Wald chi2(8)		=	109.35	
Log pseudolikelihood		=	-122.9	
Prob > chi2		=	0	
Pseudo R2		=	0.3894	

#### Table 8: Estimation result of Spring airline's entry Probit model

In addition, coefficient for variable  $AirportCap_i$  is significantly negative. This variable  $AirportCap_i$  measures potential demand on one route with similar effect as controlling "Population" and "Personal income". Thus this negative sign indicates that Spring airline is more likely to enter secondary cities, such as Lanzhou, Shijiazhuang, Fuzhou, and Huaihua etc. This observation is in line with Spring airline market

positioning to attract leisure and price sensitive travelers. It is also, however, noticed that Spring airline's entry decisions have not been affected by the route concentration because the coefficient of  $HHI_i$  is not statistically significant. For those density dummies, interesting observations are drawn. First coefficients for  $Density1_i$  and  $Density2_i$  are significantly positive, indicating Spring airline is more likely to enter dense routes. Even for the top 20 densest routes, Spring airline has succeed to enter several of them despite great efforts have to be made to obtain entry permits from CAAC. In year 2011, after six-year wait, Spring airline is finally allowed to serve the Shanghai to Beijing route. Table 9 summarize the distribution of Spring airline's entering routes based on density categories, it is can be shown that 38% of its operating routes rank within top 150 densest out of total 1393 Chinese domestic routes in July 2012.

Route Density Rank	No.	%
1-50	12	23%
51-150	8	15%
Other	32	62%

Table 9: S	Spring	Air's route typ	e distribution	based on	route traffic	volume rank	(2012 July)
	- F						

Source: OAG data.

Last, it is revealed that Spring airline prefers to add service originating from its hubs in Shanghai. This result is intuitive in twofold aspects. First adding routes from hub airports lowers Spring airline average operating cost given the *ex ante* sunk cost already spent in this airport. Hub airports normally provide airline with more favorable user on terminal rent, ground handling, slot and gate assignment. Second, in network design aspect, focusing on hub airports to add new route helps Spring airline to maximize aircraft utilization because one aircraft can be switched among different routes more efficiently. This is rather important to Spring airline given its relatively small fleet size and difficulty to expand fleet size in a timely manner due to CAAC's aircraft purchase control. This explains why Spring airline achieves 12 to 13 hours daily aircraft utilization rate. Finally Spring airline avoids to operate in Guangzhou and Beijing airports which are the hubs for China Southern and Air China respectively. This is because Spring airline is much disadvantaged when competing with the incumbent Air China and China Southern in their home airports, as the state-owned airlines have absolute dominance in Beijing and Guangzhou.

#### 5. Conclusion

Despite phenomenal development of Chinese civil aviation in past decades, its deregulation is only a recent policy change. Many obstacles still exist for LCC to thrive in China. However, Spring airline has achieved great success, indicating LCC can be a feasible model under Chinese aviation market circumstance. In the light of Spring airline's rapid growth, its impact on other Chinese legacy carriers is investigated. It is found that that Spring airline adopts "cream skimming" strategy to enter those high priced routes. This strategy allows it to easily distinguish from FSCs and to attract significant demand without lowering too much of its fares. In response to Spring airline's entry, FSCs reduced fares in response. However, this reduction is insignificant, different from what is observed in U.S and European markets where air fares are reduced dramatically with LCC competition. The FSCs' modereate response in China is probably attributed to Spring airline's still low route market capacity. This low market capacity could be a result of CAAC's implicit capacity control in order to protect legacy carriers, or could be a "Puppy Dog" strategy used by Spring airline to prevent serious retaliation by incumbent FSCs.

Regarding market entry pattern, it is found that Spring airline is more likely to enter long haul routes. This is different from Southwest and Rynair focusing on short-haul markets. Spring airline's such route selection probably aims to avoid fierce competition of Chinese HSR with absolute advantage in short and medium haul markets. In addition, Spring airline targets to serve secondary cities in China. This may help Spring airline to attract more price sensitive passengers and also enjoy lower airport charge. Besides, despite relatively tight route entry permit for dense routes, Spring airline still tries to penetrate into dense truck domestic routes. Last in order to reduce average operating cost and maximize aircraft utilization, Spring airline is more likely to add new routes originating from its hub airports in Shanghai.

In spite of Spring airline's extraordinary achievement, it is evident that LCC development in China still lags behind those in developed countries. The market share for Spring airline is still very low and the general aviation policy is more favorable to those legacy carriers. LCC has to work extremely hard to survive in China. But it should be noted healthy LCC development in long run can benefit Chinese airline industry and contribute to higher consumer surplus. Passengers can enjoy lower fares and industry efficiency can improve with intense competition. Thus, further deregulation and embrace of market-oriented mechanism is pivotal for the prosperity of Chinese civil aviation industry in the future.

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Table 10: Yield regression estimation result for Air China

Pooled OLS				<b>Fixed-Effect</b>				Random-Effect			
		Robust				Robust				Robust	
lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>z
InDist	0.465	0.006	0.000	InDist				InDist	-0.500	0.034	0.000
lnAirportCap	0.009	0.002	0.001	InAirportCap	0.113	0.016	0.000	InAirportCap	0.064	0.010	0.000
IHHII	0.166	0.008	0.000	IHHI	0.152	0.031	0.000	IHHII	0.151	0.031	0.000
lnAirShareM	0.099	0.003	0.000	InAirShareM	0.059	0.016	0.000	InAirShareM	0.068	0.013	0.000
Spring	0.003	0.011	0.808	Spring	-0.040	0.025	0.111	Spring	0.041	0.025	0.093
MU	0.008	0.005	0.134	MU	0.011	0.012	0.368	MU	0.008	0.012	0.488
CZ	0.001	0.005	0.843	CZ	-0.006	0.014	0.671	CZ	0.007	0.013	0.613
HU	0.008	0.005	0.118	HU	-0.017	0.019	0.371	HU	0.013	0.018	0.484
Tour	0.017	0.006	0.007	Tour				Tour	0.017	0.033	0.612
q2	0.058	0.006	0.000	q2	0.046	0.007	0.000	q2	0.051	0.006	0.000
q3	0.190	0.006	0.000	q3	0.152	0.008	0.000	q3	0.170	0.008	0.000
q4	0.094	0.007	0.000	q4	0.070	0.008	0.000	q4	0.080	0.007	0.000
y2009	0.142	0.010	0.000	y2009	0.105	0.012	0.000	y2009	0.125	0.011	0.000
y2010	0.241	0.010	0.000	y2010	0.193	0.017	0.000	y2010	0.221	0.015	0.000
y2011	0.332	0.010	0.000	y2011	0.271	0.018	0.000	y2011	0.306	0.016	0.000
y2012	0.389	0.011	0.000	y2012	0.299	0.022	0.000	y2012	0.346	0.018	0.000
CONS	0.381	0.097	0.000		-4.941	0.281	0.000	_cons	0.801	0.364	0.028
				sigma_u	0.325			sigma_u	0.138		
				sigma_e	0.116			sigma_e	0.116		
No. of Obs	11		6783	No. of Obs	11	6783		No. of Obs	11	6783	
<b>R-Squared</b>	11		0.694	<b>R-Squared</b>	11	0.322		<b>R-Squared</b>	11	0.628	

Pooled OLS				Fixed-Effect				Random-Effect			
		Robust				Robust				Robust	
lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>t	<b>lnYield</b>	Coef.	Std. Err.	P>z
InDist	-0.498	0.005	0.000	lnDist				lnDist	-0.488	0.03	0.00
InAirportCap	-0.004	0.002	0.086	InAirportCap	0.017	0.021	0.400	InAirportCap	0.004	0.01	0.73
IHHII	0.216	0.006	0.000	IHHI	0.200	0.019	0.000	IHHI	0.197	0.02	0.00
lnAirShareM	0.015	0.003	0.000	InAirShareM	0.016	0.013	0.221	InAirShareM	0.017	0.01	0.07
Spring	0.070	0.006	0.000	Spring	-0.021	0.015	0.168	Spring	-0.016	0.01	0.25
CA	0.085	0.005	0.000	CA	0.008	0.019	0.690	CA	0.015	0.02	0.41
CZ	0.022	0.004	0.000	CZ	0.022	0.017	0.216	CZ	0.019	0.02	0.21
HU	-0.047	0.004	0.000	HU	0.004	0.019	0.838	HU	-0.002	0.02	06.0
Tour	-0.018	0.005	0.000	Tour				Tour	-0.022	0.02	0.30
q2	0.033	0.005	0.000	q2	0.032	0.006	0.000	q2	0.033	0.01	0.00
q3	0.151	0.005	0.000	q3	0.142	0.009	0.000	q3	0.146	0.01	0.00
q4	0.077	0.005	0.000	q4	0.074	0.008	0.000	q4	0.077	0.01	0.00
y2009	0.130	0.007	0.000	y2009	0.132	0.013	0.000	y2009	0.136	0.01	0.00
y2010	0.235	0.008	0.000	y2010	0.240	0.017	0.000	y2010	0.246	0.01	0.00
y2011	0.325	0.008	0.000	y2011	0.324	0.021	0.000	y2011	0.333	0.02	0.00
y2012	0.373	0.009	0.000	y2012	0.367	0.025	0.000	y2012	0.378	0.02	0.00
	-0.759	0.071	0.000		-4.293	0.285	0.000	Cons	-0.742	0.26	0.00
				sigma_u	0.279			sigma_u	0.279		
				sigma_e	0.119			sigma_e	0.119		
No. of Obs	11	10107		No. of Obs	11	10107		No. of Obs	11	10107	
<b>R-Squared</b>	II	0.729		<b>R-Squared</b>	11	0.179		<b>R-Squared</b>	11	0.713	

Table 11: Yield regression estimation result for China Eastern

<b>Pooled OLS</b>				Fixed-Effect				Random-Effect			
		Robust				Robust				Robust	
lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>z
InDist	-0.430	0.004	0.000	lnDist				lnDist	-0.472	0.020	0.000
InAirportCap	-0.004	0.002	0.024	InAirportCap	0.073	0.013	0.000	lnAirportCap	0.040	0.010	0.000
IHHII	0.210	0.005	0.000	IHHII	0.178	0.016	0.000	IHHII	0.175	0.015	0.000
InAirShareM	-0.037	0.003	0.000	InAirShareM	0.032	0.015	0.035	InAirShareM	0.016	0.013	0.238
Spring	0.063	0.008	0.000	Spring	0.003	0.014	0.855	Spring	0.005	0.014	0.696
CA	0.040	0.004	0.000	CA	-0.003	0.016	0.872	CA	0.003	0.015	0.851
MU	-0.048	0.004	0.000	MU	-0.017	0.012	0.146	MU	-0.017	0.011	0.127
HU	-0.024	0.004	0.000	HU	-0.026	0.013	0.054	HU	-0.025	0.013	0.053
Tour	-0.038	0.004	0.000	Tour				Tour	-0.025	0.021	0.234
q2	0.025	0.004	0.000	q2	0.020	0.005	0.000	q2	0.022	0.005	0.000
q3	0.152	0.004	0.000	q3	0.129	0.007	0.000	q3	0.138	0.006	0.000
<b>q4</b>	0.057	0.005	0.000	q4	0.050	0.006	0.000	q4	0.054	0.006	0.000
y2009	0.112	0.006	0.000	y2009	0.095	0.009	0.000	y2009	0.104	0.008	0.000
y2010	0.203	0.006	0.000	y2010	0.181	0.012	0.000	y2010	0.195	0.011	0.000
y2011	0.278	0.007	0.000	y2011	0.256	0.014	0.000	y2011	0.273	0.012	0.000
y2012	0.312	0.008	0.000	y2012	0.286	0.017	0.000	y2012	0.306	0.015	0.000
CONS	-1.248	0.054	0.000	_cons	-4.704	0.215	0.000	_cons	-1.063	0.192	0.000
				sigma_u	0.315			sigma_u	0.134		
				sigma_e	0.122			sigma_e	0.122		
No. of Obs	11	13312		No. of Obs	11	13312		No. of Obs	11	13312	
<b>R-Squared</b>	II	0.683		<b>R-Squared</b>	11	0.188		<b>R-Squared</b>	11	0.647	

Table 12: Yield regression estimation result for China Southern

<b>Pooled OLS</b>				Fixed-Effect				Random-Effect			
		Robust				Robust				Robust	
lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>t	lnYield	Coef.	Std. Err.	P>z
InDist	-0.381	0.006	0.000	InDist				InDist	-0.409	0.028	0.000
InAirportCap	0.033	0.003	0.000	InAirportCap	0.138	0.022	0.000	lnAirportCap	0.068	0.014	0.000
IHHII	0.188	0.008	0.000	IHHI	0.174	0.027	0.000	IHHII	0.169	0.024	0.000
InAirShareM	0.025	0.003	0.000	InAirShareM	-0.001	0.013	0.919	lnAirShareM	0.003	0.011	0.790
Spring	0.003	0.017	0.854	Spring	-0.081	0.014	0.000	Spring	-0.075	0.014	0.000
CA	0.076	0.006	0.000	CA	0.023	0.022	0.287	CA	0.029	0.018	0.098
MU	-0.091	0.005	0.000	MU	-0.044	0.018	0.014	MU	-0.045	0.015	0.003
CZ	-0.014	0.006	0.025	CZ	0.038	0.019	0.047	CZ	0.030	0.017	0.077
Tour	-0.037	0.006	0.000	Tour				Tour	-0.016	0.023	0.501
q2	-0.005	0.006	0.450	q2	-0.002	0.009	0.841	q2	-0.001	0.009	0.934
q3	0.158	0.006	0.000	q3	0.134	0.011	0.000	q3	0.150	0.011	0.000
q4	0.033	0.007	0.000	q4	0.015	0.009	0.084	q4	0.026	0.009	0.003
y2009	0.169	0.010	0.000	y2009	0.128	0.014	0.000	y2009	0.153	0.012	0.000
y2010	0.297	0.010	0.000	y2010	0.232	0.017	0.000	y2010	0.270	0.015	0.000
y2011	0.398	0.010	0.000	y2011	0.319	0.021	0.000	y2011	0.366	0.017	0.000
y2012	0.449	0.012	0.000	y2012	0.346	0.026	0.000	y2012	0.406	0.020	0.000
cons	-1.807	0.088	0.000	_cons	-5.825	0.386	0.000		-2.019	0.329	0.000
				sigma_u	0.304			sigma_u	0.131		
				sigma_e	0.143			sigma_e	0.143		
No. of Obs	11	6603		No. of Obs	11	6603		No. of Obs	11	6603	
<b>R-Souared</b>		0.598		<b>R-Squared</b>	11	0.121		<b>R-Squared</b>	11	0.551	

Table 13: Yield regression estimation result for Hainan Airlines

# Competitive Responses of an Established Airline to the Entry of a Low-cost Carrier into its Hub Airports

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#### Abstract

This paper investigates the competitive responses of China Eastern to the entry of Spring Airlines into its hub airports in Shanghai taking into account of the actual and adjacent competition for both LCCs and full-service airlines (FSAs) within an airport-pair framework. The results of econometric analysis showed that Spring put downward pressure on China Eastern's average fares on routes where it competed from the same and nearby airports. In terms of Spring's impact on market average price of incumbent carriers, it was found that the negative effects were mainly reflected from adjacent airport competition. When the dataset is further split into trunk and thin routes, the study revealed that Spring competed aggressively with the incumbents on the thin routes resulting in substantial price reduction of the latter. Interestingly, Spring's impacts on the incumbent's fares on the trunk routes were positive and significant. The contrasting pricing behavior of Spring may be explained by current regulatory regime where strict restrictions are imposed on heavily travelled trunk routes in terms of route authority, capacity and frequency. Another important finding is that actual and adjacent competition from FSA plays an important role in suppressing the airfares for overall market, trunk- and thin-routes. Findings in this research have important policy implications.

Key words: Low-cost carriers, Airline competition, Spring Airlines, China Eastern, China

#### 1. Introduction

The rise of low-cost carriers (LCCs) in the past few decades is widely considered as one of the most important outcomes of airline deregulation and liberalization. Started in the United States (US) in the 1970s, the phenomenon of LCCs spread to Europe in the 1990s and to the Asia Pacific a decade later. These LCCs have driven down the cost of air travel and forced a fundamental restructuring of many existing full-service airlines (FSAs) (Njegovan, 2006; Papatheodorou and Lei, 2006). Intensified price competition between airlines has stimulated demand for short-haul air travel, leading to phenomenal growth of passenger traffic. According to the data from Centre for Aviation (2011), by early 2011, worldwide, LCCs had controlled 24% of market share by scheduled capacity on short-haul routes. Although LCCs have become a formidable force in many countries around the world, their presence in China is rather insignificant. With less than 3% of market share in the domestic market in 2012, China's LCC penetration is one of the lowest in the world. Since the first and the only LCC, Spring Airlines, started operations in China in 2005, there has been considerable changes of competitive landscape in the airline industry. To date, however, there is no published research systematically assesses the impact of LCCs in Chinese domestic market. Given China's status as the world's second largest aviation market and its explosive growth of air travel at a sustained annual passenger growth rate of 17% a year since 1978, a study into airline competition and LCCs in China is an important topic in contemporary aviation research.

The impacts of LCCs have generated considerable interests in the academic literature since the deregulation of the domestic airline market in the US in 1978. Studies of the US domestic market have consistently found that LCCs significantly lowered airfares on routes they entered. In the US, there is well known "Southwest

effects" where the market that Southwest entered saw a dramatic increase in passenger volumes and a decrease in average airfare. Such effects are replicated in Europe by LCCs such as Ryanair and easyJet. Previous studies on this topic generally adopted either "city-pair" approach or "airport-pair" approach to examine the impact of low cost competition. "City-pair" approach does not make any distinction between different airports in a multiple airport region; all airports in the same region are assumed to be a single origin (or destination) (Brueckner, et al, 2013). However, in reality, they are always perceived differently by passengers in terms of access cost, level of services, and so on. In contrast, "airport-pair" approach considers each individual airport-pair as a distinct market. Given the fact that LCCs mainly operate out of secondary airports within large metropolitan areas, an LCC's fare impact in an airport-pair market often arises via service at "adjacent" airports. A way to fix the problem is to take competition from adjacent airports into account (Morrison, 2001; Goolsbee and Syverson, 2008).

This paper assesses the impacts of LCCs and airline competition in Chinese domestic market. Rather than duplicating previous efforts, our research focuses on a less studied area: to examine competitive responses of an established carrier to the entry of a LCC into its hub airports. More specifically, we investigate the competitive responses of China Eastern Airlines to the entry of Spring Airlines into its hub airports in Shanghai taking into account of the actual and adjacent competition for both LCCs and full-service airlines (FSAs) within an airport-pair framework. Shanghai is selected as the focus of the study not only because it is one of the largest and most competitive aviation markets in China but also because the city has two commercial airports: Shanghai Pudong International Airport (PVG) and Shanghai Hongqiao International Airport (SHA). Both airports are considered the hub airports for China Eastern and are used as the main operating bases by Spring Airlines.

The remainder of this paper is structured as follows. Section 2 reviews the effects of LCCs and airline competition on airfare. Section 3 discusses the development of LCCs and airline competition in China. Section 4 explains the data and the construction of the empirical models used in this study. Section 5 presents the regression results, while Section 6 summarizes the main findings and concludes the paper.

#### 2. The Effects of LCCs and Airline Competition on Airfares

There is abundant research on the impacts of LCCs on airfares. Windle and Dresner (1995) found that the entry of Southwest onto a route decreased fares, on average, by 48% and resulted in increases in passengers of 200%. Vowles (2000) found that the presence of LCCs lowered the average fare in a market and Southwest had a greater impact than other LCCs.

In Europe, Alderighi, et al (2012) investigated the price-setting behavior of full-service airlines. Using data on published airfare of Lufthansa, British Airways, Alitalia and KLM for the main city-pairs from Italy to the rest of Europe, they found that competition among full-service carriers had negative impact on the price level with greater reduction in the leisure segments than the business segments. In contrast, competition with LCCs reduces both the business and leisure fares of full-service airlines uniformly.

The US Department of Transportation (1996) examined the competitive responses of established carrier Delta Airlines to the entry of LCCs on routes from two of Delta's hubs, Atlanta and Salt Lake City. The study found that on the Salt Lake City routes, Delta lowered fares by 33% on the routes where it competed with low cost competitor Morris Air; however, Delta's fares changed only modestly on the Atlanta routes after the entry of LCC VlueJet. The moderate response by Delta to the entry of ValuJet, as the study concluded, was due to the lower market shares achieved by ValuJet on the Atlanta routes, as compared to those achieved by Morris on the Salt Lake City routes. In a similar study, Windle & Dresner (1999) examined the impact of route entry of a LCC, ValuJet into an established carrier's hub, Delta. They found that Delta lowered its fares on competitive routes in response to competition by Valujet.

In terms of LCC competition from nearby airports, Dresner et al (1996) examined competitive effects from the entry of Southwest Airlines onto two routes, to Cleveland and Chicago, from Maltimore-Washington International Airport (BWI). The authors found that not only did prices decrease significantly on the routes

Southwest entered, but they also fell on competitive routes to Cleveland and Chicago from the other two Washington/Baltimore area airports.

Morrison (2001) further estimated the full effects of Southwest taking into account of actual, adjacent and potential competition using data from the US domestic market in 2008. The study showed that fares were reduced by 46% when Southwest served a route; fares were 15-26% lower when Southwest served an adjacent route that consumers view as a reasonable substitute for the route in question. Potential competition from Southwest was most effective when it served both endpoints of a route (but not the route itself) and least effective when it only served one airport that is near one of the airports in question.

Brueckner et al (2013) extended Morrison's (2001) work on the fare impacts of LCCs by examining the competitive effects of both legacy carriers and LCCs. Using quarterly data from July 2007 to June 2008 in the US domestic market, the results showed that competition from legacy carriers generally had weak effects on average fares, while low-cost competition had dramatic fare impacts on the airport-pair, at adjacent airports, or as potential competition.

In summary, substantial literature found that LCCs put downward pressure on FSAs airfares. How FSAs respond to low-cost competition depends on LCCs competitive position (e.g. the route market share controlled by LCCs). There is some evidence indicating that price impact of low cost competition is not only reflected in the actual airport-pair market but also out of nearby airports. Nevertheless, most the research was conducted in the US domestic market. It would be interesting to see whether similar results could be replicated in other countries.

# 3. LCC and Airline Competition in China

The airline industry in China used to be heavily regulated: all aspects of the industry such as market entry, route entry, frequency, fare levels and aircraft purchasing were tightly controlled by the Civil Aviation Administration of China (CAAC) (Zhang and Chen, 2003). The market was partially deregulated in 2004 with the establishment of five privately owned airlines, namely, United Eagle Airlines, Okay Airways, Lucky Air, Spring Airlines and China Express Airlines. By the end of 2008, 14 new scheduled passenger airlines were established (Lei and O'Connell, 2011). However, the domestic market is still dominated by three state-controlled carriers, namely, Air China, China Southern Airlines, and China Eastern Airlines.

Spring Airlines was set up by Shanghai Spring International Travel Services and started operation in July 2005. It has been profitable since its second year of operation. In 2012, Spring carried 9 million passengers with a fleet of 36 aircraft on 40 destinations. The airline adopted low cost business model with such features as single class cabin and no free food or drinks on board. Spring has tried many ways to save costs including the use of its own computer reservation system and encouraging online sales. Cost saving also comes from the improved daily aircraft utilization rate which reaches 12-13 hours compared with 9-10 hours for China's traditional airlines. However, regulatory constrains remained as new entrants are generally not allowed to serve the most profitable routes to minimize the impacts on state-owned incumbent carriers. Other regulatory restrictions imposed on new entrant carriers include airport charges, aircraft purchase, and fuel purchase. Consequently, the operating cost of Spring Airlines is estimated to be only 18% lower than the domestic industry average, despite its high load factor of 90% (Fu et al, 2011).

While LCCs in the US and Europe focus on underutilized or secondary airports, Spring targets major airports with limited spare capacity and concentrated traffic. For example, it recently expanded into major cities such as Beijing, Guangzhou, and Shenzhen. Spring's deviation from the traditional low-cost business model may due to the following reasons. Firstly, constraints imposed by the current regulatory environment make it difficult for Spring to reduce the operating costs to a level comparable to its Western counterparts. Secondly, given the fact that Spring's main operating base – Shanghai, is China's financial center and one of the most economically prosperous cities, it makes sense for Spring to target high yield business travelers. Finally, there is unbalanced development in Chinese domestic aviation market where routes between Shanghai, Beijing, Guangzhou and Shenzhen account for the majority of profits for most Chinese airlines.

#### 4. Empirical Models and Data

To assess the effects of competition on airfares, a reduced form price equation is developed as follows:  $\ln Fare_{ijt} = \alpha_0 + \alpha_1 Spring_{ijt} + \alpha_2 Spring_A dj_{ijt} + \alpha_3 \ln Dist_{ij} + \alpha_4 \ln Freq_{ijt} + \alpha_5 NFSA_{ijt}$ 

+ $\alpha_6 NFSA \_ Adj_{ijt} + \alpha_7 \ln OAPHHI_{it} + \alpha_8 \ln DAPHHI_{jt} + \alpha_9 Primary_{ij} + \alpha_{10} Tourist_{ij}$ 

$$+ \alpha_{11} \ln Income_{ijt} + \alpha_{12} \ln Pop_{ijt} + \sum_{m=1}^{11} \gamma_m Month_m + \sum_{n=2007}^{2009} \lambda_n Year_n$$

## 4.1 The Dependent Variable

The dependent variable  $Fare_{ijt}$  is the average one-way fare for economy class tickets of airlines on the route from airports *i* (where *i*=SHA or PVG) to airports *j* at time *t*. Only the economy class fares are used in the analysis as Spring Airlines does not provide business class services on its flights. To control for inflation, airfares are adjusted using Consumer Price Index (CPI). The logarithm form of fares is used.

The above regression equation is estimated by using different airline fares as the dependent variable. In Model 1, China Eastern's average fare is used as the dependent variable. In Model 2, the dependent variable is the average fares from all airlines in the airport-pair markets, excluding the fares of Spring Airlines to avoid treating Spring as its own competitor. Furthermore, in each model, we consider three scenarios: whole sample (all routes) and two sub-samples, namely, trunk routes and thin routes. This is because we suspect that airlines may use different pricing strategies on different types of routes. A threshold of 25,000 monthly scheduled seats is used to define trunk and thin routes. That is, if a route whose total number of seats in an airport-pair market is greater than 25,000 seats a month, it is classified as trunk routes; otherwise, thin routes.

The fare on a route is regressed on measures of actual and adjacent competition of both Spring and FSAs and other control variables that are believed to influence the cost and demand characteristics of the route. Each of the explanatory variables is discussed below.

# 4.2 The Competition Variables

Two categories of competition variables are included in the model. One category is to measure the fare impacts of Spring Airlines when it competed with the incumbents on the airport-pair market and at adjacent airports. Dummy variable *Spring* takes the value of one if Spring had a presence on the route, where the presence is defined as possessing a market share of equal to or greater than 5%, and zero otherwise. Dummy variable *Spring\_adj* takes the value of one if Spring Airlines competed from an adjacent airport in the same city-pair market.

The other category of competition variables measures the price impacts of full service airlines (FSAs). In-market competition is measured by *NFSA* which is a count variable defined as the total number of FSAs serving a route subtracting one to exclude the focal airline itself. FSAs in the sample include China Eastern, Air China, China Southern Airlines, Hainan Airlines, Shanghai Airlines, Juneyao Airlines, and several other carriers. *NFSA\_Adj* is similarly defined as *NFSA* but measures competition from the adjacent airport in the same city-pair market.

# 4.3 Control Variables

It is crucial to control for the effects of other variables which may affect airfare at the route level.

# Distance (Dist):

Everything else being equal, fares are expected to rise as distance increases because the costs are higher. The logarithm of the great circle distance from the orgin to the destination is used.

Frequency (Freq):

Frequency is measured by the number of scheduled departures in a month. Higher flight frequency may lead to reduced schedule delays, thus, increasing service quality. However, the positive effects on fares could be offset by negative effects caused by excessive capacity due to increasing frequency which put downward pressure on airfares. Logarithm form is also used for this variable.

*Origin and Destination Airport Concentration (OAPHHI and DAPHHI)*: Fares on routes involving high concentrated airports may be expected to be higher. Since we are using directional traffic data, airport concentration at either end of the airport (Origin airport HHI is coded with OAPHHI, while DAPHHI is for destination airport HHI) is used in the model. The logarithm is used for both variables.

#### Tourist routes (Tourist):

In general, tourism markets have a larger share of price sensitive leisure travelers than do business travelers, hence putting downward pressure on airfare. A dummy variable *Tourist*, is created to capture such effects taking the value of one if the route is from Shanghai to one of the following cities: Guilin, Huangshan, Jiuzhaigou, Lijiang, Sanya, Wuyishan and Zhangjiajie.

#### Primary routes (Primary):

Routes linking Shanghai to Beijing, Guangzhou or Shenzhen have high proportion of business passengers. Airlines use yield management to charge business travelers higher fares than leisure travelers (Morrison, 2001). Therefore, other things being equal, airfares are expected to be higher on these routes. A dummy variable *Primary* is created to capture such effects taking the value of one if the route in question is one of them, and zero otherwise. Moreover, airports in Shanghai, Beijing, Guangzhou and Shenzhen are highly congested and are subject to CAAC's slot control. This variable, thus, also takes into account of the effects of the demand restrictions on fares.

## Population and Income:

Both variables are traditional indicator of potential market size. Population is measured by the geometric mean of the endpoint city populations, while income equals to the geometric mean of the per capita incomes of the endpoints cites. Income data have been adjusted for inflation by using CPI. Logarithm is used for both variables. Higher incomes (and more population) may affect demand (and thus fares) by raising the propensity for air travel in a market. However, these positive demand effects on fares could be offset through cost savings associated with higher traffic densities, which are realized when high demand leads to large passenger volumes on a route (Brueckner, et al., 2013).

# Time effects:

To control for time period fixed effects, three dummy variables for years 2007 - 2009 were used, eleven dummy variables were created to capture the monthly effects.

# 4.4 Data

Our empirical analysis is based on two major databases: OAG and PaxIs. Frequency and capacity data were compiled from the OAG database while fare data were exacted from PaxIs database developed by International Air Transport Association (IATA). In addition, population and income data were obtained from China Statistical Yearbook for Cities and China Statistical Yearbook for regional economy.

The sample uses monthly data from January 2006 to December 2009. As the merger of China Eastern and Shanghai Airline was announced in December 2009, we believe that a sample ending in that month is appropriate considering the likely change of market structure after the merger.

One-way directional traffic data was used in the analysis. Thus, observations are recorded as one-way travel from Shanghai (both Hongqiao and Pudong airports) to the rest of mainland China within an airport-pair market. Each observation in the dataset is determined by a unique combination of carrier-route-time period. Those observations with frequency less than eight flights a month were dropped. In total, we have 2,687 observations for China Eastern Model (Model 1), and 8,902 observations for Market Average Model (Model 2).

# 5. Results

Summary statistics are presented in Table 1. In the whole sample, the first thing to notice is that China

	Ma	arket Avera	age Mode	ł	C	China Easte	ern Mode	:l
Variables	,	All routes (Ob	s.= 8902)			All routes (O	bs.=2687)	
variables	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
FARE	103.75	40.31	34.62	583.20	100.77	37.37	34.62	372.38
Spring	0.0822	0.2747	0	1	0.0752	0.2637	0	1
spring_adj	0.0424	0.2014	0	1	0.0480	0.2138	0	1
NFSA	2.0274	1.3872	0	5	1.7696	1.3138	0	5
nfsa_adj	0.7264	1.1897	0	5	0.5981	1.0433	0	5
Distance	697.34	322.75	92	2035	651.81	344.61	92	2035
frequency	62.25	59.55	8	460	79.22	72.18	8	460
OAP_HHI	0.2234	0.0104	0.2040	0.2591	0.2237	0.0109	0.2040	0.2591
DAP_HHI	0.2897	0.1548	0.0995	1	0.2812	0.1224	0.0995	1
Primary	0.1089	0.3115	0	1	0.0830	0.2759	0	1
Tourist	0.0887	0.2844	0	1	0.1016	0.3022	0	1
Income	44540	12700	19936	80393	44126	12128	19936	76532
population	876.74	323.81	96.15	2142.00	864.10	311.78	175.06	2142.00
Variables		runk routes ((	Obs.=4473)			runk routes (	Obs.= 1156	)
· ·	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
FARE	98.52	32.33	38.44	282.73	98.27	32.47	45.60	270.91
Spring	0.1438	0.3509	0	1	0.1522	0.3594	0	1
spring_adj	0.0250	0.1563	0	1	0.0234	0.1511	0	1
NFSA	3.0351	0.8225	1	5	2.8486	0.8480	1	5
nfsa_adj	0.7930	1.2504	0	5	0.7197	1.1891	0	5
Distance	703.99	267.65	217	2035	692.29	276.47	217	2035
frequency	92.42	69.50	8	460	133.86	78.40	12	460
OAP_HHI	0.2233	0.0101	0.2040	0.2591	0.2236	0.0104	0.2040	0.2591
DAP_HHI	0.2332	0.0661	0.0995	0.4788	0.2392	0.0686	0.0995	0.4788
Primary	0.2043	0.4033	0	1	0.1860	0.3893	0	1
Tourist	0.0217	0.1457	0	1	0.0199	0.1397	0	1
Income	49708	11882	24459	76532	49295	11474	24459	76532
population	990.29	344.21	267.80	2142.00	983.19	332.17	267.80	2142.00
Variables	Τ	<i>Thin routes (O</i>	bs.= 4429)			Thin routes (C	Obs.=1531)	
EADE	Mean	Std. Dev.	<u>Min</u>	Max	Mean	Std. Dev.	<u>Min</u>	Max
FARE	109.04	46.42	34.62	583.20	102.66	40.58	34.62	372.38
Spring	0.0201	0.1405	0	1	0.0170	0.1292	0	1
spring_aaj	0.0598	1.0507	0	1	0.0000	0.2494	0	1
NFSA	1.0097	1.0597	0	4	0.9549	0.9/15	0	4
nfsa_adj	0.6591	1.1213	0	4	0.5062	0.9077	0	4
Distance	690.63	370.08	92	2035	621.25	385.50	92	2035
frequency	31.78	20.04	8	127	37.97	23.38	8	127
OAP_HHI	0.2235	0.0107	0.2040	0.2591	0.2238	0.0112	0.2040	0.2591
DAP_HHI	0.3467	0.1932	0.0995	1	0.3129	0.1429	0.1000	1
Primary	0.0124	0.1108	0	1	0.0052	0.0721	0	1
Tourist	0.1565	0.3633	0	1	0.1633	0.3698	0	1
Income	39320	11288	19936	80393	40224	11108	19936	74994
population	762.06	254.83	96.15	1278.80	774.17	261.82	175.06	1207.84

 Table 1: Descriptive Statistics

Eastern's average fare was lower than that of market average (\$101 vs. \$104). The level of concentration does not vary too much at the origin airports but ranges from highly competitive markets to monopoly at destination airports. There are large variations in terms of number of full service carriers, distance, frequency, income and population. When the whole sample is split to trunk and thin routes, it is clear that average fares are higher on thin routes than on trunk routes despite the fact that average distance on the thin routes is shorter than that of trunk routes. Overall, trunk routes have much higher income per capital, more population and are served by more frequent flights than that of thin routes. Whether it is in the whole sample or in the sub-samples, descriptive statistics of variables in the China Eastern Model (Model 1) have similar characteristics as those of the Market Average Model (Model 2).

	10	ioic <b>2</b> .	Correlation Multimator China Lastern Model (005-2007)										
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	InFare												
2.	Spring	-0.13											
3.	spring_adj	-0.06	-0.06										
4.	InDist	0.67	-0.04	-0.01									
5.	InFreq	-0.07	0.19	-0.08	0.04								
6.	NFSA	0.08	0.15	-0.03	0.38	0.65							
7.	nfsa_adj	-0.02	0.05	0.23	0.05	0.05	0.09						
8.	InOAPHHI	0.15	-0.09	-0.08	-0.02	0.02	-0.03	-0.07					
9.	Indaphhi	0.01	-0.20	-0.11	-0.09	-0.32	-0.39	-0.30	0.09				
10.	Primary	0.13	-0.04	-0.02	0.13	0.36	0.30	0.52	-0.02	-0.07			
11.	Tourist	0.01	-0.04	0.03	0.04	-0.23	-0.10	0.13	0.02	-0.08	-0.10		
12.	InIncome	-0.12	0.17	0.12	-0.14	0.46	0.27	0.30	-0.15	-0.25	0.46	-0.38	
13.	Inpop	-0.06	0.04	-0.10	-0.02	0.31	0.27	0.05	-0.01	-0.22	0.11	-0.49	0.02

 Table 2:
 Correlation Matrix for China Eastern Model (obs.=2687)

Table 3: Correlation Matrix for Market Average Model (obs
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		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	InFare												
2.	Spring	-0.13											
3.	spring_adj	-0.10	-0.06										
4.	InDist	0.68	-0.08	-0.06									
5.	InFreq	-0.08	0.11	-0.03	0.01								
6.	NFSA	-0.06	0.13	-0.02	0.24	0.53							
7.	nfsa_adj	-0.10	0.07	0.21	-0.04	0.10	0.07						
8.	Inoaphhi	0.18	-0.09	-0.07	0.00	0.03	-0.04	-0.07					
9.	Indaphhi	0.10	-0.19	-0.11	-0.07	-0.32	-0.51	-0.31	0.08				
10.	Primary	0.12	-0.05	-0.04	0.11	0.36	0.30	0.48	0.00	-0.09			
11.	Tourist	0.06	0.01	0.03	0.08	-0.12	-0.09	0.15	0.01	-0.13	-0.11		
12.	InIncome	-0.18	0.16	0.10	-0.14	0.43	0.36	0.36	-0.13	-0.29	0.52	-0.31	
13.	Inpop	-0.16	0.02	-0.10	-0.12	0.25	0.31	0.00	-0.01	-0.21	0.08	-0.47	0.03

Correlation matrix for China Eastern (Model 1) and Market Average (Model 2) models is presented in Table 2 and Table 3, respectively. Overall, there does not appear to be excessive multicollinearity between the independent variables. In the China Eastern model (Table 2), *NFSA* and *Frequency* are correlated at 0.65. This level of correlation is expected as frequency services normally rise as the number of airlines increases. *Primary* and *NFSA\_adj* are correlated at 0.52. This is probably because primary routes are characterized by dense traffic and high profit, which have attracted the entry of *FSAs*. Moreover, China Eastern may have taken advantage of its hub carrier status and gained dominant share in airport-pairs market, forcing competitors to operate out of adjacent airports. In the market average model (Table 3), high level of correlation is observed between *NFSA* and *Frequency* (0.53); and *NFSA* and *DAPHHI* (-0.51). The figures are expected given the interrelationship between the degree of market competition (*NFSA*) and service level

(*Frequency*)/concentration (*DAPHHI*). Correlation coefficient larger than 0.5 is also observed between *Income* and *Primary* (0.51). This is due to the fact that cities at the both endpoints of primary routes have the highest GDP per capitals in China.

The results of the regression analysis are presented in Table 4. We first focus on the China Eastern model (Model 1). It can be seen that the presence of Spring Airlines on a route had a significant effect of suppressing the airfares charged by China Eastern. Competition from Spring in the same airport-pair market reduced China Eastern's fares by 4.3%, while competition from the nearby airport in a city-pair market reduced China Eastern's fares by 5.1%. While Spring's negative impacts on China Eastern's airfares are expected, why does adjacent competition have stronger effects on airfares than actual competition? In their study of the US domestic market, Morrison (2001) and Bruckner et al. (2013) found that both actual and adjacent competition from LCCs have significant impacts on reducing the legacy carriers' fares, but the effects of actual competition are much larger than that of adjacent competition. Why is it different in China? This is probably due to the fact that in the city-pair markets, Spring's market share on the adjacent routes was generally higher than that on the actual routes. Figure 1 shows that in 2006, Spring's average market share on the actual routes was 31%, as opposed to 36% on the adjacent routes. This pattern persists from 2006 to 2009. With higher market share on the adjacent routes, it is not surprising that adjacent competition brought by Spring had greater impacts on airfares than the actual competition.

Veriebles	China Easter	n Model (Mod	lel 1)	Market Average Model (Model 2)				
variables	All Routes	Trunk	Thin	All Routes	Trunk	Thin		
Spring	-0.0433*	0.0396*	-0.0933*	-0.0069	0.0378***	-0.0305		
	(0.0172)	(0.0161)	(0.0475)	(0.0086)	(0.0083)	(0.0249)		
Spring_adj	-0.0513*	0.1431***	-0.1101***	-0.0254*	0.1212***	-0.0600***		
	(0.0211)	(0.0356)	(0.0274)	(0.0117)	(0.0175)	(0.0158)		
NFSA	-0.0756***	-0.0367***	-0.0671***	-0.0756***	-0.0370***	-0.0816***		
	(0.0050)	(0.0077)	(0.0074)	(0.0024)	(0.0038)	(0.0041)		
NFSA_adj	-0.0432***	-0.0048	-0.0480***	-0.0397***	-0.0006	-0.0649***		
	(0.0056)	(0.0067)	(0.0085)	(0.0025)	(0.0031)	(0.0041)		
InDist	0.4461***	0.5945***	0.4423***	0.4858***	0.6098***	0.4738***		
	(0.0086)	(0.0162)	(0.0111)	(0.0051)	(0.0087)	(0.0070)		
InFreq	-0.0185*	0.0186	0.0128	-0.0080*	0.0104**	0.0002		
	(0.0076)	(0.0123)	(0.0114)	(0.0035)	(0.0038)	(0.0066)		
InOAPHHI	0.6158***	0.7889***	0.6038**	0.7001***	0.7973***	0.7669***		
	(0.1409)	(0.1671)	(0.2025)	(0.0740)	(0.0860)	(0.1135)		
Indaphhi	-0.0873***	-0.018	-0.0799***	-0.0469***	0.0072	-0.0799***		
	(0.0139)	(0.0222)	(0.0181)	(0.0071)	(0.0111)	(0.0093)		
Primary	0.1666***	0.0813**	0.1423	0.2074***	0.0684***	0.0735*		
	(0.0222)	(0.0257)	(0.0911)	(0.0104)	(0.0129)	(0.0346)		
Tourist	0.0255	0.1565***	0.0357	0.0184	0.1498***	0.0143		
	(0.0209)	(0.0407)	(0.0281)	(0.0110)	(0.0199)	(0.0156)		
InIncome	0.1691***	0.1885***	0.2689***	0.0345**	0.2120***	0.0985***		
	(0.0273)	(0.0410)	(0.0371)	(0.0134)	(0.0214)	(0.0191)		
Inpop	0.0306*	0.0908***	0.0513*	0.0161*	0.1017***	0.021		
	(0.0146)	(0.0188)	(0.0216)	(0.0077)	(0.0091)	(0.0130)		
Observations	2687	1156	1531	8902	4473	4429		
R <sup>2</sup>	0.5891	0.7002	0.588	0.6164	0.6873	0.6106		
Adjusted R <sup>2</sup>	0.5851	0.6933	0.5809	0.6152	0.6855	0.6083		

 Table 4: Fare regression estimation results

Monthly and yearly dummies suppressed.

Standard errors are reported in parentheses.

\* p<0.05; \*\* p<0.01; \*\*\* p<0.001

Figure 1: Average market share of Spring Airlines in July of each year: actual vs. adjacent competition



When the dataset is split into trunk and thin routes, the study reveals that Spring competed aggressively with the incumbents on the thin routes resulting in substantial price reduction of the latter. The presence of Spring reduced China Eastern's fares dramatically by 9.3% in the same airport-pair market and 11.0% when competing from the nearby airport.

A striking finding of this research is that Spring had a positive and significant impacts on China Eastern's fares on the trunk routes. A close look into the data revealed that Spring's market shares on the trunk routes were generally much lower, around 10-15%, compared to its market shares on the thin routes which were in the region of 50-100% (See Figure 2). A low market share on the trunk routes suggests that Spring Airlines may not pose the same degree of competitive threat to China Eastern as it poses on the thin routes. However, this cannot explain why the Spring variables have positive sign. The positive impact of Spring is possibly due to strict restrictions imposed by the CAAC on the heavily travelled trunk routes in terms of route authority, capacity and frequency to protect the interests of major airlines. Since established, Spring Airlines has always faced restrictions to enter onto lucrative routes and/or obtain desirable slots. For example, it had waited for six years before being approved to fly on Shanghai-Beijing route in 2011. As demand is strong on trunk routes and it is difficult for Spring to add more capacity, as a rational player, Spring would increase airfares in line with the market trend to maximize the profit. Furthermore, given the fact that the trunk routes are the lifeblood of major carriers and the absence of competition law in China, aggressive price competition by Spring on trunk routes would attract fierce retaliation from the majors in the form of predatory pricing or political pressure by lobbying the CAAC to limit the Spring's capacity growth on the trunk routes or block its entry onto other lucrative routes. Hence, it is in Spring's best interest to collude with majors to fix the price instead of launching price wars against them on these routes.



Figure 2: Average market share of Spring Airlines on trunk and thin routes in July of each year

Another interesting finding of this study is that both actual and adjacent competition from FSAs played an important role in suppressing the airfares for all routes, trunk routes and thin routes. An additional FSA in-market competitor reduced China Eastern's fare for all routes, trunk routes, and thin routes by 7.6%, 3.7%, and 6.7%, respectively, while an additional FSA adjacent competitor reduced China Eastern's fare on all
routes and thin routes by 4.3% and 4.8%, respectively, though the effects on trunk routes were not statistically significant. It is noteworthy that the impact from actual competition is much greater than that from adjacent competition. These results differ from those findings in the US market which indicated that most forms of FSA competition had weak effects on average fares while LCC competition had dramatic fare impacts. However, Brueckner et al. (2013) found that prior to 2000, legacy competition in the US, both in-market and from adjacent airports, had substantial effects on airfares. It is probably due to sustaining decline of LCC costs and the rapid expansion of LCCs into new markets since 2000, competition from LCCs has started to exert greater downward pressure on airfares than that made by FSAs (Brueckner et al., 2013). Considering that the development of the LCC business model is still at the preliminary stage in the Chinese market, the results obtained in our analysis are consistent with what observed in the US market.

We now turn our attention to the market average model (Model 2). In terms of Spring's impacts on market average price of incumbent carriers, it is found that the negative effects were mainly reflected from adjacent competition while the effects from actual competition are not significantly different from zero. Comparing with 4.3% fare reduction of China Eastern resulting from the competition of Spring, the presence of Spring on adjacent routes reduced market average fares by a mere 2.5%. These findings showed that China Eastern was under greater pressure from Spring's competition than other FSAs. The results are reasonable as both China Eastern and Spring shared the same airports and had a number of overlapping routes in the same city-pair markets.

In terms of FSAs' fare impacts of actual and adjacent competition, the results in Market Average Model is highly consistent with those obtained in China Eastern Model. FSAs played an important role in suppressing the airfares for all routes, trunk routes and thin routes; and the magnitude of the coefficients of *NFSA* and *NFSA\_adj* in both models across three different scenarios is very close, suggesting the results are highly robust.

It is worth pointing out that most other variables in the models are highly significant and have the expected signs. Fares go up when distances increase, everything else being equal. Variable *Frequency* has negative sign in all-route sample. This is probably because better service quality derived from higher flight frequency could not compensate the negative effects caused by excessive capacity due to increasing frequency which put downward pressure on airfares. In line with expectation, origin airport HHI in both China Eastern Model and Market Average Model is positive and highly significant for all samples and the two sub-samples. But the destination airport HHI has a negative effect on airfares. This is probably because those airports with high HHI are mainly small regional airports characterized by insufficient demand, hence having negative effects on airfares.

As expected, everything else being equal, fares on the primary routes are higher than other routes. Tourist variable is highly significant but positive in trunk-route market models, which is not consistent with what we expected at the beginning. But when we looked into the data, the reason for this became quite clear. The tourism routes in trunk-route sub-sample contain a total number of 275 observations, 173 of which linked Shanghai to Sanya while 99 of which were connect to Guilin. Both tourist destinations are very popular all year around for visitors from Shanghai because of their tropical climate, hence fares are generally higher on both routes than market average, everything else being equal.

Income and population variables are positive and significant for both models across the whole sample and two sub-samples, indicating a positive relationship between potential market size and airfares. The monthly dummies, which are not reported in the table, all have positive signs, showing that fare level is lowest in December. In contrast, all year dummies have negative sign, indicating a downward fare trend over the sample period since 2006.

## 6. Summary and Conclusions

The results of econometric analysis showed that Spring put downward pressure on China Eastern's average fares on routes where it competed from the same and nearby airports. In terms of Spring's impact on market average price of incumbent carriers, it was found that the negative effects were mainly reflected from adjacent airport competition.

When the dataset is further split into trunk and thin routes, the study revealed that Spring competed aggressively with the incumbents on the thin routes resulting in substantial price reduction of the latter. Interestingly, Spring's impacts on the incumbent's fares on the trunk routes were positive and significant. The contrasting pricing behavior of Spring may be explained by current regulatory regime where strict restrictions are imposed on heavily travelled trunk routes in terms of route authority, capacity and frequency. Another important finding is that actual and adjacent competition from FSAs plays an important role in suppressing the airfares for overall market, trunk- and thin-routes.

Findings in this research have important policy implications. First, given the negative impact of Spring on airfares, government should encourage the entry of LCCs in order to increase consumer welfare. Moreover, the strong competitive effects of legacy carriers, as our study has showed, suggest that mergers between legacy carriers that reduce such competition may lead to higher fares on overlapping routes. A further study into the pricing effects of China Eastern's merger with Shanghai Airlines would provide interesting insights into this issue.

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# Hub-and-Spoke Liner Shipping Network Design with Demand Uncertainty

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#### Abstract

The hub-and-spoke (H&S) liner shipping network design problem with uncertain container demand is one of the risk management issues in the liner shipping industry. This paper provides a methodology to deal with this problem, which ensures that the designed H&S liner shipping network can satisfy the shipping requirement of shippers at least with a predetermined service-level. The problem is formulated as a joint chance constrained programming (JCCP) model to minimize the total expected cost incurred in shipping network design and container shipment. As the critical issue of the JCCP model is that the closed forms of the joint chance constraints are analytically intractable, the sample average approximation (SAA) method is used to deal with this issue and a SAA model is then proposed to approximate the JCCP model. Further, the SAA model is equivalently transformed into a mixed-integer nonlinear programming (MINLP) model and a linearized technique is used to treat the nonlinearity in order to avoid solving a MINLP problem. Finally, a numerical example is implemented to show the applicability of the proposed model.

Keywords: hub-and-spoke liner shipping network design; uncertain demand; joint chance constraint; sample average approximation

#### 1. Introduction

Over the past decades there has been an increase in the size of containerships serving the world's densest maritime routes, from thousands of TEUs (twenty-foot equivalent unit) to over 10,000 TEUs (the ship with such capacity is called mega-ship). The introduction of mega ships can be attributed to benefiting from the economics of scale achieved through the employment of them. However, when comparing the service offered to shippers by mega ships to that of smaller ships, there are some drawbacks as it is inevitable for the former to reduce the calling frequency if there is not an enormous increase in cargo demand (Van der Jage, 2003). If the present calling frequency is maintained, the mega-ship turns out to be under-utilized; this increases the operating cost per carried container instead of achieving economics of scale (Willmington, 2002). In addition, the deployment of mega ships poses severe constraints on ports, in view of the physical and logistical requirement, on land as well as at sea. A major impediment is draft restrictions in ports such as low water depth of access channels and berths to accommodate deep-draft ships (Damas, 2001). Driven by the above mentioned forces, ports were consequently obliged to split into the so called hub ports, where these mega ships call in and the secondary ports, the so called spoke ports, where these smaller ships call in (here called feeder ships). Hereafter, in the hub-and-spoke (H&S) liner shipping network, containers begin its moving by feeder ships along feeder line from spoke ports to hub ports and then moving by mega ships along main line between hub ports. Note that the H&S liner shipping networks have been created around the world, witnessed in the case of Singapore, Hong Kong and Rotterdam which are hub ports in Asia and Europe.

The determination of a port to be hub or spoke not only depends on its geographical location, but also relates to the container shipment demand to and from it. Therefore, the container shipment demands of port pairs have significant effect on the hub and spoke ports location. Before the decision of hub and spoke ports, the decision-makers have to estimate the container shipment demand. However, the container shipment demand is

almost impossible to be estimated precisely. It is more realistic to regard the container shipment demand as uncertain rather than deterministic. Consequently, there is a need to take the uncertainty of container demand into account in the H&S liner shipping network design problem. Therefore, the research of this paper focuses on formulation of the H&S liner shipping network design problem with consideration of uncertain demand.

## 1.1. Literature review

The hub and spoke network design problems on freight, public and air transportation have been studied by many researchers (see the review literature: O'kelly and Miller, 1994; Klincewicz, 1998; ReVelle and Eiselt, 2005; Alumur and Dara, 2008). However, the studies of hub and spoke network design problems on maritime transportation are much less. To the best knowledge of the authors, Mourao et al. (2001) took the first step to consider a ship assignment problem with hub and spoke constraints. But in this paper, the H&S network is already given. Aversa et al. (2005) proposed a mixed integer programming model for locating a hub port in the East coast of South America. Imai et al. (2006) analyzed the container mega ship viability by consideration of competitive circumstances and proposed a formulation for deployment of mega ships onto H&S shipping network. Konings (2006) discussed the typical cost, service and geographical characteristics of H&S networks in order to answer whether H&S services could be a fruitful tool in improving the performance of container-on-barge transport and so in gaining market share. Hsu and Hsieh (2007) formulated a two-objective model to design a shipping network by minimizing shipping costs and inventory costs, and then applied it in a case of H&S network design. Takano and Arai (2008) considered a containerized cargo transport problem with H&S network and used a genetic algorithm to solve it. Imai et al. (2009) compared the multi-ports liner shipping network design and H&S liner shipping design problems.

# 1.2. Objectives and contributions

It is noted that none of the above mentioned literature involved consideration of demand uncertainty in the H&S liner shipping network design problems, which indicates that the H&S liner shipping network design problem under uncertain demand remains a research issue deserved to make effort. This paper focuses on this issue and proposes a joint chance constrained programming (JCCP) model to deal with it. As chance constraints with probabilistic forms in the JCCP model is hard to evaluate, the sample average approximation method is thus used to approximate the JCCP model in this research.

The contribution of this paper is threefold: First, it contributes to the literature by proposing a realistic H&S liner shipping network design problem with uncertain demand. Second, a JCCP model is developed for the proposed problem. Third, an appropriate solution algorithm is proposed to solve the proposed model.

The remainder of this paper is organized as follows: Section 2 presents the H&S liner shipping network design problem with uncertain demand in details. Section 3 develops a JCCP model for the proposed H&S liner shipping network design problem. Section 4 addresses the difficulties in solving the JCCP model and proposes the SAA approach to handle these difficulties. Section 5 uses a numerical example to evaluate the model and solution algorithm proposed in this study. Finally, Section 6 concludes the study and provides recommendations for future work.

# 2. Problem Statement

The H&S liner shipping network design problem is described as follows. Given a set of ports, these ports can be divided into two levels: hub and spoke. The hub ports represent the consolidation and distribution ports which feed the main line liner shipping trades. To be a hub port, it not only has advantaged location to facilitate cargo consolidation and distribution, but also provides suitable accommodation for ships, involving deep navigational channels, efficient cargo handling, and big gantry cranes for mega ships, container parking space, skilled labour, short turnaround times and lower port costs. As the hub ports consolidate and distribute containers, the volume between hub ports, namely, the container demand on main line is very high. As for those non-hub ports, they are called spoke ports which feed the feeder line liner shipping trades.

Different ships, compatible with the ports' physical and logistical conditions, perform the two levels of voyages: the mega ships ply between hub ports, while the feeder ships link the hub to each respective set of spoke ports. Each ship is characterized by a given capacity and an intrinsic cost, expressed per TEU transport. The intrinsic cost of a ship refers to the fixed cost of operating this ship, including manning cost, stores and consumables, insurance and administration cost, together with an allowance for day-to-day routine repairs and maintenance. A typical H&S liner shipping network may be depicted in Figure 1.



## Figure 1: A Typical Hub-and-Spoke Liner Shipping Network

The assumptions are made as follows:

- 1) Containers are homogeneous, all refer to TEUs;
- 2) The liner operators are required to maintain a weekly shipping frequency only on main line, as for the feeder line, no such a requirement due to low volume on feeder line;
- 3) The time of ships travelling between any ports are known and fixed;
- 4) There is no direct link between any two spokes
- 5) The containers can be transferred via at most two hub ports

As aforementioned, the container shipment demand between any two ports is uncertain, which indicates that one can hardly find any decision that would definitely exclude later constraint violation caused by unexpected random effects, in other words, once the decisions in the H&S liner shipping network design problem are determined, the liner operator may encounter such a possibility that it is unable to fully meet the shipment requirement for its customers. Here, we introduce the concept of service-level to interpret it. For example, if there are 20% containers are not met, and then the service-level is 80%, which means that the liner operator can fully meet 80% of container shipment demand. Since the possibility is hardly unavoidable, we can involve it as a constraint in the H&S liner shipping network design problem. Therefore, the problem finally can be summarized to determine the following issues:

- 1) Hub ports allocation, i.e., main line;
- 2) Feeder ports allocation to each hub port, i.e. feeder line;
- 3) Ship deployment on main line and feeder line

in such a way that the whole costs (intrinsic cost, transporting cost, transshipping cost) is minimized to satisfy a predetermined service-level.

#### **3.** Mathematical Model

Before the development of mathematical model formulated for the proposed H&S liner shipping network design problem, we first introduce the notation used in the formulation.

Deterministic parameters  $H = \{1, ..., H\}$  set of hub ports  $S = \{1, ..., S\} \text{ set of spoke ports}$   $V^{Feeder} = \{1, ..., K\} \text{ set of feeder ships}$   $V^{Mega} = \{1, ..., V\} \text{ set of mega ships}$   $t_{khs}^{Feeder} \text{ travel time (in days) between hub port } h \in H \text{ and spoke port } s \in S \text{ for feeder ship } k \in V^{Feeder}$   $t_{khs}^{Mega} \text{ travel time (in days) between hub port } h \in H \text{ and hub port } j \in H \text{ for mega ship } v \in V^{Mega}$   $t_{khs}^{Max} \text{ maximum available time (in days) of mega ship } k \in V^{Feeder} \text{ during the planning horizon}$   $t_{v}^{Max} \text{ maximum available time (in days) of feeder ship } v \in V^{Mega} \text{ during the planning horizon}$   $t_{khs}^{Mega} \text{ time (in days) required for feeder ship } k \in V^{Feeder} \text{ to load and/or unload at hub port } h \in H \text{ for mega ship } v \in V^{Mega}$   $t_{khs}^{Mega} \text{ capacity of feeder ship } k \in V^{Feeder} \text{ to load and/or unload at hub port } j \in H \text{ C}_{khs}^{Feeder}$   $C_{khs}^{Mega} \text{ capacity of mega ship } v \in V^{Mega}$   $t_{khs}^{Mega} \text{ capacity of mega ship } v \in V^{Mega} \text{ capacity of mega ship } v \in V^{Mega} \text{ capacity of mega ship } v \in V^{Mega}$   $c_{khs}^{Feeder} \text{ unit cost of transporting a container by feeder ship } k \in V^{Feeder} \text{ between hub port } h \in H \text{ and spoke port } s \in S$ 

 $c_{vhj}^{Mega}$  unit cost of transporting a container by mega ship  $v \in V^{Mega}$  between hub port  $h \in H$  and hub port  $j \in H$  $c_{vhj}^{trans}$  unit cost of transporting a container at hub port  $h \in H$ 

- $c_{khs}^{*Feeder}$  intrinsic cost of operating feeder ship  $k \in V^{Feeder}$  on its voyage segment between hub port  $h \in H$  and spoke port  $s \in S$
- $c_{vhj}^{*Mega}$  intrinsic cost of operating mega ship  $v \in V^{Mega}$  on its voyage segment between hub port  $h \in H$  and hub port  $j \in H$

Stochastic parameters

- $\xi_{hs}$  demand of containers between hub port  $h \in H$  and spoke port  $s \in S$
- $\xi_{hi}$  demand of containers between hub port  $h \in H$  and hub port  $j \in H$

Decision variables

- $\delta_{khs}^{Feeder}$  binary variable, it equals to 1 if hub port  $h \in H$  and spoke port  $s \in S$  is directly connected in the feeder line of feeder ship  $k \in V^{Feeder}$ , otherwise 0
- $\delta_{vhj}^{Mega}$  binary variable, it equals to 1 if hub port  $h \in H$  and hub port  $j \in H$  is directly connected in the main line of mega ship  $v \in V^{Mega}$ , otherwise 0
- $x_{khs}^{Feeder}$  number of containers transported by feeder ship  $k \in V^{Feeder}$  between hub port  $h \in H$  and spoke port  $s \in S$
- $x_{vhi}^{Mega}$  number of containers transported by mega ship  $v \in V^{Mega}$  between hub port  $h \in H$  and hub port  $j \in H$
- $y_{khs}^{Feeder}$  number of containers transshipped to feeder ship  $k \in V^{Feeder}$  at hub port  $h \in H$  and to destination spoke port  $s \in S$
- $y_{vhs}^{Mega}$  number of containers from origin spoke port  $s \in S$  and transshipped to mega ship  $v \in V^{Mega}$  at hub port  $h \in H$

 $z_k^{Feeder}$  number of voyages feeder ship  $k \in V^{Feeder}$  makes in a planning horizon, if assigned on a feeder line  $z_v^{Mega}$  number of voyages mega ship  $v \in V^{Mega}$  makes in a planning horizon, if assigned on a main line

#### 3.1. Objective function

The objective is to minimize the total cost incurred in the container shipment, including intrinsic costs, transporting costs and transshipping costs.

Intrinsic costs:

$$C_{1} = \sum_{s \in \mathbf{S}} \sum_{h \in \mathbf{H}} \sum_{k \in \mathbf{V}^{Feeder}} c_{khs}^{*Feeder} z_{k}^{Feeder} + \sum_{h, j \in \mathbf{H}} \sum_{\nu \in \mathbf{V}^{Mega}} c_{\nu hj}^{*Mega} z_{\nu}^{Mega}$$
(1)

Transporting costs:

$$C_2 = \sum_{s \in S} \sum_{h \in H} \sum_{k \in V^{Feeder}} c_{khs}^{Feeder} x_{khs}^{Feeder} + \sum_{h, j \in H} \sum_{v \in V^{Mega}} c_{vhj}^{Mega} x_{vhj}^{Mega}$$
(2)

Transshipping costs:

$$C_3 = \sum_{s \in S} \sum_{h \in H} \sum_{k \in V^{Feeder}} c_h^{trans} y_{khs}^{Feeder} + \sum_{s \in S} \sum_{h \in H} \sum_{v \in V^{Mega}} c_h^{trans} y_{vhs}^{Mega}$$
(3)

The objective function can be expressed as follows:

$$\min Z = C_1 + C_2 + C_3 \tag{4}$$

#### 3.2. Constraints

#### Capacity constraints

A ship's capacity cannot be exceeded on any voyage segment, which is formulated as follows:

$$x_{khs}^{Feeder} \le z_k^{Feeder} C_k^{Feeder}, \forall k \in \mathbf{V}^{Feeder}, h \in \mathbf{H}, s \in \mathbf{S}$$
(5)

$$x_{vhi}^{Mega} \le z_{v}^{Mega} C_{v}^{Mega}, \forall v \in \mathbf{V}^{Mega}, h, j \in \mathbf{H}$$
(6)

#### Transshipment constraints

For a feeder link connected hub port  $h \in H$  and spoke port  $s \in S$ , the containers transported by a feeder ship on the link includes the transhipped containers from hub port  $h \in H$ , then we have

$$y_{khs}^{Feeder} \le x_{khs}^{Feeder}, \forall k \in \mathbb{V}^{Feeder}, h \in \mathbb{H}, s \in \mathbb{S}$$

$$\tag{7}$$

For a segment connected hub port  $h \in H$  and hub port  $j \in H$  contained in a main line, the containers transported by a mega ship on the segment includes the transshipped containers from spoke ports connected with hub port  $h \in H$ , thus we have

$$\sum_{s \in S} y_{vhs}^{Mega} \le x_{vhj}^{Mega}, \forall v \in V^{Mega}, \forall h, j \in H$$
(8)

#### Time constraints

The time of transporting and transshipping containers spent by a ship should not exceed the available maximum time in the planning horizon:

$$z_{k}^{Feeder}\left(t_{khs}^{Feeder} + \hat{t}_{kh}^{Feeder}\right) \leq t_{k}^{\max}\delta_{khs}^{Feeder}, \forall k \in \mathbf{V}^{Feeder}, h \in \mathbf{H}, s \in \mathbf{S}$$

$$\tag{9}$$

$$z_{v}^{Mega} \sum_{h,j\in\mathbf{H}} \left( t_{vhj}^{Mega} + \hat{t}_{vj}^{Mega} \right) \delta_{vhj}^{Mega} \le t_{v}^{\max}, \forall v \in \mathbf{V}^{Mega}$$
(10)

Ships constraints

For each feeder ship, it can only be assigned on at most one feeder line:

$$\sum_{s \in \mathbf{S}} \delta_{khs}^{Feeder} \le 1, \forall h \in \mathbf{H}, k \in \mathbf{V}^{Feeder}$$
(11)

For each feeder line, at least one feeder ship is assigned on this line:

$$\sum_{k \in V^{Feeder}} \delta_{khs}^{Feeder} \ge 1, \forall h \in \mathbf{H}, s \in \mathbf{S}$$
(12)

Since the main line has to maintain a weekly liner shipping service for shippers, thus we have

$$\sum_{v \in \mathbf{V}^{Mega}} \delta_{vhj}^{Mega} \ge \frac{\sum_{h, j \in \mathbf{H}} t_{vhj}^{Mega} \delta_{vhj}^{Mega}}{7}, \forall v \in \mathbf{V}^{Mega}, \forall h, j \in \mathbf{H}$$
(13)

#### Chance constraints

Given a predetermined service level  $1-\alpha$  where  $\alpha$  is termed as a confidence parameter, the requirement that the liner operator can fully meet the shipment demand at least with the service level on feeder line and main line can be respectively formulated as follows

$$\Pr\left(\sum_{k \in \mathbf{V}^{Feeder}} z_k^{Feeder} C_k^{Feeder} \ge \xi_{hs}, \forall h \in \mathbf{H}, s \in \mathbf{S}\right) \ge 1 - \alpha$$
(14)

$$\Pr\left(\sum_{v \in \mathbf{V}^{Mega}} z_v^{Mega} C_v^{Mega} \ge \xi_{hj}, \forall h, j \in \mathbf{H}\right) \ge 1 - \alpha$$
(15)

Let  $\Delta^{FL}(\mathbf{z}^{Feeder}, \boldsymbol{\xi}_{Feeder}) = \max_{h \in \mathbf{H}, s \in \mathbf{S}} \left\{ \xi_{hs} - \sum_{k \in \mathbf{V}^{Feeder}} z_k^{Feeder} C_k^{Feeder} \right\}, \ \Delta^{ML}(\mathbf{z}^{Mega}, \boldsymbol{\xi}_{Mega}) = \max_{h, j \in \mathbf{H}} \left\{ \xi_{hj} - \sum_{v \in \mathbf{V}^{Mega}} z_v^{Mega} C_v^{Mega} \right\}, \text{ we define}$ 

the probability function  $p(\mathbf{z}^{Feeder}) := \Pr(\Delta^{FL}(\mathbf{z}^{Feeder}, \boldsymbol{\xi}_{Feeder}) > 0)$ ,  $p(\mathbf{z}^{Mega}) := \Pr(\Delta^{ML}(\mathbf{z}^{Mega}, \boldsymbol{\xi}_{Mega}) > 0)$ , then Equation (14) and (15) can be respectively rewritten as follows:

$$p(\mathbf{z}^{Feeder}) \le \alpha \tag{16}$$

$$p(\mathbf{z}^{Mega}) \le \alpha \tag{17}$$

where z and  $\xi$  are vector forms of corresponding variables and parameters. Therefore, we can get a joint chance constrained programming model with chance constraints (16) and (17), named JCCP1: [JCCP1]

$$\min Z = C_1 + C_2 + C_3 \tag{18}$$

Subject to constraints  $(5) \sim (13)$ , (16) and (17).

#### 4. Solution Technique

As the decision variables of the proposed model JCCP1 are integers, which indicate that the approaches of convex approximation of chance constraints cannot be used to solve our model (Ben-Tal and Nemirovski, 2000; Hong et al., 2011), therefore, the sample average approximation (SAA) method which is to discretize the probability distribution using Monte Carlo simulation is employed in this paper (Atlason et al., 2008; Luedtke and Ahmed, 2008).

#### 4.1. Sample average approximation

The theoretical background of SAA approach is based on the Law of Large Numbers theory which indicates that the probability of an event occurrence can be approximated by the frequency of the events that occur in number of trials (say *N* trials). Let  $\xi_{hs}^1, ..., \xi_{hs}^N$  be an independent Monte Carlo sample of *N* realizations of the random parameter  $\xi_{hs}$  ( $h \in H, s \in S$ ), we can obtain *N* realization of the random vector  $\xi_{Feeder}^1, ..., \xi_{Feeder}^N$ . Similarly, *N* realization of random vector  $\xi_{Mega}^1, ..., \xi_{Mega}^N$  can be obtained as well. Let  $1_{\{0,\infty\}}$ :  $\mathbb{R} \to \mathbb{R}$  be the indicator function of  $(0, \infty)$ , i.e.,

$$\mathbf{1}_{(0,\infty)}(y) := \begin{cases} 1, & \text{if } y > 0, \\ 0, & \text{if } y \le 0. \end{cases}$$
(19)

Then, the sample version of the probability function  $p(\mathbf{z}^{Feeder})$  and  $p(\mathbf{z}^{Mega})$  is defined as follows:

$$p^{N}\left(\mathbf{z}^{Feeder}\right) = \sum_{n=1}^{N} \mathbf{1}_{[0,\infty)}\left(\Delta^{FL}\left(\mathbf{z}^{Feeder}, \boldsymbol{\xi}_{Feeder}^{n}\right)\right) / N$$
(20)

$$p^{N}\left(\mathbf{z}^{Mega}\right) = \sum_{n=1}^{N} \mathbb{1}_{[0,\infty)}\left(\Delta^{FL}\left(\mathbf{z}^{Mega}, \boldsymbol{\xi}_{Mega}^{n}\right)\right) / N$$
(21)

That is,  $p^{N}(\mathbf{z}^{Feeder})$  and  $p^{N}(\mathbf{z}^{Mega})$  are equal to the proportion of times that  $\Delta^{FL}(\mathbf{z}^{Feeder}, \boldsymbol{\xi}_{Feeder}) > 0$  and  $\Delta^{ML}(\mathbf{z}^{Mega}, \boldsymbol{\xi}_{Mega}) > 0$ , respectively. Thus the constraints (16) and (17) are replaced by

$$p^{N}\left(\mathbf{z}^{Feeder}\right) \leq \beta \tag{22}$$

$$p^{N}\left(\mathbf{z}^{Mega}\right) \leq \beta \tag{23}$$

where  $\beta$  is a confidence parameter and can be different from the original one  $\alpha$  (Luedtke and Ahmed, 2008). Therefore, the sample version of the JCCP1 model is named JCCP2 and defined as [JCCP2]

$$\min Z_{\beta}^{N} = C_{1} + C_{2} + C_{3} \tag{24}$$

Subject to constraints  $(5) \sim (13)$ , (22) and (23).

#### 4.2. Solving the sample average approximation problem

The sample approximation model JCCP2 can be rewritten as a mixed-integer nonlinear programming (MINLP) model with auxiliary binary variables  $\mathcal{G}_n^{Feeder}$  (n = 1, ..., N) and  $\mathcal{G}_n^{Mega}$  (n = 1, ..., N) for each sample point [MINLP]

$$\min Z_{\beta}^{N} = C_{1} + C_{2} + C_{3} \tag{25}$$

Subject to constraints  $(5) \sim (13)$ , and

$$\Theta_n^{Feeder} \xi_{hs}^n + \sum_{k \in \nabla^{Feeder}} z_k^{Feeder} C_k^{Feeder} \ge \xi_{hs}^n, \forall n = 1, \dots, N; \forall h \in \mathbf{H}, s \in \mathbf{S}$$

$$(26)$$

$$\sum_{n=1}^{N} \vartheta_n^{Feeder} \le N\beta$$
(27)

$$\vartheta_n^{Mega} \xi_{hj}^n + \sum_{\nu \in \mathcal{V}^{Mega}} z_{\nu}^{Mega} C_{\nu}^{Mega} \ge \xi_{hj}^n, \forall n = 1, \dots, N; \forall h, j \in \mathcal{H}$$

$$(28)$$

$$\sum_{n=1}^{N} \vartheta_n^{Mega} \le N\beta \tag{29}$$

$$\boldsymbol{\vartheta}_{n}^{Feeder}, \boldsymbol{\vartheta}_{n}^{Mega} \in \left\{0,1\right\}^{N}$$
(30)

# Proposition: JCCP2 and MINLP are equivalent.

Proof: Let  $\mathbf{v} = \left(\delta_{khs}^{Feeder}, \delta_{vhj}^{Mega}, x_{khs}^{Feeder}, x_{vhj}^{Mega}, y_{khs}^{Feeder}, y_{vhs}^{Mega}, z_{k}^{Feeder}, z_{v}^{Mega}, g_{n}^{Feeder}, g_{n}^{Mega} : k \in V^{Feeder}, v \in V^{Mega}, h, j \in H, s \in S\right)$  be feasible solution to MINLP. According to constraints (26) and (28), we can deduce that  $\mathcal{G}_{n}^{Feeder} \ge \mathbf{1}_{\{0,\infty\}} \left( \Delta^{FL} \left( \mathbf{z}^{Feeder}, \mathbf{\xi}_{n}^{n} \right) \right)$  and  $\mathcal{G}_{n}^{Mega} \ge \mathbf{1}_{\{0,\infty\}} \left( \Delta^{ML} \left( \mathbf{z}^{Mega}, \mathbf{\xi}_{n}^{n} \right) \right)$ , respectively. And according to constraint (27), we have  $\beta \ge N^{-1} \sum_{n=1}^{N} \mathcal{G}_{n}^{Feeder} \ge N^{-1} \sum_{n=1}^{N} \mathbf{1}_{\{0,\infty\}} \left( \Delta^{FL} \left( \mathbf{z}^{Feeder}, \mathbf{\xi}_{n}^{n} \right) \right) = p^{N} \left( \mathbf{z}^{Feeder} \right)$ . Similarly, from constraint (29), we also have  $\beta \ge N^{-1} \sum_{n=1}^{N} \mathcal{G}_{n}^{Mega} \ge N^{-1} \sum_{n=1}^{N} \mathbf{1}_{\{0,\infty\}} \left( \Delta^{ML} \left( \mathbf{z}^{Mega}, \mathbf{\xi}_{n}^{n} \right) \right) = p^{N} \left( \mathbf{z}^{Mega} \right)$ . Thus,  $\mathbf{v}$  is feasible to JCCP2 which has the same objective function value as in MINLP. Conversely, let  $\mathbf{v}$  be a feasible solution to JCCP2, and define  $\mathcal{G}_{n}^{Feeder} = \mathbf{1}_{\{0,\infty\}} \left( \Delta^{FL} \left( \mathbf{z}^{Feeder}, \mathbf{\xi}_{n}^{n} \right) \right)$  and  $\mathcal{G}_{n}^{Mega} = \mathbf{1}_{\{0,\infty\}} \left( \Delta^{ML} \left( \mathbf{z}^{Mega}, \mathbf{\xi}_{n}^{n} \right) \right)$ , we have that  $\mathbf{v}$  is feasible for MINLP with the same objective value. Therefore, proposition is proved.

#### *4.3. Solution quality*

It is noted that JCCP2 is an approximation of JCCP1, and MINLP is equivalent to JCCP2, which indicates that MINLP is an approximation of JCCP1 as well, but may not be equivalent to JCCP2, even assuming  $\beta = \alpha$ . However, we still can evaluate the quality of solution to MINLP to see how close it is to the solution of JCCP1. If we enlarge  $\alpha$  in JCCP1, then Z may decrease since the objective function aims to minimize while the solution space is enlarged. Therefore, we can get a lower bound of JCCP1 with  $\alpha$  by solving the same model with  $\beta^L$  ( $\beta^L > \alpha$ ). But it is hard to solve the model JCCP1. Since MINLP is an approximation to JCCP1, we can expect that  $Z_{\beta^{L}}^{N}$  is a lower bound of Z with a significance level. This expectation has been proved by Luedtke and Ahemd (2008). The sample size, *N*, to ensure that  $Z_{\beta^{L}}^{N} < Z$  with probability at least  $1-\varepsilon$ , where  $\varepsilon \in (0,1)$ , is given by

$$N \ge \frac{1}{2\left(\beta^{L} - \alpha\right)^{2}} \ln\left(\frac{1}{\varepsilon}\right)$$
(31)

Contrary to the above description, if we reduce  $\alpha$  in JCCP1, then Z may increase since the objective function aims to minimize while the solution space is reduced. In other words, solving MINLP model with  $\beta^{U} < \alpha$  yields an upper bound of Z with some probability, denoted by  $Z_{\beta^{U}}^{N}$ . Therefore, though we cannot get an exact value of Z, we can get its lower and upper bound.

#### 4.4. Treating nonlinearity

It is noticed that if variables  $z_v^{Mega}$  is removed from constraints (10), then the MINLP problem (25) is reduced to a mixed integer linear programming (MILP) problem. The distance between each port pair is known. If the mega ship v serves only the two ports and does not visit any other port enroute, it makes the maximum number of trips, which can be calculated from the given travel time. At the other extreme, the mega ship may visit all ports enroute. This itinerary is the most time consuming; and if followed, this mega ship makes the minimum number of round voyages. In addition to these two extreme cases, all possible combinations of port visits are possible. For example, if the mega ship v serves at least 2 round voyages and at most 5 round voyages, then  $z_v^{Mega}$  have a value from 2 to 5. Therefore, we will have to solve four different problems with different values of  $z_v^{Mega}$ , in order to avoid solving a MINLP problem. As for each MILP problem, it can be efficiently solved by an optimization solver, such as CPLEX.

#### 5. Numerical Example

A shipping network example consisting of 9 ports is depicted in Figure 2. The distance between each port is listed in Table 1 (Each port is coded by a number from 1 to 9 according to the order from top to button) and the travel time between each port is listed in Table 2. The unit cost of transporting a container and intrinsic cost of feeder ships are shown in Table 3 and Table 4, respectively. For simplification of data generation, we assume that the unit cost of transporting a container is half due to the economies of scale and the intrinsic cost of mega ships is twice of those corresponding to feeder ships. The planning horizon in this numerical example is assumed to be six months. We assume that the uncertain parameters of container demand in the numerical example follow log-normal distributions to generate the demands because log-normal distributions were well suited for modelling economic stochastic variables such as demands (Kamath and Pakkala, 2002) and we assume that the service level is 95%, i.e.  $\alpha = 0.05$ .



#### Figure 2: A shipping Network Example of 9 Ports

Port	1	2	3	4	5	6	7	8	9
Port									
1	-	209	348	661	1320	1351	3031	2878	2677
2	209	-	408	784	1475	1501	3154	3001	2800
3	348	408	-	957	1128	1159	2839	2686	2485
4	661	784	957	-	835	867	2547	2393	2192
5	1320	1475	1128	835	-	26	1817	1663	1463
6	1351	1501	1159	867	26	-	1827	1673	1473
7	3031	3154	2839	2547	1817	1827	-	165	354
8	2878	3001	2686	2393	1663	1673	165	-	198
9	2677	2800	2485	2192	1463	1473	354	198	-

## Table 1: Distance Matrix (nautical mile)

Source: The port distances are from the website: http://www.searates.com/reference/portdistance/

Port	1	2	3	4	5	6	7	8	9
Port									
1	-	0.5	1.0	2.0	4.0	4.0	9.0	9.0	8.0
2	0.5	-	1.5	2.5	4.5	4.5	9.5	9.0	8.5
3	1.0	1.5	-	3.0	3.5	3.5	8.5	8.0	7.5
4	2.0	2.5	3.0	-	2.5	2.5	7.5	7.5	6.5
5	4.0	4.5	3.5	2.5	-	0.5	5.5	5.0	4.5
6	4.0	4.5	3.5	2.5	0.5	-	5.5	5.0	4.5
7	9.0	9.5	8.5	7.5	5.5	5.5	-	0.5	0.5
8	9.0	9.0	8.0	7.5	5.0	5.0	0.5	-	0.5
9	8.0	8.5	7.5	6.5	4.5	4.5	0.5	0.5	-

<sup>*a</sup>It is assumed that all vessels sail at an average speed of 14 knots/hr.*</sup>

## Table 3: Cost Matrix of Transporting A Container for Feeder Ships (\$/TEU)

Port	1	2	3	4	5	6	7	8	9
Port									
1	-	100	200	400	800	800	1800	1800	1600
2	100	-	300	500	900	900	1900	1800	1700
3	200	300	-	600	700	700	1700	1600	1500
4	400	500	600	-	500	500	1500	1500	1300
5	800	900	700	500	-	100	1100	1000	900
6	800	900	700	500	100	-	1100	1000	900
7	1800	1900	1700	1500	1100	1100	-	100	100
8	1800	1800	1600	1500	1000	1000	100	-	100
9	1600	1700	1500	1300	900	900	100	100	-

## **Table 4: Intrinsic Cost Matrix for Feeder Ships**

Port	1	2	3	4	5	6	7	8	9
Port									
1	-	1000	2000	4000	8000	8000	18000	18000	16000
2	1000	-	3000	5000	9000	9000	19000	18000	17000
3	2000	3000	-	6000	7000	7000	17000	16000	15000
4	4000	5000	6000	-	5000	5000	15000	15000	13000
5	8000	9000	7000	5000	-	1000	11000	10000	9000
6	8000	9000	7000	5000	1000	-	11000	10000	9000
7	18000	19000	17000	15000	11000	11000	-	1000	1000
8	18000	18000	16000	15000	10000	10000	1000	-	1000
9	16000	17000	15000	13000	9000	9000	1000	1000	-

#### 5.1. Sensitivity analysis of SAA parameters

From the above description of solution technique, it is found that the parameters,  $\beta$ ,  $\epsilon$  and *N* have to be determined in the SAA approach. Therefore, we firstly test a number of sets of these SAA parameters in order to do the sensitivity analysis. The results are shown in Table 5. The solution algorithm is implemented in a programming language Lua (v5.1) coded in Microcity (http://microcity.sourceforge.net) and the SAA problems are solved by CPLEX (v12.1). All computations are carried out on a desktop personal computer with Intel (R) Core (TM) i5-2400S CPU 2.50 GHz and 4.0 GB of RAM under Microsoft Windows 7.

	14	one 5. Benshi vit	y Analysis of BAA		
$\beta^{L}$	$\beta^{U}$	3	N	Relative gap (%)	CPU time (sec)
0.08	0.04	0.10	1800	1.24	3795.59
0.10	0.03	0.09	500	1.89	1165.55
0.12	0.02	0.08	300	2.21	589.02
0.15	0.015	0.07	200	3.14	102.45
0.20	0.01	0.06	100	3.59	14.21

 Table 5: Sensitivity Analysis of SAA Parameters

The relative gap is computed by  $(Z_{\beta^{U}}^{N} - Z_{\beta^{L}}^{N})/Z_{\beta^{L}}^{N} \times 100\%$ . As can be seen from Table 5, the relative gap generally has the increasing trend with the interval  $(\beta^{L}, \beta^{U})$  increases. This trend is reasonable because when  $\beta^{L}$  increases, the feasible set increases as well, which results in that the lower bound  $Z_{\beta^{L}}^{N}$  may decrease. Similarly, the upper bound  $Z_{\beta^{U}}^{N}$  may increase when  $\beta^{U}$  decreases. Therefore, it makes the relative gap enlarge for an increasing interval  $(\beta^{L}, \beta^{U})$ .

## 5.2. Computational results

According to the results, the hub-and-spoke shipping network is depicted in Figure 3. As can be seen that Shanghai, Hong Kong and Singapore are hub ports and the others are spoke ports. In order to examine the effect of service level  $1-\alpha$  on average cost, we vary  $\alpha$  from 0.05 to 0.1 with increments of 0.01 and show the trend in the cost as  $\alpha$  changes in Figure 4. As Figure 4 shows that the average cost value has the decreasing trend when  $\alpha$  increases. It is reasonable because when  $\alpha$  increases, which indicates that the service level  $1-\alpha$  decreases, therefore, the shipping network takes less cost to maintain it.

#### Figure 3. Hub-and-Spoke Network Design for the Numerical Example





#### 6. Conclusion

This paper provides a methodology to deal with the hub-and-spoke liner shipping network design problem with uncertain container shipment demand and formulated the problem as a joint chance constrained programming (JCCP) model which ensures that the designed H&S liner shipping network can satisfy the shipping requirement of shippers at least with a predetermined service-level. The JCCP model aims to minimize the total expected cost incurred in shipping network design and container shipment. As the critical issue of the JCCP model is that the closed forms of the joint chance constraints are analytically intractable, the sample average approximation (SAA) method is used to deal with this issue and a SAA model is then proposed to approximate the JCCP model. Further, the SAA model is equivalently transformed into a mixed-integer nonlinear programming (MINLP) model, and then a linearized technique is used in order to avoid solving the MINLP model. A numerical example is implemented to show the applicability of the proposed model. A sensitivity analysis of SAA parameters was conducted and the gaps between lower and upper bound to the real problem is small, indicating that the solution technique is effective.

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# Applying the CRAVE Framework to Strategic Decisions in SCM, with a Container Security System Example

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#### Abstract

This paper systematically argues how the CRAVE (Costs, Risks and Values Evaluation) framework, developed for global technology deployment (GTD) decisions is equally relevant in the specific context of strategic decisions related to container security. Specifically, we demonstrate how CRAVE could be applied to a novel Smart Container-based system for supply chain security. The paper is inspired by the fundamentals of cost-benefit analysis (CBA) literature in Business Information Systems (BIS, or IS/IT), and resulting macro observations about today's SCM scenario. To be precise, these observations are in terms of major similarities, a déjà vu, between the BIS scenario of the 1980s, the GTD scenario of the 1990s, and today's SCM revolution fuelled by the forces of globalization and resulting global competition. Finally, the paper concludes by illustrating these general ideas in the specific context of strategic decisions for container security, by applying CRAVE to a Smart Container-based system for maritime supply chain security.

Keywords: SCM, Container Security, CBA methodology, CRAVE framework

## 1. Introduction

As the popularity and importance of supply chain management (SCM) systems continues to grow (Naslund and Williamson, 2010), today it is tempting to put aside any questions related to their cost-benefits analysis (CBA) (Rothenberg, 2005) for future research to worry about. However, based on the humongous research available on Business Information Systems (BIS), especially in cost-benefits related research on IT investment decisions, it seemed reasonable to ask whether cost-benefits related research on SCM was keeping up with their current popularity and growth! This initial concern is reinforced by recent observations of contagion effects (McFarland et al., 2008) and inflexion points (Holmes, 2012) in SCM. Because, it was precisely at such contagion-like critical stages of growth in the BIS (Business-IS/IT), during the 1980s, that MIS/BIS research community began paying serious attention to cost-benefit analysis (CBA) of business IS/IT, and associated methodological challenges (Kaplan, 1986). Even a priori, in the absence of any major developments related to cost-benefits of SCM systems, researchers should wonder whether the currently implicit competition-based need for SCM and the ever-advancing power of IT, alone can justify all investments in SCM, and for how long? Second, as is evident from the currently growing attention to the challenges of SCM projects, their high downside risks as well as their value-adding potential, suggests that it is time SCM researchers look for more formalized, theoretically sound, analysis/evaluation approaches applicable to SCM projects of today and tomorrow.

Following the above research rationale, this paper is aimed at contributing to this Conference at two conceptually important levels: (a) Showing how a unique cost-benefit style evaluation framework, named CRAVE (Costs, Risks And Values Evaluation) (Joglekar and Toraskar, 1994), is indeed highly applicable and valuable in today's SCM arena, and (b) Demonstrating such application in the specific context of strategic decisions related to Container Security. Briefly, we believe the CRAVE framework is unique because it was originally tailor-made for the global technology deployment (GTD) decisions in the manufacturing context of multinational corporations (MNCs), and as we show in this paper today's SCM decisions hold many similarities with GTD decisions, thus increasing CRAVE's applicability to SCM. Secondly, CRAVE is unique

because, not only is it very comprehensive, formal or explicit, and multi-perspective in character, but that these features of CRAVE actually emerged as various drawbacks and limitations of the then CBA-practice were revealed in the context of GTD decisions. Thus, in the first place CRAVE was tailor-made for the complexities of GTD decisions, and in this paper we show how today's SCM decisions are so similar to GTD decisions. It follows that applying CRAVE to SCM decisions should be very promising! In short, this paper systematically argues how and why the CRAVE (Costs, Risks And Values Evaluation) framework, originally developed for global technology deployment (GTD) decisions in multinational corporations (MNCs) in the 1990s, indeed applies equally to today's supply chain management (SCM) decisions in general, and then attempts to apply it in the specific context of strategic decisions related to container security. Specifically, we demonstrate how CRAVE could be applied to a novel, Smart-Container-based, system for supply chain security.

The paper is organized as follows. Section 1 sets the stage by presenting our overarching research rationale, and what the paper is trying to accomplish in the context of this Conference. Section 2 briefly outlines the major challenges and risks, as well the costs and benefits, associated with the SCM systems/projects pointing to the need for methodologically strong and sound approaches and frameworks for evaluating them. Section 3 presents a compact summary of the tough cost-benefit challenges of global technology deployment (GTD) decisions of the 1990s and the CBA-related methodological arguments, which led to Joglekar and Toraskar's (1994) CRAVE framework. We highlight how CRAVE was indeed tailor-made to handle the special GTD decision characteristics, i.e. multi-phased, high uncertainty, multi-party, controversial, etc. Knowing these evolutionary methodological developments (which led to CRAVE rather logically) helps reader to appreciate the "built-in" logical rigor of CRAVE. CRAVE itself can then be presented rather simply in terms of its major Principles, Requirements and Guidelines. Section 4 first prepares us for applying CRAVE to SCM by discussing how today' SCM decisions share crucial major characteristics with GTD decisions, and how various stakeholders of SCM (shipping companies, governments, vendors and regulators) could use CRAVE to make more effective SCM project decisions in general. Finally, Section 5 illustrates this general idea in the specific context of strategic decisions for container security; by applying CRAVE to a Smart Container-based system for maritime supply chain security.

## 2. SCM Today: A Bewildering Mix of Costs, Benefits, Challenges and Risks

Before we can appreciate the CRAVE (Costs, Risks and Values Evaluation) framework and its methodological strengths in evaluating today's SCM systems, it helps to first recognize what the SCM evaluators are up against vis-à-vis the costs, benefits, challenges and risks of such systems. Given the primarily methodological aim of this paper (i.e. to show how CRAVE is well-suited for evaluating today's SCM systems), and the limitations of space, we need not enumerate the detailed costs or benefits (e.g. training costs, and container examination benefits) of SCM here. All we need here is an overall appreciation for the rather bewildering variety (i.e. number of types) of costs, benefits and risks that one must take into account when evaluating today's SCM systems. Therefore, only a bird's eye-view of the vast landscape of the major categories of SCM costs, benefits and risks is attempted here.

Today, benefits of SCM are popularly described using major categories such as: increased supply-chain (SC) visibility, better SC coordination, and reduced uncertainty, resulting in a wide variety of cost-reductions and overall improved SC performance, customer satisfaction and so on (Business-software.com) (Eresourceerp.com). However, for a truly systematic and formalized type of evaluation that CRAVE insists on, we believe a much more systematic and comprehensive view of SCM cost/benefits and risks emerges rather logically if we look for them across the different areas particularly transportation, warehousing and distribution costs, as being relevant here. Conceptually, a more compact view, which may also be necessary and useful in CBA-related SCM research, appears in McLaren et al. (2004). This rather comprehensive and multi-level taxonomy of SCM costs and benefits consists of four major categories: (1) Total cost of ownership or TCO of the system, (2) Partnership-related Opportunity Costs, (3) Market Responsiveness benefits, and (4) SC Cost-reduction benefits. Moreover, this taxonomy clearly shows how these four major categories are systematically broken down into more specific types of costs/benefits, i.e. (1) system implementation costs, process integration costs and data-transition and integration costs, (2) partnership instability as well as switching costs, and (3) Reductions in product costs, inventory costs, and process costs.

Supply chain literature today also lists several different phrases under the banner of the "challenges" to SCM today. SCC summarises the 5 top SC challenges in terms of Superior Customer Service, Cost Control, Planning and Risk Management, Partnership Relationship Management, and the institutional talent needed. Again, from the standpoint of a systematic and formalized kind of evaluation, much work is needed to operationalize these challenges so as to include them in such evaluations. However, our insights from the methodology of CRAVE (briefly reviewed here in Section 3), suggest that these challenges need to be clearly operationalized and expressed in terms of their associated costs, benefits and risks before they can be really incorporated into formal cost-benefit research in SCM.

While risk has been researched for much longer in the financial, banking and insurance research, SC risk and security threats came to the forefront of SCM literature mainly after the 9/11 disaster (White et al., 2002). Still, perhaps following the lead of the financial risk research, in SC research also attention was initially focused on the economic (i.e. monetary) impacts of SC risks and SC security threats (White et al., 2002). Thus, more comprehensive, holistic, discussions on supply chain risk management (SCRM) in general (McCormack et al., SCC Risk Research Team, 2008) (Vanany et al., 2009), and on global SC security (Thai, 2009) in particular, are just emerging in SCM research.

Given the methodological focus of this paper, here it is necessary to mention our broad observations about the cost-benefits and risks of today's supply chains, and about their treatment in any kind of formal evaluations of SCM projects/systems. First, the wide-ranging variety or the "bewildering mix" of today's SC cost-benefits implies major challenges of conceptually clear definitions, measurements and valuations which indicate the need for methodologically powerful approaches/frameworks for evaluating today's SCM systems. This need is clearly reinforced by Naslund and Williamson's (2009) warning about the "hype and potentially unrealistic claims" concerning SCM today. Second, the whole issue of "intangibility" of many important costs, benefits, and especially risks, does not appear to have hit the cost-benefit efforts in SCM. While this is exactly what was predicted by our déjà vu of the BIS scenario of the 1980s and the GTD scenario of the 1990s, our paper is aimed at averting the same mistakes in SCM cost-benefit research. Third, a growing awareness and importance of SCM frameworks involving Collaboration, Integration and Sustainability in SCM literature (Naslund and Williamson, 2009) also suggests that SCM evaluation approaches will have to be explicitly holistic, multi-perspective, and even proactively facilitating tough-to-reach (Pareto Optimum) group-decisions involving a variety of stake-holders of SCM today. (Looking ahead, CRAVE was consciously "designed" to handle precisely such challenges in the context of GTD decisions.) Finally, presently the so-called SCM challenges, as they are popularly called, are not sufficiently well-defined and articulated to be of a significant use in formal cost-benefit research in SCM. Therefore, these challenges need to be conceptualized more clearly, and operationalized through their associated cost-benefits and risks, before they can be accounted for (and, if they really mean something, then accounted they must be!) in any kind of cost-benefit evaluations.

# 3. CRAVE Framework: A Methodological Development to Deal with the Challenge of GTD Decisions

The acronym CRAVE stands for Costs, Risks And Values Evaluation. To really generate active research interests in CRAVE today, it is crucial show how the applicability of CRAVE to SCM arises quite logically from the methodological challenges before it. For this reason, below, we first review relevant background of the development of CRAVE, before simply describing it in a declarative mode. As we see it, global technology deployment (GTD) decisions became the ultimate battle-ground where Joglekar and Toraskar (1994) conducted the research-diagnosis of these challenges and, through rather meticulous methodological arguments, logically derived the CRAVE framework.

## 3.1 Characteristics of GTD Decisions and Related Cost-Benefit Methodological Challenges

Even before GTD became a major concern, since the early 1980s the classical approach called Cost Benefits Analysis (CBA), and its long-respected computational methods, were being increasingly challenged by industry experts (Lay, 1985) and academics (Hays and Garvin, 1982). This was directly in response to the spiralling infrastructure investments at large, which, at the same time, were deemed necessary in practice to meet business competition. However, it was in the context of the GTD decisions that crucial issues of multi-

stage and multi-perspective complexities (of such decisions) came to the forefront of analysis. Therefore, it is truly instructive, here, to understand the exact nature of these GTD decisions in terms of their major characteristics, and how they are different or similar from other types of decisions.

GTD decision situations, by their very nature, refer to situations where large institutions and their partners, and/or governments, regulators, global bodies, are considering deploying a large complex system using a new/old technology (invariably requiring huge investments and significant time-horizons) over major geographic regions. Readers can think of many obvious examples of such situations in their own industry or field of expertise, i.e. shipping, or SCM in general, or SC Container Security. For this methodologically driven paper, we have identified (and somewhat refined) the following list of general GTD decision characteristics:

High Initial, as well as Total, investments/costs

Multi-stage, multi-phase, project with significant Time-Horizon, Mile-stones, etc. Wide Variety of Stakeholder Groups at different Hierarchic Levels of: Business and Industry: A Champion MNC or Industry-Group, and their value-chain Partners, National Governments/Regulators, and Global Bodies like U.N., WHO, World bank etc. End-User Customers/Consumers of the main product/service of the GTD Project Society-at-large: Affected Non-Users, and concerned NGOs, e.g. Green Peace Technological and Technical Complexities of the: Underlying special Technology involved Business Information Systems (BIS) and communication systems Project Planning, and Project Management

It is interesting to see GTD decisions compare with other kinds of decisions, i.e. the 1980s corporate IT investments decisions, and the Federal Agency-type public sector decisions (for which, in fact, the classical CBA methodology created; see Footnote 2). Unlike traditional 1980s, firm-level, IT investment decisions, GTD decisions are not a simple one-shot approval (or rejection) of a master plan. Instead, the GTD decision process consists of a guided evolution of option-generating events and incremental choices or negotiated agreements, in the midst of technological advances and changes in the host-country's laws and standards. No wonder, GTD decisions are more complex and controversial, and should not be treated like the 1980s corporate IT decisions.

On the other hand, the success (and even feasibility and the start) of GTD decisions depend on approval and support from many different stakeholder groups that pursue varied economic and non-economic values. In this sense, GTD decisions are more like Public Sector decisions rather than corporate or private-sector decisions of even Today! This rather counter-intuitive, but CRAVE-crucial, similarity is supported by the fact that most GTD decisions evolve over a period of time through the actions and reactions of a multitude of participants. For example, an MNC may develop a tentative GTD plan, and then get local managers, employees, and governments to accept portions of the plan. Often this process requires a modification of the original plan. The implementation of the approved portions of the plan may take several years, during which time such factors as technology advances and changes in local laws may require further modification of the plan. Sounds like any protracted Public Sector decision that is still pending?

The ensuing cost-benefit evaluation challenges of GTD-type decisions can be captured primarily through (a) the Intangibility of some costs/benefits, (b) the Risks and Uncertainties of long time-horizons, technological advances, and socioeconomic-political changes in different countries/regions, and perhaps most importantly (c) the need for Approval and Support from the Disparate Stakeholder Groups! Briefly, just from the MNC perspective alone, today's advanced technologies and systems based on them have many strategic yet intangible benefits, such as improved management decision-making, reduced pollution, and a better fit with the company's long term competitive strategy. Such intangibles are quite difficult to quantify in monetary terms. Intangible cost/benefits in the broader socio-cultural and climate/environmental context are even harder to quantify and evaluate due to different valuations by different stakeholder groups. Next, although risk analysis has advanced considerably in finance/insurance arena, risks and uncertainties in the social/political arena are largely left to subjective assessment today, which brings us to the final challenge.

The challenge of getting different stakeholders to participate in a joint assessment/evaluation/decision-making process is especially tough, in the first place, because of the unavoidable (but hopefully, valuable!) role of subjectivity. In GTD decisions, this basic challenge is further compounded by the presence of significant intangibles (both costs and benefits), risks, and uncertainties! Simply because of who they are (relative to the system under evaluation), and their overall perspective or "world-view," different stakeholders almost always hold differing subjective views and assessments of such complications. Thus, without an effective process to engage different stakeholders in a participative and "holistic" dialogue, everything is delegated to their isolated subjectivities, thereby making joint decisions even harder to arrive at.

## 3.2 The CRAVE Framework: Its Essential Principles, Requirements and Guidelines

Briefly, the challenges of GTD's cost-benefit evaluation suggest "dual" requirements for an approach or overall framework for such evaluation. First, the approach/framework used must follow some systematic theory/methodology of rational decision-making and evaluation. And second, it must also be conducive for involvement, and active participation, of the wide variety of partners and stakeholders mentioned above. We qualified these requirements as dual deliberately, because each of them is critically important (CSF) for an effective cost-benefit evaluation and yet, each is so challenging and difficult to achieve, making it likely for an approach/framework itself to focus on one at the cost of the other, and become lopsided. Simply stated, what GTD situations are calling for is not only an evaluation-methodology that of course yields rational and objectively defendable GTD decisions, but also an evaluation-process that explicitly includes and involves the wide variety of stakeholders whose active participation (in evaluation) is essential for the ultimate success of GTD. Below, we simply describe it, through its basic principles, requirements and guidelines.

First, at the outset CRAVE is designed as a deliberately formal, explicit, and multi-perspective evaluation framework, to counteract the often informal, implicit and single-perspective character of many important evaluations in practice. Secondly, CRAVE explicitly endorses and encourages (or essentially, requires) the use of the good old classical CBA methodology for all cost-benefit evaluations. Therefore, CRAVE emphasizes the need to understand, and to capitalize on, the many rich principles and concepts of the classical CBA when evaluating any complex decisions. Thus, the fundamental principles behind CRAVE are same as those of the classical CBA methodology. Moreover, the CRAVE framework as argued out and constructed by its authors, is actively interested in avoiding the common pitfalls of prevalent CBA practice. Suffice to say here, CRAVE comes with a healthy skepticism, namely that merely listing the great principles is not enough; we must also concretely "show and tell" how those principles are missed in practice, i.e. the pitfalls.

Finally, integral to CRAVE is a 5-stage implementation process for carrying out CRAVE-based cost-benefit evaluations. We find this implementation process to be a crucial and therefore integral part of CRAVE, because of the following. First, a clear separation and logical sequencing of the various activities (i.e. enumeration, measurement, valuation, adjustments, and final integration of CRAVE clearly makes it a very formal and explicit evaluation framework where, for example, valuation of observed changes is clearly differentiated from their technical measurement. Second, the logical as well as process-flow-like character of Figure-1 adds to the overall validity and reliability of the evaluation process, and hopefully the ultimate decision. Everyone connected with the evaluation can know exactly what happens in a CRAVE-based evaluation, why and when, etc. Finally, a presentation tool like Figure-1 (or its project-specific variations) is most useful in making "multi-perspective" evaluations truly possible, orderly, and most importantly, effective in securing support from all stakeholders.



Figure-1: Process-Flow Logic of the CRAVE Framework, Adapted for Container Security

### 3.3 Five Stages of the CRAVE Implementation Process

In the crucial Stage-1, Enumeration, various stakeholder-groups jointly identify any important Incremental Changes (in their inputs and outputs) expected due to the System being evaluated. Only the truly measurable ones are then subjected to the technical work of Measurement in Stage-2, carefully correcting for any doublecounting of joint use. Owing to the importance of keeping valuation of changes separate from their raw measurement, we believe the pivotal Stage-3 (Valuation) is quite important in the overall CRAVE process. This stage is all about identifying (again, joinly!) various kinds of values (e.g. monetary, intangible, or purely subjective) accrued to (or perceived by) various stakeholder-groups as a result of the system being evaluated. Perhaps even more crucial, yet important, is the Stage-4 where various kinds of risk-analyses, sensitivity analyses, are used to study their effects on the base-line average values from Stage-3. Wide variety of risks and uncertainties (financial, physical security, or reputation-related) must be actively dealt with in this stage. Here, it is important to understand that CRAVE is not tied to any specific mathematical techniques and tools used in Stage-4, but actively encourages the use of the most applicable and effective ones, depending of course on the type of risk or uncertainty involved. Finally, Stage-5 (Combining) is really about integrating all component results (from Stage-4) through appropriate weighting and scoring schemes, again jointly created by the stakeholder-groups. At this point, the task of costs, risks and values evaluation, that is CRAVE itself, is complete and the resulting recommendations (be it accept/reject, modify, or re-CRAVE!) goes to the ultimate project decision-makers (where all stakeholder-groups may or may not be represented).

## 4. Applying CRAVE to Today's Container Security Decisions

## 4.1 How Today's Container Security Decisions Mirror Global Technology Deployment (GTD) Decisions

In Section 3, we have already identified the important characteristics of GTD decisions. To bring out the parallels between GTD decisions and today's container security decisions, here we rely on those same characteristics as they can be seen in today's global supply chain decisions also. Even a cursory look at today's global supply chains reveals how related strategic decisions resemble the GTD decisions described in the earlier sections. Briefly, today's supply chains (SC) are expanding and becoming vastly more complex vis-a-vis their organizational, geographical, as well as technological dimensions. Moreover, such SCs resided mostly within one nation/country. Today, this picture of SC has transformed radically in two different ways. Even before globalization became intense, large corporations began expanding their basic SCs to include new business partners. Simultaneously, on the Technological dimension a host of new ITs (e.g. RFID and Smart Containers) are being actively considered for use in the latest global-SC designs, promising significant benefits. The ultimate effect of these increasing, multi-dimensional, complexities of today's supply chain scenario is that the related systems and decisions are also becoming very challenging and risky. What is of essence here, to see the similarities between GTD and today's container security decisions, is the broad-base fact that the above multi-dimensional complexities are clearly growing.

Apart from the obvious similarities in their big-budget, Hi-Tech, and multi-stage (significant time-horizons) character, the growing similarity between GTD and today's container security decisions becomes particularly clear along the Stakeholder-Groups dimension. From the four subcategories (a to d) of this characteristics (in Sec. 3.1), it is easy to see that today's global SCs, or rather Global Supply Chain Networks (GSCNs,) are bound to be of interest and/or concern to many disparate stakeholders ranging all the way from its champion MNC, its overseas business-units (BU) and their partners/suppliers, to various Governmental/Regulatory bodies and NGOs, not to mention the customers/consumers involved, the system-operators and managerial users. This rich similarity between GTD and GSCN decisions becomes especially important in view of the Public Sector-like character that it renders to all such decisions, and the suitability of CRAVE for their multi-perspective evaluation.

Finally, today, the steadily growing concerns about the all-important global Container Security issues, and possible risk management solutions (which must be evaluated), make the analogy between GTD and GSCN decisions almost complete! A wide variety of security-related risks and uncertainties appear in relevant literature on supply-chain security and SC risk-management (SCRM) today, and we will not discuss them here. What is important about all such security-related issues here is the fact that security in general and the

associated "state of protection" from threats is a "public good" in Economics (White et al., 2004). No one truly wants to pay for public goods, and so market forces alone cannot provide enough incentive for their supply, thereby requiring governments (Public Sector) to provide them. This view of security as a public good further reinforces the above public-sector effects of multiple stakeholder-groups effects, thus making today's SC or GSCN decisions very similar to the public-sector like GTD decisions. Thus, applying CRAVE to today's SCM decisions should be promising.

## 4.2 Using CRAVE to Evaluate Strategic SCM Decisions in General

The above similarity between GTD decisions and today's container security decisions already supports the theoretical applicability of CRAVE to today's strategic SCM decisions. Therefore, here we will mainly focus on the more practical, substantive, aspects of such application of CRAVE in the context of today's SCM scenario. Given the logical process-flow of CRAVE (Figure-1), this basically involves outlining "who" does "what," and possibly "how," at each stage of the process. From the overall understanding of CRAVE and its process (Sec. 3), it seems clear that the "who" here largely depends on the industry context of application (here, today's SCM scenario), whereas "what" is to be done is largely dictated by the particular stage in Figure-1. This rationale leads us to the following outline of many substantive and practical aspects of applying CRAVE to today's SCM decisions in general.

As a typical example of today's SCM-related strategic decisions, suppose a logistics service provider is looking into developing a new facility for its global operations, and wants to use CRAVE to make the decision. In this scenario, it is easy to see that the stakeholder groups, who should be involved in applying CRAVE, include at least the following:

The lead service provider Head-Office (minimally, its Finance, Operations, and Technology Units). Its relevant business-units (BU) and any SC partners (whose cooperation is vital to system success). Relevant Governmental Agencies, Regulatory Bodies, (Customs etc). The End-Customer/Consumer groups Societal-level concerned NGOs (Security Auditors)

To launch the process in Figure-1, first a CRAVE Working Group (CWG) with representatives from various stakeholder-groups is formed, and briefed on CRAVE and its process in general (requisite policy education!). With this CWG and its participants in mind, below we outline what should be done (and not done) during the various stages of Figure-1, to follow the CRAVE principles and requirements from Sec. 3.2.

As seen in Figure-1, the focus of Stage-1 (Enumeration) is on identifying the important changes in resources used, management information output, and of course, the business performance. This may seem rather straightforward at first, but not so if we remember the various guidelines and requirements of CRAVE. First and foremost, we must strive to be comprehensive, explicit and multi-perspective. This basic principle transforms the simple idea above into various qualifications and requirements, of which we can mention only the major ones here. For example, we must carefully isolate the incremental changes (e.g. in resource-usage) that can be attributed to change-over to new system. Also, the various stakeholder groups (hereon, simply participants) should actively engage in identifying all such changes of interest first from their own perspective, and then jointly, as a super-group. Not only we enumerate them for all the constituent business-units and groups involved, but enumerate all different types of such changes shown in Table-1 fixed/variable, direct/indirect, etc. We do not enumerate specific costs/benefits here, not because the task is indeed huge in practice, but because CRAVE does not endorse using any specific tools/techniques simply because they are popular or quantitative. SCM literature already contains useful classifications of costs/benefits/risks, and they should be judiciously employed for such exhaustive enumeration in practice.

Finally, before hastily jumping to Measurement, careful expert consideration is used to separate meaningfully (and of course explicitly) measurable changes from the un-measurable ones. But, in CRAVE the un-measurable changes are not simply forgotten or subjected to forced and meaningless quantification. Instead, they play a vital role in satge-5 where all stakeholders are formally involved in jointly integrating all changes of interest through proven weighting/scoring techniques.

In contrast to stage-1 where the stakeholder-groups play the active role, stage-2 (Measurement) is largely delegated to the technical measurement specialists, including cost-accounting experts for traditional monetary costs. Examples of main issues of concern here include double-counting of joint costs/benefits, and the common neglect of any changes that do not first appear in monetary/dollar units. In CRAVE, any change of interest, whether monetary or not, must be measured if it is measurable in any practical way. The measurement of changes is deliberately isolated from Valuation of those changes (stage-3) to facilitate and enhance the multi-perspective character of evaluations, precisely because different stakeholder-groups often assign quite different value (meaning, importance here) to same magnitude of change.

What goes on during the Valuation stage needs to be carefully understood along several different dimensions, to recognize its pivotal importance in CRAVE, and thereby to conduct it properly. First, here, is to keep in mind what is meant by "valuation" of a given change in contrast to its "measurement." Moreover, the basic distinction between must be understood by the participants before they can come up with valuations of different changes from their individual perspectives, and then try their best to participate in a joint valuation of greatest The critical importancestage-3Here again, stakeholder-groups play an active role and the overall dynamics of stage-3 is similar to stage-1.

## 5. Applying CRAVE to Strategic Decisions for Container Security

## 5.1 Special Characteristics of Container Security Strategic Decisions and How CRAVE Could Handle Them

The system of international maritime shipping handled approximately 500 million twenty feet equivalent container units (TEUs) in 2012, of which 41 million TEUs (21 million actual container boxes) came through North American ports. Under normal conditions, the system of international maritime transport depends on the ability to maintain steady flow of container traffic through the world's major ports. Efforts to achieve a secure system must not threaten the economic viability of the network or by extension, the system of global trade. Consequently, container security should be viewed in the context of overall security architecture for preventing, disrupting, deterring, and protecting against terrorism. A comprehensive analysis of the threats posed by international terrorism requires consideration of our own exploitable security weaknesses as well as the operational capabilities of the organizations that pose a threat. A security assessment that attempts to fully account for the costs of enhancing the security of international container traffic in the context of other threats and vulnerabilities should also factor in counterbalancing, non-terrorism-related benefits. For example, criminal activities are common in the realm of international container shipping. Private shippers, insurers, and governments routinely attempt to minimize theft, Customs violations, and the flow of illegal narcotics and other contraband. Some of the technologies and equipment recommended here as components in a "systems approach" to detect the transport of illicit nuclear materials have been developed and marketed commercially for these purposes.

A significant proportion of international shipping passes through very large super ports. Roughly 25 percent of all container handling worldwide is performed at the five busiest container ports—Hong Kong, Singapore, Pusan, Kaohsiung, and Rotterdam. Early efforts should focus on detecting illicit nuclear materials at these and other choke points in the international system of maritime shipping. This level of concentration does not eliminate the need to secure the many smaller installations that could provide vulnerable entry points, but it makes it possible to begin testing equipment and system approaches in a few major locations with a realistic expectation that practices adopted at those sites may, with suitable inducements and economies of scale, spread to cover the rest of the industry.

A security-oriented approach to container inspection should be structured as a "layered defense," incorporating independent detection opportunities along the supply chain. System design and continued system monitoring are as important as appropriate equipment and practices, given that all static systems and technologies are vulnerable to eventual evasion by a sophisticated enemy. Attention to minimizing overall system vulnerabilities including those arising from human operators—is important. To be readily embraced by system participants, the costs of achieving a secure system will have to be small relative to shipping costs (a few percent of the cost of the goods shipped), unless significant government subsidies are made available to

alleviate the financial burden. Deciding how to spread these costs fairly, and in such a way as to maximize incentives for compliance among legitimate market participants, will be a critical component in reducing opportunities for maritime transport to be used as either a conduit for illegal purposes.

#### 5.2 Using CRAVE to Evaluate Strategic Container Security Systems and Decisions

Container security challenges, and possible solutions to deal with them, are at the forefront of the overall SCM arena today. The applicability of CRAVE to SCM decisions in general was already demonstrated in Sec. 4, suggesting the general applicability of CRAVE to container security systems as well. In addition, the above scenario of container security challenges suggest even more convincing reasons why CRAVE may be particularly valuable in dealing with the strategic decisions in this area. On the one hand, many new approaches, technological systems and equipments are currently being developed and proposed both in research literature and commercial context. At the same time, related literature also reveals a basic dilemma which may be in the way of timely implementation and deployment of these systems and solutions in practice. The essence of this dilemma is best understood through various inter-twined issues related to, just as major examples, the cost of these new security solutions, their adverse impact on supply chain efficiencies, and the difficulties of estimating their true security benefits, as follows.

As for costs, advanced container security solutions seem to be riddled with many tough questions arising from the very nature of the "security" concept itself, plus the complexities of its cost-allocation not only when you seem to have the promised security but also (and especially) when it fails! We can only briefly allude to some such questions and issues here. First and foremost, due to the popular view of security as a "public good," the vexing question of 'who should pay for security' seems to always slow down investments in security systems in general. And, in a society anchored on 'free enterprise', this issue becomes particularly nefarious because of the wide variety of stakeholder groups concerned with it. When security fails, as in case of a damaged cargo container for example, a host of otherwise dormant questions arise: What are its contents? Are they really same as those listed on the cargo-manifest, or shipping label, in quantity, quality, etc? If not, who should bear the cost of associated losses: the carrier, the customer, the insurance company, security-system vendor/operator, or concerned Regulatory Authority, or any nation-state Government(s)? Finally, security solutions of any kind inevitably degrade operational systems operations with additional time-delays, customer inconvenience, frustration, and so on. But, in the end, why these issues culminate in a dilemma for security systems development today becomes clear when we recognize that different stakeholder-groups have quite different valuations for many of the changes involved, especially when a suitable forum for communication among them is absent. In addition to CRAVE's basic principles and guidelines (Sec. 3.2), it provides precisely this kind of forum for needed stakeholder communications, and indeed operates it as integral part of its process-logic in Figure-1 (Sec. 3.3). The obvious inference is that the argument in favour of applying CRAVES to strategic container security decisions/systems appear to be even stronger than SCM decisions in general. Below, we work through various stages of the CRAVE process to supplement this inference in theory, and to illustrate such a process in more practical terms. For succinctness, and limitations of space, here we adopt a more compact format, segmented by the stages of CRAVE, listing only the salient issues involved in applying CRAVE specifically to strategic container security decisions and systems.

## Stage-1: Enumeration

The security system/service provider, the shippers and consigners, and relevant Regulatory Authority (as a minimal set of stakeholders) engage in a comprehensive and explicit enumeration of the various security threats and vulnerabilities, and the risks they pose. Potential changes in container security, and corresponding changes in the cargo and cargo manifest must be enumerated. Cases of Uncertainty, which defy any sensible risk measurement, are explicitly identified for separate handling as unmeasurable.

#### Stage-2: Measurement

Measurement of the magnitude of changes must be kept un-influenced by, isolated from, the valuation stage below. Examples of important issues to deal with again be technical measurements of the cargo changes, and cases of joint use of resources, most notably the security service resource.

#### Stage-3: Valuation

As always for CRAVE, explicit valuation (even if non-quantitative, e.g. using subjective rating and scoring schemes) of various changes identified in stage-1. Given the public good overtones of security, values from the societal and environmental perspectives should be estimated by the stakeholder groups. To be comprehensive, valuations of potential cargo changes, user-perceived container security changes, as well as from the security system provider's standpoint should be covered.

#### Stage-4: Adjustments & Sensitivity Analyses

In the context of security risks and uncertainty, adjustments for different locations, cities, and geographic regions become more relevant, in addition to the usual time-adjustments (present values) for corresponding monetary equivalents. Similar, innovative, improvisations need to be explored in the area of sensitivity analyses.

#### Stage-5: Combining all Stages

Following CRAVE's focus on formal and explicit evaluation, container security system's evaluations using CRAVE should ideally be first performed separately from that of the overall SCM system, rather than as only as part of the latter. The results can, and ideally should be, incorporated in the larger SCM evaluations. However, doing it in this way could help compensate for the common view of security as either an overhead or a public good, both which suffer from a downward bias on valuation of security thereby discouraging related strategic investments.

#### 6. Conclusion

In this paper, we have shown how and why the CRAVE framework of cost-benefit evaluation of GTD decisions of the late 1980s-90s seems rather ideally suited for strategic decisions in SCM, and especially in container security. The "why" here was argued in terms of the methodological motivations that led to CRAVE itself, the defining characteristics of the GTD decisions for which it was tailor-made, and finally, the similarities between the GTD decisions and today's strategic SCM decisions, especially related to cargo container security. Furthermore, the "how" was primarily articulated in terms of the logical process-flow of CRAVE in general, and showing how it can be operationalized for practical applications of CRAVE in the supply chain arena today, and also specifically for strategic systems/decisions to meet today's container security challenges. The unique match between CRAVE's ability to deal with the variety of stakeholder-groups and the need for such ability in the case of strategic SCM/container security decisions was also brought out analytically, thereby supporting the case for using CRAVE in SCM arena. The hope is that this work will generate informed interest in CRAVE on part of the SC researchers and practitioners leading to its use in real world. However, before CRAVE can be truly put to test in practice, significant amount of further work is needed in terms of relevant corporate education about CRAVE itself, and cost-benefit evaluation approaches in general.

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# The Effects of Corporate Social Responsibility on Organizational Commitment and Performance in the Logistics Service Industry

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#### Abstract

This study empirically examines the impact of corporate social responsibility on organizational commitment and firm performance for logistics service providers. Four critical corporate social responsibility dimensions were identified based on factor analysis: consumer interests, environmental management and community involvement, employee interests, and disclosure and corporate commitment. A structural equation modeling (SEM) was subsequently performed to examine the effect of corporate social responsibility on organizational commitment and firm performance. Results indicated that corporate social responsibility had significantly positive effects on organizational commitment, whereas organizational commitment was positively related to firm performance. However, the corporate social responsibility was not found to have positive effect on logistics firms' performance in this study.

Keywords: Corporate social responsibility; Organizational commitment; Organizational performance; Logistics service providers

#### 1. Introduction

The concept of corporate social responsibility (CSR) actually has developed over the last four decades (Lu et al., 2009) and widely accepted by firms to create the greatest possible values for the stakeholder. Traditionally, enterprises are pursuit of profit making only. However, the socioeconomic view argued that an organization's social responsibilities go beyond making profits to include protecting and improving society's welfare. Thus, enterprises have to involve in the CSR activities on the aspects of economic, legal, ethical, and philanthropic. In addition, as awareness of consumer interests, employee interests, and treats to environment, the firms had adopted the principle of corporate social responsibility (CSR) to achieve the goal of sustainable development.

Taiwan is an island-based economic entity in the center of Asia-Pacific, and its prosperity is highly dependent on foreign trade, in which international logistics plays an important role. Logistics service providers (LSPs) that are providers of add value directly by providing a number of service attributes to shippers, such as storage, cargo tracking, an inland transport, custom clearance, packing, and documentation services (Lu, 2003), play an important role in the provision of integrated logistics-related services to shippers or their clients (Lieb and Miller, 2002; Lai, 2004). According to the 2006 Taiwan Logistics Yearbook published by the Ministry of Economic Affairs (2006), the service industry contributed 71.7% of GDP in 2006 in Taiwan and the logistics industry's annual revenue reached US\$24 billion and contributed 6.1% of GDP in the same year (Lu and Yang, 2010).

Given that barriers to enter the logistics service market are relatively low to firms, the logistics service industry in Taiwan has become highly competitive. Moreover, after Taiwan accessed to the World Trade Organization (WTO) and signed an economic cooperation framework agreement (ECFA) with the Mainland China in 2010, the competition within logistics industry is likely to continue and increase in the foreseeable future (Yang, 2012). Thus, it is imperative for LSPs to increase competitive advantage and pursuit the sustainable development. As demonstrated by previous studies, CSRs have been proved to lead to win-win situations in which both social welfare as well as the organizational performance (McWilliams and Siegel, 2001; Lu et al., 2009). Therefore, LSPs should integrate CSR initiatives into its strategy and create competitive advantage.

The logistics service industry typical has the characteristics of dirty, hard, danger, and low paid and the employee turnover is accordingly relative high in Taiwan. Employees have been viewed as the most value assets to service industry in this knowledge era. Thus, logistics service providers have to lower their employee turnover and which in turn provide customized service to clients. Several studies had concluded that the involvement of CSR could improve a firms' reputation (Javalgi et al., 1994; Perrini et al., 2006). Particularly, a firm has a good reputation can enhance employees' commitment to organization. Although the concept of CSR has been strongly emphasized in the strategic management field, most prior research has mainly evaluated the effect of CSR on organizational performance and few studies are in the logistics service provider context. To fill the gap in the literature, this study aims to evaluate corporate social responsibility for logistics service providers and further to examine the impacts of corporate social responsibility on organizational commitment and organizational performance.

There are five sections in this study. Section 1 introduces the motivation and purpose of the research. Section 2 reviews the literature on CSR, organizational commitment, and organizational performance. A conceptual framework and research hypotheses are also provided in this section. Section 3 describes the research methodology, including questionnaire design, sampling technique, and methods of analysis. Section 4 presents the results of analysis. The conclusions and implications are discussed in the final section.

# 2. Literature Review

## 2.1 Corporate social responsibility

The CSR is defined as the "consideration of, and response to, issues beyond narrow economic, technical and legal requirements of the firm to accomplish social (and environmental) benefits along with the traditional economic gains which the firm seeks" (Aguilera et al., 2007, pp. 836-837). Thus, a firm should beyond its legal and economic obligations, to do the right things and act in ways that are good for society. Basically, the dimensions of CSR included economic, legal, ethical, and philanthropic (Carroll, 1979). Carter and Jennings (2002) evaluated the logistics social responsibility activities and extended the CSR dimensions to six, namely, environment, ethics, diversity, human rights, safety, and philanthropy/community. Lu et al. (2009) identified three dimensions of CSR in container shipping and examined their impacts on organizational performance. These three dimensions were community involvement and environment, disclosure, and employee and consumer interests based on factor analysis. Mishra and Suar (2010) also proposed a composite measure of CSR including six dimensions, namely, employees, customers, investors, community, natural environment, and suppliers, to evaluate its effects on organizational performance.

With the emphasis on CSR, several principles or guidelines pertain to CSR have been proposed. For example, the United Nations (UN) proposed ten principles for doing business global in the areas of human rights, labor, the environment, and anticorruption. In addition, the Organization for Economic Co-operation and Development (OECD, 2011) also proposed ten guidelines for multinational enterprises. The guidelines generally involved in disclosure, human rights, employment and industrial relations, environment, combating bribery, bribe solicitation and extortion, consumer interests, science and technology, and competition. The World Business Council for Sustainable Development (WBCSD, 2000) also suggested enterprises should involve in human rights, employee interests, environment, community, supplier relations, auditing, and stakeholders for improving their core value.

Based on a review of the literature relating to corporate social responsibility attributes, 30 attributes were selected for use in a questionnaire survey. They are presented in the analysis of findings derived from the survey in Section 4.

## 2.2 Organizational commitment

Organizational commitment can be defined as the willingness of an employee exert high levels of effort on behalf of the organization, a strong desire to stay with the organization, and an acceptance of its goals and values (Buchanan, 1974). Thus, it refers to a person's affective reactions to characteristics of his employing organization (Cook and Wall, 1980). Organizational commitment basically involved affective, continuous, and

normative components (Allen and Meyer, 1990). Buchanan (1974) and Cook and Wall (1980) pointed out that organizational commitment consisted three components, namely, identification, involvement, and loyalty. Moreover, Porter et al. (1974) argued that organizational commitment could be measured by value commitment, effort commitment, and retention commitment. Based on previous studies, this study adopted Cook and Wall's (1980) scale and though organizational commitment included three components, namely, identification, involvement, and loyalty.

## 2.3 Organizational performance

Performance is the measurement and comparison of actual levels of achievement of specific objectives. It basically can be measured by financial and non-financial indicators (Venkatraman and Ramanujam, 1986). To comprehensively measure a firm's performance, a composite measure of performance has been recommended by Dess and Robinson (1984). This study, thus, used a combination of both financial and non-financial or customer service measures to evaluate the performance of LSPs.

Reviewing the prior studies on corporate social responsibility, four performance indicators commonly used were used to measure customer service performance (Kaplan and Norton, 1992; Lu et al., 2009; Mishra and Suar, 2010; Yang, 2012), namely service quality, customer satisfaction, customer loyalty, and competitive position. On the other hand, five indicators were used to measure financial performance (Kaplan and Norton, 1992; Lu et al., 2009; Mishra and Suar, 2010; Yang, 2012), namely, grofit rate, market share, sales' growth rate, return on investment, and reduced operational cost.

## 2.4 *Research hypotheses*

A large number of previous studies on CSR have concluded that a firm can increase its performance and competitive advantage by adopting CSR initiatives (Ullmann, 1985; Lu et al. 2009; Mishra and Suar, 2010). Ullmann (1985) pointed out that a positive relationship existed between CSR and financial performance. Although the involvement in CSR activities could impose additional costs on firms, integrating CSR initiatives into its strategy typically can lead firms create more revenue in the long term (McWilliams and Siegel, 2001). Lu et al. (2009) also noted that disclosure and community involvement and environment were positive related to container carriers' financial performance. In addition, employee and consumer interests were positively related to non-financial performance.

The involvement of CSR was also demonstrated to improve a firms' reputation (Javalgi et al., 1994; Perrini et al., 2006). Generally, a firm has a good image or reputation can enhance employees' commitment to organization. Therefore, Brammer et al. (2007) found that the adoption of CSR initiatives significantly influenced employees' commitment to organization. Kim et al. (2010) pointed out that a firm's CSR initiatives could increase employee-company identify and which in turn increased employees commitment to their organization. Carter and Jennings (2002) also pointed out that logistics social responsibility has a direct positive effect both on job satisfaction and employee motivation.

Organizational commitment refers to a person's affective reactions to characteristics of his employing organization (Cook and Wall, 1980). A firm can increase employees' commitment to organization and which in turn improve employees' satisfaction and further to improve the organizational performance (Subramaniam et al., 2002). Thus, if an employee has higher organizational commitment, an employee will has lower turnover intention. That is organizational commitment has a positive effect on organizational performance (Mayer and Schoorman, 1992). Accordingly, based on these previous studies as discussed above, a conceptual model is proposed in Figure 1 and three hypothesizes were proposed as follows:

H1: Corporate social responsibility has a positive effect on LSPs' organizational commitment H2: Corporate social responsibility has a positive effect on LSPs' organizational performance

H3: Organizational commitment has a positive effect on LSPs' organizational performance

#### Figure 1: Research framework



## 3. Methodology

#### 3.1 *Questionnaire design and measures*

Data for this study were collected from a questionnaire survey which was designed based on the stages outlined by Churchill and Iacobucci (2002). The measures for the CSR, organizational commitment and organizational performance of LSPs used in this study were drawn from previous works, and then, to ensure their validity, they were discussed with logistics service executives and experts. As regards the CSR, 30 items were drawn from previous studies (Lu et al., 2009; OECD, 2011) and slightly revised to measure CSR in the current work. The measure scale of organizational commitment was mainly adopted from Cook and Wall's (1980) work and included three components, namely organizational identification, organizational loyalty, and organizational involvement. Finally, the organizational performance including financial and customer service performance was drawn from previous studies.

Each CSR and organizational commitment variable was assessed using a five-point Likert scale, ranging from "1= strongly disagree" to "5= strongly agree". As regards the organizational performance, a five point Likert scale, ranging from "1= very poor" to "5= very good" was used.

#### 3.2 Sampling techniques

A logistics service provider is a provider of logistics services to customers. This study focused on container shipping perspective and the data for the study was thus collected from a questionnaire survey according to the Directory of National Association of Chinese Ship owners and Shipping Agencies and the Members of the International Ocean Freight Forwarders and Logistics Association in Taiwan. The survey questionnaire was sent to 520 managers and yielded 154 usable responses. The overall response rate for this study was 29.6%. A t-test recommended by Armstrong and Overton (1977) was carried out to test for non-response bias. The 154 survey respondents were divided into two groups, early (n=90, 58.4%) and late (n=64, the remaining 41.6%), based on their response wave (first and second). T-tests were performed on the two groups' perceptions of the various CSR attributes. Results showed that there were no significant differences between the two groups' perceptions of the various attributes at the 5% significance level, and thus that non-response bias was not a problem, since the responses of late respondents appeared to reflect those of the earlier ones.

#### *3.3 Research methods*

An exploratory factor analysis was employed to identify the key CSR dimensions. A structural equation modeling (SEM) approach was subsequently used to test the research hypotheses. A two-step approach suggested by Anderson and Gerbing (1988) was employed to analyze the data. In the first step, confirmatory factor analysis way performed to assess the validity of the measurement model. Once it is validated, then, the second step requires estimating the structural model from the latent variables. All analyses were carried out using the SPSS 18.0 for Windows and AMOS 18.0 statistical packages.

## 4. **Results of Empirical Analysis**

## 4.1 Characteristics of respondents

The profile of respondents and their companies revealed that most respondents were managers/assistant managers (38.9%) and vice presidents or above (37.0%). In general, managers are actively involved in and anchor operations in their businesses, and since more than 75% of responses from managers, vice presidents or above thus endorsed the reliability of survey findings. Moreover, over 80% of respondents had worked in the logistics industry for more than 10 years, suggesting that they had abundant practical experiences to answer the questions appropriately. As regards the types of responding firms, 55.2% were from ocean freight forwarders, 29.2% from liner shipping agencies, and 15.6% from liner shipping companies. Nearly 90% (87.7%) of responding firms had been in operation for more than 10 years. Around 55% of the responding firms had fewer than 50 employees, while 12.4% had more than 501 employees. Results also revealed that 52.1% of the respondents reported that their firms' annual revenue was below NT\$100 million, 37.7% were between NT\$101 million and NT\$10 billion, and 10.3% reported revenue of more than this.

## 4.2 Crucial corporate social responsibility dimensions of logistics service providers

An exploratory factor analysis with VARIMAX rotation was employed to reduce the 30 CSR attributes to a smaller, manageable set of underlying factors. An eigenvalue greater than one was used to determine the number of factors in each data set (Churchill and Iacobucci 2002). To aid interpretation, variables with loadings of 0.5 or greater on only one factor were extracted, which is a conservative criterion based on Hair et al. (2009). However, four items were found to load on two factors or on a factor with a loading lower 0.5, and therefore suggesting these items should be removed from further analysis. Based on surveyees' responses, four factors, as shown in Table 1, were subsequently found to underlie CSR dimensions of LSPs, and these accounted for 70.0% of the total variance.

Table 1. Factor analysis of corporate social responsibility								
Corporate social responsibility attributes	F1	F2	F3	F4				
Our company does not make representation or omissions, nor engage in any other practices that are deceptive, misleading, fraudulent or unfair	0.837	0.086	0.126	0.183				
Our company emphasizes consumer privacy and provides protection for personal data	0.807	0.255	0.179	0.034				
Our company complies with the tax laws and regulations in all countries in which it operates and contributes to the public finances of host countries by making timely payment of their tax liabilities	0.806	0.057	0.245	0.070				
Our company emphasizes the storage and carriage of dangerous cargoes	0.763	0.293	0.250	0.049				
Our company emphasizes the safety of cargoes	0.708	0.152	0.343	0.120				
Our company and competitors can carry out activities in a manner consistent with all applicable competition laws and regulations	0.703	0.210	0.307	0.123				
Our company provides transparent and effective procedures to address consumer complaints and contribution to fair and timely resolution of consumer disputes without undue cost or burden	0.623	0.327	0.412	0.247				
Our company does not obtain business interests by cheating our customers	0.567	0.315	0.377	0.124				
Our company undertakes initiatives to promote greater environmental responsibility	0.507	0.461	0.366	0.225				

 Table 1: Factor analysis of corporate social responsibility

The first factor, as shown in Table 1, consisted of nine items and accounted for 47.60% of the total variance. Since six items are related to consumer interests, this factor, therefore, was called consumer interests. Factor 2 consisted of seven items and those items are related to environmental management and the involvement in community. This factor, therefore, was termed environmental management and community involvement and accounted for 11.84% of the total variance. Factor 3 included five items and all items are related to employee interests. Thus, this factor was named employee interests and accounted for 5.94% of the total variance. Factor 4 consisted of five items and those items are related to disclosure activities and the commitment in corporate social responsibility activities. This factor, therefore, was named disclosure and corporate commitment and accounted for 4.62% of the total variance.

To examine the consistency and reliability of the factors, a reliability test based on Cronbach's alpha statistics was used in this study. The results, as shown in Table 1, indicated that the Cronbach alpha values for each measure were well above the suggested threshold of 0.8, and thus can be seen as reliable (Churchill and Iacobucci 2002). Table 1 also shows the respondents' agreement level with each CSR dimensions in current situation. Results indicate that LSPs performed well with regard to consumer interests (mean=4.334), followed by employee interests (mean=4.039), environmental management and community involvement (mean=3.773), and disclosure and corporate commitment (mean=3.492).

Table 2. Factor analysis of corporate social responsion		unuc)		
Corporate social responsibility attributes	F1	F2	F3	F4
Our company requests our business partners to enhance environmental	0.176	0.741	0.156	0.329
protection awareness and comply with related environmental regulations				
Our company participates in community development and inhabitants'	0.088	0.735	0.418	0.034
welfare				
Our company cooperates with customers to advocate environmental	0.256	0.721	0.119	0.320
management activities				
Our company devotes to developing green logistics services	0.379	0.646	0.166	0.275
Our company sponsors cultural and artistic activities	0.208	0.597	0.445	0.151
Our company has established environmental auditing programs	0.239	0.535	0.116	0.452
Different departments in our company cooperate with each other to improve	0.372	0.507	0.268	0.268
the environment				
Our company emphasizes the reserved staff development, skill training, and	0.251	0.164	0.805	0.149
on-job training				
Our company has a fair system to employment and promotion without	0.253	0.195	0.798	0.181
discrimination				
Our company takes adequate steps to ensure employees' occupational health	0.400	0.195	0.723	0.109
and safety in their operations				
Our company emphasizes employees' interests	0.407	0.241	0.716	0.124
Our company provides appropriate compensation and counseling to	0.330	0.273	0.664	0.049
employees who are lay-offs or dismissals				
Our company applies high-quality standards for disclosure, accounting,	0.079	0.143	0.029	0.911
audit, environmental and CSR reporting where it is located				
Our company ensures that timely, regular, relevant information is disclosed	0.156	0.026	0.146	0.880
regarding our activities, structure, financial situation and performance				
Our company adopts high standards of environmental and CSR reporting	0.125	0.320	0.146	0.814
Our company has an environmental-health-and-safety department	-0.011	0.405	0.108	0.764
Our company's top managers advocate to the corporate social responsibility	0.260	0.388	0.222	0.554
activities				
Eigenvalues	12.375	3.077	1.543	1.202
Percentage variance	47.598	11.836	5.936	4.624
Cronbach α	0.934	0.892	0.907	0.906
Mean	4.334	3.773	4.039	3.492

#### Table 2: Factor analysis of corporate social responsibility (continue)

#### 4.4 Analysis of the measurement model

Confirmatory factor analysis was performed to assess the unidimensionality, reliability and validity of the construct (Anderson and Gerbing, 1988; Segars, 1997). The initial mode ( $\chi 2=87.095$ , df=24, p=0.000) was found statistically significant at the 0.05 level of significance, indicating the model needed to be modified by examining the statistical criteria, such as standardized residuals and modification indices. After eliminated the variable "disclosure and corporate commitment" which had the residual value exceeded 2.58 (Hair et al., 2009), the revised model provided adequate fit ( $\chi 2=30.064$ , df=17, p=0.026) and was credible. A series of goodness-of-fit indices, i.e., GFI>0.9, RMR<0.05, RMSEA<0.08, provide an acceptable representation of the hypothesized constructs. The subsequent tests of validity, reliability, and unidimensionality are described below.

As regards convergent validity, results indicate that all the C.R. values were significant at the 0.05 level, effectively suggesting that all the indicators measure the same construct and providing satisfactory evidence of their convergent validity and unidimensionality (Anderson and Gerbing, 1988). Discriminant validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs (Fornell and Larcker, 1981; Koufteros, 1999). As can be seen in Table 2, the highest squared correlation was observed between CSR and organizational commitment, and it was 0.579. This was significantly lower than their individual AVEs, which were 0.681 and 0.760, respectively. Accordingly, the results demonstrate the discriminant validity of the study constructs.

Variable	AVE <sup>a</sup>	Construct reliability <sup>b</sup>	ξ1	η1	η2
			CSR	OC	FP
ξ1	0.681	0.864	1.000		
CSR					
η1	0.760	0.905	0.761(0.579)	1.000	
OC					
η2	0.520	0.670	0.573(0.328)	0.624(0.389)	1.000
FP					

Table 3: Average variance extracted and composite reliability for each measure

Construct reliability provides a measure of the internal consistency and homogeneity of the items comprising a scale (Churchill, 1979). Highly reliable constructs are those in which the indicators are highly intercorrelated, indicating that are all measuring the same latent construct. The range of values for reliability is between 0 and 1. The results in Table 2 indicate that the reliability of the each construct all exceeded the recommended level of 0.60 (Bagozzi and Yi, 1988; Sanchez-Rodriguez et al., 2005; Hair et al., 2009). To summarize, the overall results of the goodness-of-fit and the assessment of the measurement model lend substantial support to the proposed model.

## 4.5 Structural equation modeling: hypotheses testing

After confirming the fitness of the proposed model, this study then examined the hypothesized relationships. Results, as shown in Table 3, revealed the CSR was found to have significant positive impact on organizational commitment (estimate = 0.910, C.R. > 1.96), and organizational commitment (estimate = 0.626, C.R. > 1.96) was also found to have positive impact on organizational performance. However, there was no support for a significant positive relationship between CSR (estimate = 0.018, C.R. < 1.96) and organizational performance in this study. Results implied that LSPs which make efforts to undertake CSR activities can enhance their employee-organizational commitment. By increasing the employees' commitment to organization, LSPs can further to improve its financial and customer service performances. The above findings are consistent with those in Subramaniam et al. (2002) and Kim et al. (2010).

Table 4: Results of the structural equation modeling									
Relationships	Estimate	S. E.	C.R.	Р	Sign	Supported			
Corporate social responsibility-> Organizational commitment	0.910	0.074	12.278	$0.000^{**}$	+	Supported			
Corporate social responsibility-> Organizational performance	0.018	0.157	0.116	0.908	+	Not supported			
Organizational commitment -> Organizational performance	0.626	0.154	4.062	$0.000^{**}$	+	Supported			

Fit indices:  $\chi^2$ =30.064 (p=0.026),  $\chi^2$ /df= 1.768, GFI=0.949, AGFI=0.893, RMR=0.013, RMSEA=0.071.

#### 5. Conclusions and Discussions

This study aims to examine the impact of corporate social responsibility on organizational commitment and organizational performance for logistics service providers. The main findings are summarized below.

Factor analysis was employed to identify the critical CSR dimensions, four of which were identified, namely, consumer interests, environmental management and community involvement, employee interests, and disclosure and corporate commitment. The findings indicated that logistics service providers perform well with regard to consumer interests, followed by employee interests, environmental management and community involvement, and disclosure and corporate commitment. Thus, logistics service providers need to make efforts in disclosure and corporate commitment.

Structural equation modeling (SEM) was subsequently employed to evaluate the relationships among CSR, organizational commitment, and organizational performance. A significantly positive relationship was found between CSR and organizational commitment (H1), which implies that LSPs can significantly enhance employees' commitment to organization by purchasing CSR activities. Therefore, the involvement of CSR on the aspects of employee and consumer interests, environment management and community involvement can significantly improve LSPs' organizational commitment. The finding is consistent with previous studies (Carter and Jennings, 2002; Brammer et al., 2007; Kim et al., 2010).

Results also indicate a significantly positive relationship between organizational commitment and organizational performance (H3). This implies that employees with higher commitment to organization are more satisfied with their organization and have lower turnover intention. The finding is consistent with previous studies (Mayer and Schoorman, 1992; Subramaniam et al., 2002; Brammer et al., 2007; Kim et al., 2010).

However, the effect of CSR on organizational performance (H2) was not supported in this study, which implies that the involvement of CSR activities does not directly influence organizational performance. It is not surprising because the involvement of CSR activities could impose additional costs on firms. Thus, the involvement of CSR activities could not provide superior performance in the short term. The finding is consistent with previous studies (McWilliams and Siegel, 2001).

One of the major contributions of this study is that it is the first attempt to examine the impacts of corporate social responsibility on organizational commitment and organizational performance in the context of logistic service providers. Moreover, this study contributes to the literature by demonstrating that the purchasing of CSR activities can enhance employees' commitment to organization and which in turn improve organizational performance. Finally, this study indicates that the purchasing of CSR activities can not lead to superior organizational performance in the short term. However, LSPs can put more efforts on the aspects of employee and consumer interests, environment management and community to enhance employees' commitment to organizational performance in the long term.

From a theoretical perspective, this study contributes to the field by identifying crucial CSR dimensions and examining their effects on organizational commitment and organizational performance. However, it suffers from several limitations. First, different sized LSPs may have different resources for purchasing CSR activities, and thus future research could examine the effects of organizational characteristics on CSR activities. Another worthwhile direction for future research might be using the strategic group concept to classify logistics service providers into different CSR oriented firms based on the aforementioned CSR dimensions.

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<sup>&</sup>lt;sup>a</sup> Average variance extracted (AVE) = (sum of squared standardized loading)/[(sum of squared standardized loadings)+(sum of indicator measurement error)]; Indicator measurement error can be calculated as 1- (standardized loading)<sup>2</sup>

<sup>&</sup>lt;sup>b</sup> Construct reliability = (sum of standardized loading)<sup>2</sup>/[(sum of standardized loading)<sup>2</sup>+(sum of indicator measurement error)]; Indicator measurement error can be calculated as 1- (standardized loading)<sup>2</sup>
# Service Quality Assessment Based on Customer Satisfaction in International Freight Forwarding Industry: An Empirical Study in East Asia

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### Abstract

The purpose of this paper is to improve service quality of freight forwarders and explore the quality function deployment (QFD) in terms of quality management technique. Freight forwarder business is mainly characterized by lower capital investment and entry barrier comparing with a shipping line. Freight forwarders usually work closely with shipping or airline companies as intermediary agent and their major customers are small or medium size manufactures or traders. Providing the quality service to enhance customer satisfaction is the key mission since every company provides similar service and the competition is extremely severe especially after global economic crisis. The QFD is one of the distinctive procedures to describe the requirements of customer and transform them into managerial missions by cross-relations evaluation between customer requirements and technical measures. The relative weight of each customer requirement would be calculated by applying fuzzy analytic hierarchy process (FAHP). Furthermore, the feature of the study by using QFD approach would not only identify key technical measures but also explore meaningful business solution as direction of quality improvement. The empirical study is performed to investigate service quality of freight forwarding industry by focusing on a group of anonymous leading forwarders in East Asia. In conclusion part, we would explore the empirical result and managerial meaning for decision making.

Keywords: Quality function deployment; Freight forwarder; Shipping line; Fuzzy analytic hierarchy process.

### 1. Introduction

The world trade is the vital force drive the growth of both regional and global economy. International trade brings a lot of benefits to countries and business units to enjoy the profits from comparative advantages as well as provides consumers a variety of options to purchase their daily needs. Today's trade and business activities rely on transportation to connect cargo, people and country to facilitate business growth and regional prosperity. Transportation also provides time utility and place utility from the point of merchandise production to the point of consumption for the business supply chain management. Governments also make effort to lower logistics cost through improve infrastructure to overcome the trade barriers and vitalize their manufactures and products to stay competitive in the global market. According to the maritime review of UNCTAD, around 90% of the global trade is completed by ocean transportation and the rest of the cargo is dependent on air transportation. International shipping business plays a significant role to complete these economic activities and support enterprises with various logistics solution. Until 2012, more than 500 registered major freight forwarders in Japan and over one million registered logistics providers in China provide logistics service in the market. After global financial crisis, key issues such as bunker prices, exchange currency, economic downturn, and constant change of supply chain and future uncertainty of market make the operation much more complex. Some major carriers suffer financial loss more than billions dollars, and this is why K+N's executives also advises the freight forwarders especially in Europe to prepare for the downswing and low margin for future outlook as shipping lines suffer particularly in 2013. Some carriers adopt several aggressive measures such as new formation of G6 alliance and Daily Maersk to develop the clear strategies for the future. On the other hand, shipper wants better, cheaper, safer, reliable, speedy and professional service. Customer's requirement is getting demanding and picky than ever, so it is necessary for forwarders to redefine standards and strategies to face the changing market and challenges.

In 2013, our research team interviews with executives of leading forwarder A in Taiwan and forwarder B in Korea (Company name keeps confidential), they emphasize the current market condition is fully competitive and not so profitable. From marketing perspective, the business cycle for forwarders in East Asia is in the recession period as one executive mentioned. The market structure and competition makes the providers difficult to survive. Though they already achieve the economies of scale to reduce our cost but their key weapons to gain core competency is through providing high quality service. For general customer, they will provide general or no frill services. Sales staff should have regular visit our important customer to understand their needs and adjust our operation to cater their requirement. They care about price as well as diversified services such transit time, logistics support, slot supply and customized ability. Nowadays, customer wants not only good service but great service and service providers may soon lose a client if they only cause little failure or criticism. They stress there is almost no entry and exit barriers in this industry and have more flexibility to change than carrier because the capital investment is much lower. Therefore, this research is motivated by these insights and perspectives, and then we empirically explore the important technical measures for enhancement of customer satisfaction. The research process is shown in Figure 1.





## 2. Brief Description of the Freight Forwarder Service

In order to effectively consolidate LCL (Less than container loaded) cargo to containers especially for small medium size manufactures or traders, it is necessary for them to use the service providing by international freight forwarders as intermediary connection to efficiently complete the delivery. In general, the duties of forwarders may include space booking on a ship or aircraft, non-vessel operating carriers (NVOCCs), organizing local and international shipping, providing necessary paperwork and custom clearance, delivery and distribution service, information service, warehousing, consolidation and other related formalities. On the other hand, forwarder's target market is slightly different from liner carrier. Forwarders tend to target on LCL customer for consolidation while liner carriers focus more on attracting FCL (Full container loaded) container cargo. The market is extremely competitive because service providing by freight forwarder seems to be same or similar to one another, along with the increasing number of new entrants. It is necessary to explore appropriate measures to enhance customer satisfaction in East Asian region. Thus, competitive advantage of freight forwarders only based on cheaper price is not enough. Delivering high quality of service becomes strategic and survival issue for forwarders to stay competitive and build sustainability.

Measuring service quality of freight forwarder is not an easy task due to its heterogeneity, intangibility and inseparability. Perceived service quality is the description of interaction between customer and service provider, so we could obtain service quality requirement from shipper with quantitative and qualitative surveys. On the other hand, through past academic literature and practical publication, we could find some researches regarding to the service quality requirement of related logistics or freight forwarding industry. Brooks (1985) classifies the service attributes of liner shipping industry for consideration of decision maker such as transit time, directness of sailings, carrier's reputation for reliability, frequency of sailing and next ship leaving. Bernanl (2002) empirically explore the international network development of regional forwarders. Collaboration between competing forwarders may create favourable condition and network sharing for each other. Gardiner (2004) found the reasons that affect the airport choice of freight operators with increasing levels of congestion at the major cargo hubs and further restrictions on noise and night-time flying. They evaluate several factors such as passenger hub location, airport quality, airline network configuration and other works relating to airport choice to paint a full picture of the current research in this area. Lai and Cheng (2004) empirically study the freight forwarding industry in terms of demographic profiles, capabilities of providing different type of logistics services, service performance and the perceived prospects in Hong Kong. He explains many forwarders have high capability to provide freight forwarding and traditional logistics service, but they seem to lack the ability to provide other value-added service. Rau (2006) applied a learning-based approach to analyze negotiation between shipper and forwarders in terms of price, delay penalty, due date and shipping quantity. Lu (2007) indentifies seven capability dimensions for liner shipping including purchasing, operation, human resource management, customer service, information integration, pricing, and financial management. Results show four factors are significant differ between shipping companies and agency: marine equipment, information equipment, operation, and information integration. Chow (2007) stated the downturn of Hong Kong freight forwarding industry owing to the growing competition and challenge from the neighbouring ports of Yantian and Shekou in China, which operated in a much cheaper way. He suggested a tactical knowledge-based scheduling system implemented in a local freight forwarder for supporting the scheduling process of a shipping plan. The result reveals that both customer retention rate and resource utilization has increased significantly with introduction of this technique. Liang et al. (2008) pointed out four critical service items for an ocean freight forwarder. The four service items include operations convenience and response ability, integrated service, transportation ability, and price. Tongzon (2009) empirically studied on port choice issue from the freight forwarders' perspective in Southeast Asia. Efficiency is found to be the most significant factor followed by shipping frequency, adequate infrastructure and location.

Lun et al. (2009) examine liner shipping from network perspective with an aim to develop a descriptive framework for operation and development of liner shipping networks. The framework supports liner shipping companies and their partners for cost and service improvement in renovating their networks. Bach (2010) proposed a real-time-oriented control approach for freight forwarders to expand load consolidation, reduce empty vehicle trips, and handle dynamic disturbances. Feo (2010) explored the preference analysis of Spanish freight forwarders modal choice between short sea shipping and door-to-door road transport in terms of value

of time, value of reliability and value of frequency in freight transport. Ministry of land, infrastructure and Transportation (2011) investigates important service quality items for third party logistics providers in Japan, including price, speedy delivery, schedule reliability, staff ability, trouble handling, logistics solution and information providing. After logistics diagnosis by consultant group, several strategies are proposed such as improving technical support, solution to reduce cost and time, total logistics strategies, customer service support system and web-based information sharing. Yang (2012) applied multiple regression analysis to explore the critical logistics service capabilities for ocean freight forwarders such as logistics service reliability, logistics value-added service capability, flexibility capability and logistics information capability. These factors had significant positive effects on financial performance. Shang (2012) empirically examines customer relationship management (CRM) and its impacts on performance of freight forwarder services in Taiwan. The understanding of relationships among IT, client response, KM application, profit and managerial performance may offer a reference as to how freight forwarders can amend customer relationship to improve their performance. James Marks (2013), supply chain consultant Crimson, says more demanding standards should be defined to European fresh food supply chains, but the cost may be high. The standards will define the details about if the responsibility is belonging to origins of food, transport supplier or the retailers. The standards could help all the party to pay attention to quality and source of food and monitor the supply chain from food supplier to end customer.

After reviewing the above literature regarding to measure the service quality of freight forwarder, consulting with experienced executive, professor academic as well as shippers, we choose 12 customer requirements (CRs) in Table 1 and 12 technical measures (TMs) to evaluate the service quality of freight forwarders in Table 2.

1							
Customer requirements	Description						
1. Instant response	Speed to respond customer's request						
2. Cheaper agency fee	Offer lower prices for customer.						
3. Global service ability	Ability to provide global and local service						
4. Tailor-made service	Provide service according to the request for individual customer						
5. Door to door ability	Ability to deliver freight to customer's warehouse or designated location						
6. Schedule reliability	No delay or cancel of delivery service						
7. Consult service	Expert consult to provide supply chain and logistics solution						
8. Excellent reputation	Company has good business records and trustworthy						
9. Stable space supply	Ability to provide the space or handle large delivery						
10. Fast document handling	Speed and easiness of documentation handling						
11. Instant cargo tracking	Provide sophisticated dynamic or on-line tracking						
12. Regular visit	Commercial visit to VIP customer						

# Table 1: Customer requirements in the empirical Work

<b>1</b> abic <b>2</b> , <b>1</b> comment measures in the empirical work	Table 2:	Technical	measures in	the em	pirical wor	k
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		-
Tec	hnical Measures	Description
1.	Overall information system	Implementing the system for information sharing
2.	Paperless and simple procedure	Easiness and convenience to handle customer paperwork
3.	Quality manual and certificate	Clear procedure to define corporate goal and job details
4.	Customer clearance and manual	Efficient custom clearance procedure
5.	Service point and network	Office or service centre overseas and service route
6.	Customer relationship management	Work closely with customer to build relationship and commitment
7.	IT implementation	Applying new technology to improve efficiency of cargo operation (RFID)
8.	Human resource management	Train potential employees for their valuable contribution in the future
9.	Strong intermodal ability	Ability to provide efficient mode combination to complete delivery
10.	Marketing strategy	Clear marketing goal to both VIP or general customer
11.	Free consulting service	Free market and supply chain information consulting
12.	Green shipping policy	Environmental friendly transport and low CO2 emission commitment

# 3. Methodology

### 3.1. 1<sup>st</sup> Definition of quality function deployment

Quality function deployment is a unique procedure to transform quality requirement into business practice through analyzing the relationship between technical measures and requirements. Many literature reviews show us several criticism and inadequacy of traditional QFD and how to improve this method. (Duru et al, 2012) Therefore, many scholars take advantage of these characteristics and combine OFD with other techniques such as fuzzy, process management, DEA, MSE and SERVOUAL to solve the product design, manufacture and service quality problems. The combination of the techniques makes the research result more accurately and overcomes the original weakness and criticism of QFD method. Vanegas and Labib (2001) explain the QFD is an important tool to translate the Voice of customer (VOC) into the technical requirement. He applies the fuzzy numbers to optimize the relationship between customer requirement and technical requirement for the car door design and manufacture considering the cost, technical and market factors. Orgener (2003) stresses the evolution and advantage of OFD for product design and service management. However, the teamwork concept is key factor to make OFD successful because it will take more time and effort to get the best result. Shahin and Chan (2006) improve OFD methodology by introducing the concept of customer requirement segmentation (CRS) for a four-star hotel. The contribution is to overcome the problems and difficulties such as ambiguities of VOC, handling of larger HoQ, conflict of each CR. Chen (2009) innovatively integrates the concept of QFD and process management techniques to meet customer requirement and company goals in terms of product design, process management in semiconductor industry. Process management is an important concept of Six Sigma implementation and may be significantly improved by applying the QFD method. Ip (2009) creates a model for business succession such as assessment of current situation of business, successor and competencies analysis and planning of necessary tasks for future development by utilizing the QFD method. Dror and Sukenik (2011) combine QFD and mean square error (MSE) criterion to evaluate the bank service. The important service dimensions are service quality, staff attitude, information providing, technology and management feature. Pakdil et al. (2012) apply QFD to analyze the after sales services both qualitatively and quantitatively for a manufacture firms. SERVQUAL and factor analysis are also used to include the house of quality. Munuzuri et al (2013) explore the Spanish small medium sized enterprises to discuss their certified quality management systems and logistics performances. Their current standard is ISO 9001. The authors proposed the more specific logistics management standards may be needed to improve the process.

The QFD framework is proposed to translate CRs into TMs by constructing the House of Quality (HoQ) matrix. We can obtain the priority degree of TMs through computing the sum product of relative weight of each CR. After normalizing the value of result, the obtained relative weight could show the relationship degree of TM for enhancing customer satisfaction.

The conventional HoQ matrix consists of seven major parts including the customer requirements (CRs), the priority degree for requirements, technical measures (TMs), the correlation matrix (between TMs), relationship matrix (between TMs and CRs), sum products of priority degrees and relationship degrees,  $w_j$ , and the priority degree of TMs,  $w_j^n$  (As shown in Figure 1). The correlation matrix is mainly practical for developing strategies to improve technical measures. In some cases, a technical measure has a positive or negative correlation and an improvement may give to another or deteriorate it. For evaluation of the balance of improvements, correlation matrix signifies such interactions.

The numerical procedure for assignment of priority degree of TMs is as follows:

Given *m* customer requirements signified by  $CR_i$ , (i = 1, 2, ..., m) and *n* technical measures signified by  $TM_i$  (i = 1, 2, ..., n). Let  $d_i$  (i = 1, 2, ..., m) be the priority degree for the *i*th  $CR_i$  among the whole set of *CR*s, whereas wj (j=1, 2, ..., n) signifying the relative weight of importance of the *j*th TM, is determined from the relationship between TMs and CRs. Let *R* be the relationship matrix between TMs and CRs, the component  $R_{ij}$  signifies the level of impact of the *j*th TM on satisfaction of the *i*th CR. The value of  $R_{ij}$  is assigned by an indicator value of 9 (Strong relationship,  $\blacksquare$ ), 5 (Moderate relationship,  $\blacktriangle$ ), 1 (Low relationship,  $\bullet$ ) or 0 (No relationship, "O").The sum product of the priority degree,  $d_i$  of the *i*th CR<sub>i</sub> and  $R_{ij}$  is calculated as follows;

$$w_j = \sum_{i=1}^m d_i R_{ij}, j=1,2,\dots,n$$
(1)

 $w_j^n$  is the normalised value of  $w_j$  which signifies the priority degree of the *j*th TM for customer satisfaction. The priority degree for the CRs,  $d_i$ , is defined by an original FAHP process through the pair wise comparison survey. The following section discusses the FAHP method under the synthetic extent analysis.



### 3.2. Fuzzy analytic hierarchy process

After introducing fuzzy method by Zadeh (1965), Laarhoven and Pedrycz (1983) extended analytic hierarchy process (AHP) by using fuzzy approach to deal with vagueness of human thought for decision making problem. They used a triangular fuzzy numbers (TFNs) to develop fuzzy-AHP (FAHP) method. In the FAPH method, the judgement matrix is formed in a pair-wise comparison matrix which is calculated fuzzy arithmetic and fuzzy aggregation operators and the procedure calculated a sequence of weight vectors that can be used to choose main attribute. In existing literature, many studies investigate the decision problems under uncertainty condition by using FAHP methods (Bozbura & Beskese, 2007; Buckley, 1985; Bulut, Duru, Keçeci, & Yoshida, 2012; Cakir & Canbolat, 2008; Dağdeviren & Yüksel, 2008; Duru, Bulut, & Yoshida, 2012; Ertuğrul & Karakaşoğlu, 2008; Gumus, 2009; Güngör, Serhadlıoğlu, & Kesen, 2009). In this paper, Chang's approach is used for the FAHP calculation and its algorithm is as follows (Chang, 1996); Let  $X=\{x_1, x_2, ..., x_n\}$  be an object set and  $U=\{u_1, u_2, ..., u_m\}$  be a goal set. According to the method of extent analysis, each object is taken and extent analysis for each goal is performed, respectively (Chang, 1996). Therefore, *m* extent analysis values for each object can be obtained, with the following signs:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \quad i=1, 2, ..., n,$$
 (2)  
where all the  $M_g^j (j=1, 2, ..., m)$  are TFNs.

The steps of Chang's extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent with respect to the *i*th object is defined as

$$S_{i}\sum_{j=1}^{m}M_{g_{i}}^{j}\otimes\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_{i}}^{j}\right]^{-1}$$
(3)

To obtain  $\sum_{j=1}^{m} M_{g_i}^{j}$ , the fuzzy addition operation of *m* extent analysis values for a particular matrix is performed such as:

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right)$$
(4)

And to obtain  $\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_{i}}^{j}\right]^{-1}$ , the fuzzy addition operation of  $M_{g_{i}}^{j}$  (j=1, 2, ..., m) values is performed such as:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left( \sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right)$$
(5)

and then the inverse of the vector in Eq. (5) is computed, such as:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{g_{i}}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}u_{i}}, \frac{1}{\sum_{i=1}^{n}m_{i}}, \frac{1}{\sum_{i=1}^{n}l_{i}}\right).$$
(6)

**Step 2:** The degree of possibility of  $M_2 = (l_2, m_2, u_2) \ge M_1 = (l_1, m_1, u_1)$  is defined as

ſ

$$V(M_{2} \ge M_{1}) = \sup_{y \ge x} \left[ \min(\mu_{M_{1}}(x), \mu_{M_{2}}(y)) \right]$$
(7)

and can be expressed as follows:

$$V(M_{2} \ge M_{1}) = hgt (M_{1} \cap M_{2}) = \mu_{M_{2}}(d) = \begin{cases} 1, & \text{if } m_{2} \ge m_{1}, \\ 0, & \text{if } l_{1} \ge u_{2}, \\ \frac{l_{1} - u_{2}}{(m_{2} - u_{2}) - (m_{1} - l_{1})}, & \text{otherwise.} \end{cases}$$
(8)

**Figure 2** illustrates Eq. 8 where *d* is the ordinate of the highest intersection point *D* between  $\mu_{M_1}$  and  $\mu_{M_2}$ . To compare  $M_1$  and  $M_2$ , we need both the values of V ( $M_1 \ge M_2$ ) and V ( $M_2 \ge M_1$ ).

**Step 3:** The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy  $M_i$  (*i*=1,2,...,*k*) numbers can be defined by

$$V(M \ge M_{1}, M_{2}, ..., M_{k}) = V[(M \ge M_{1}) and (M \ge M_{2}) and ... and (M \ge M_{k})]$$
  
=min V(M \ge M\_{i}), i=1,2,3,...,k. (9)

Assume that  $d'(A_i) = \min V(S_i \ge S_k)$  for k=1,2,...,n;  $k \ne i$ . Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^{\mathrm{T}}$$
(10)

Where  $A_i$  (*i*=1, 2, ..., *n*) are *n* elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \dots, d(A_n))^{\mathrm{T}},$$
(11)

where *W* is a non-fuzzy number.





Table 3 displays the linguistic comparison terms and their equivalent fuzzy numbers in this paper.

Fuzzy number	Linguistic scales	Membership function	Inverse
à 1	Equally important	(1,1,1)	(1,1,1)
Ã <sub>2</sub>	Moderately important	(1,3,5)	(1/5,1/3,1)
Ã <sub>3</sub>	More important	(3,5,7)	(1/7,1/5,1/3)
Ã4	Strongly important	(5,7,9)	(1/9,1/7,1/5)
à 5	Extremely important	(7,9,9)	(1/9,1/9,1/7)

Table 3: The linguistic comparison terms and their equivalent fuzzy numbers

#### 3.3. The consistency calculation for the FAHP method

Duru et al. (2012) proposed the centric consistency index (CCI) for the consistency calculation of FAHP method and it is based on geometric consistency index (GCI) (Crawford & Williams, 1985) The calculation of CCI is as follows;

Let  $A = (a_{Lij}, a_{Mij}, a_{Uij})_{n \times n}$  be a fuzzy judgment matrix, and let  $w = [(w_{Ll}, w_{Ml}, w_{Ul}), (w_{L2}, w_{M2}, w_{U2}), \dots, (w_{Ln}, w_{Mn}, w_{Un})]^{T}$  be the priority vector derived from A using the RGMM. The centric consistency index (CCI) is computed by

$$CCI(A) = \frac{2}{(n-1)(n-2)} \sum_{i < j} (\log(\frac{a_{Lij} + a_{Mij} + a_{Uij}}{3}) - \log(\frac{w_{Li} + w_{Mi} + w_{Ui}}{3}) + \log(\frac{w_{Lj} + w_{Mj} + w_{Uj}}{3}))^{2}$$
(12)

When CCI(A)=0, we consider A fully consistent. Aguarón et al. (2003) also provide the thresholds (GCI) as  $\overline{GCI}=0.31$  for n=3;  $\overline{GCI}=0.35$  for n=4 and  $\overline{GCI}=0.37$  for n>4. When  $CCI(A) < \overline{GCI}$ , it is considered that the matrix A is sufficiently consistent. Since the CCI is a fuzzy extended version of the GCI, thresholds remain identical.

#### 3.4. The prioritization of decision maker

The weight of each decision makers is different than each other because their experience and thought about the problem differ from each other. In this paper, therefore, the reverse value of CCI is considered as their prioritization and it is used the calculation of the aggregated fuzzy judgment matrix for the criteria of customer satisfactions (Duru, et al., 2012).

Let  $A=(a_{ij})_{n\times n}$ , where  $a_{ij}>0$  and  $a_{ij}\times a_{ji}=1$ , be a judgment matrix. The prioritization method refers to the process of deriving a priority vector of criteria  $w = (w_1, w_2, ..., w_n)^T$ , where  $w \ge 0$  and  $\sum_{i=1}^n w_i = 1$ , from the judgment matrix *A*.

Let  $D = \{d_1, d_2, ..., d_m\}$  be the set of decision makers, and  $\lambda_k = \{\lambda_1, \lambda_2, ..., \lambda_m\}$  be the priority vector of decision makers. The priority vector of decision makers  $(\lambda_k)$  is the normalized  $I_k$  for the group of experts which is calculated as follows:

$$I_k = \frac{1}{CCI_k} \tag{13}$$

where  $I_k$  is the inverse of the CCI normalization,

$$\lambda_k = \frac{I_k}{\sum_{k=1}^m I_k} \tag{14}$$

where  $\lambda_k > 0$ , k = 1, 2, ..., m, and  $\sum_{k=1}^{m} \lambda_k = 1$ .

Let  $A^{(k)} = (a_{ij}^{(k)})_{n \times n}$  be the judgment matrix provided by the decision maker  $d_k$ .  $w_i^{(k)}$  is the priority vector of criteria for each decision maker calculated by

$$w_i^{(k)} = \frac{\left(\prod_{j=1}^n a_{ij}\right)^{n_n}}{\sum_{i=1}^n \left(\prod_{j=1}^n a_{ij}\right)^{1/n_i}}$$
(15)

The aggregation of individual priorities is defined by

$$w_i^{(w)} = \frac{\prod_{k=1}^m (w_i^{(k)})^{\lambda_k}}{\sum_{i=1}^n \prod_{k=1}^m (w_i^{(k)})^{\lambda_k}}$$
(16)

where  $w_i^{(w)}$  is the aggregated weight vector. After the aggregation process, the extent synthesis methodology of Chang (1996) is applied for subsequent choice selection.

#### 4. The Empirical Study on Freight Forwarder in East Asia

Several leading freight forwarders are explored for service quality assessment and selected technical measures are used to evaluate customer satisfaction in East Asian region. The consultation experts include professors, president, senior executives and practitioners and the name of company is kept confidential. The data is collected by email, telephone and personal visits from September 2012 to March 2013. The consultation is performed according to the following steps. In the first step, an initial survey is arranged to define the appropriate customer requirements and technical measures for evaluation. Then, the primary survey is performed to complete cross relationship matrix in the second step.

The FAHP is applied to define relative weight for the priorities of customer requirement. An expert group from manufacture is asked to complete a pair wise comparison survey. Table 4 shows the aggregate fuzzy judgement matrix for the customer requirement. CCI is 0.01 which is less than the critical value of 0.37. The top three customer requirements are cheaper agency fee (0.19), door to door ability (0.16) and instant response (0.15) in Table 4. First of all, "cheaper agency fee" is the top customer requirement. Forwarders should provide competitive prices by reducing operational cost or financial planning like Porter's (1998) cost leadership approach. Second, "door to door ability" shows us the current customer's high expectation of forwarder's logistics solution in terms of time, cost and reliability. This means forwarders should work closely with partners such as truck, rail or other inland transportation firms to ensure logistics capability. Third, "instant response" shows the importance of information providing. Forwarders should have sophisticated tracking system and quick response to customer's question.

The top four relative weight of technical measures are customer relationship management (0.16), overall information system (0.14), service point and network (0.14) shown in Table 5. The evaluation and practical meaning will be explained in next section.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weight
C1	(1,1,1)	(0.36,0.6,1)	(1,1.71,2.95)	(0.68,1,2.61)	(0.6,1,1.34)	(1.68,285,3.83)	(1.34,1.57,3.80)	(1.53,2.2,2.66)	(1.75,2.98,4)	(2.05,3.27,5.63)	(3.01,4.11,6.55)	(1.31,2.59,3.74)	0.15
C2	(1,1.67,2.78)	(1,1,1)	(1.28,3.29,5.33)	(1.31,1.9,3.18)	(1,1,2.93)	(1.88,4.02,5.99)	(2.23,4.36,6.40)	(1.53, 3.67, 5.64)	(2.29,4.31,6.23)	(3,5.27,7.36)	(3.9,5.94,7.96)	(1.48,3.60,5.70)	0.19
C3	(0.34,0.58,1)	(0.19,0.3,0.78)	(1,1,1)	(0.35,0.57,1.31)	(0.26,0.58,1)	(0.73,1.31,1.9)	(0.78,1,1.75)	(0.68,1.05,2.01)	(0.68,1.79,3.37)	(1.31,2.02,2.54)	(1.52,2.44,2.86)	(0.68,1.16,2.10)	0.09
C4	(0.38,1,1.48)	(0.31, 0.53, 0.76)	(0.76,1.75,2.89)	(1,1,1)	(0.47, 0.6, 1.31)	(0.98,1.67,3.72)	(1.3,2.26,2.68)	(1.2,2.19,2.64)	(1.33,2.26,3.52)	(1.69,2.68,3.9)	(1.48,2.88,4.02)	(1.16,1.64,2.36)	0.12
C5	(0.75,1,1.67)	(0.34,1,1)	(1,1.71,3.85)	(0.77,1.68,2.13)	(1,1,1)	(1.88,2.3,4.62)	(1.71,2.93,5.19)	(1.53,2.2,4.45 )	(1.75,2.98,5.12)	(2.62, 3.67, 6.07)	(2.88, 5.15, 7.24)	(1.31,1.94,4.18)	0.16
C6	(0.26,0.35,0.6)	(0.17,0.25,0.53)	(0.53, 0.76, 1.37)	(0.27,0.60,1.02)	(022,0.43,0.53)	(1,1,1)	(0.47,0.82,2.07)	(0.71,1.2,1.67)	(0.7,1.37,2.26)	(0.94,1.79,2.8)	(0.8,1.3,2.38)	(1.16,1.64,1.64)	0.07
C7	(0.26,0.64,0.75)	(0.16,0.23,0.45)	(0.57,1,1.28)	(0.37,0.44,0.77)	(0.19,0.34,0.58)	(0.48,1.23,2.13)	(1,1,1)	(0.58,1,1.75)	(0.76,1.31,1.94)	(1,1.34,2.62)	(1.71,2.25,2.69)	(0.51,0.98,1.94)	0.07
C8	(0.38,0.46,0.65)	(0.18,0.27,0.65)	(0.5,0.96,1.47)	(0.38,0.46,0.84)	(0.22,0.46,0.46)	(0.6, 0.84, 1.41)	(0.57,1,1.71)	(1,1,1)	(0.75,1.31,1.94)	(1.02,1.96,2.4)	(0.99, 1.63, 3.38)	(0.85,1.11,1.64)	0.07
C9	(0.25,0.34,0.57)	(0.16,0.23,0.44)	(0.3,0.56,1.47)	(0.28,0.44,0.75)	(0.2,0.34,0.57)	(0.44,0.73,1.44)	(0.51,0.76,1.31)	(0.52,0.77,1.34)	(1,1,1)	(0.67,1,2.59)	(0.76,1.34,1.96)	(0.5,0.75,1.31)	0.05
C10	(0.18,0.31,0.49)	(0.14,0.19,0.33)	(0.39,0.49,0.77)	(0.26,0.37,0.59)	(0.16,0.27,0.38)	(0.36,0.56,1.06)	(0.38,0.75,1)	(0.42, 0.51, 0.98)	(0.39,1,1.49)	(1,1,1)	(0.67,1.11,2.11)	(0.44,0.57,1.31)	0.02
C11	(0.15,0.24,0.33)	(0.13,0.17,0.26)	(0.35,0.41,0.66)	(0.25, 0.35, 0.68)	(0.14,0.19,0.35)	(0.42,0.77,1.24)	(0.37,0.44,0.58)	(0.3,0.61,1.01)	(0.51,0.75,1.31)	(0.47,0.9,1.49)(	1,1,1)	(0.29,0.74,1)	0.01
C12	(0.27,0.39,0.77)	(0.18, 0.28, 0.68)	(0.48,0.87,1.47)	(0.42,0.61,0.87)	(0.24,0.52,0.77)	(0.61,0.87,1.44)	(0.52,1.02,1.96)	(0.61,0.9,1.17)	(0.77,1.34,2.01)	(0.76,1.75,2.27)	(1,1.34,3.44)	(1,1,1)	0.01
COT													
u:	= 0.01												

 Table 4: The aggregated fuzzy judgment matrix for customer requirements

### 5. Discussion and Conclusion

The top four relative weight of technical measures are customer relationship management (0.16), overall information system (0.14), service point and network (0.14) shown in Table 5. The result and proposed practical application could be useful information and supportive function for decision making process. First, the most important technical measure is "customer relationship management". In 2013, Copenhagen-based forwarder service provider Damco offers their customer, Mexican retailer HEB, a simple solution to renovate its supply chain by integrating its liner operator and restricting distribution systems. Introducing new supply chain strategies for its carrier and shippers help Damco increase its revenue by 11% and gross profit up 4% in 2012, managing more than 2.5M TEU of freight. HEB says the supply chain management is not advance in Mexico as it is in US but we are moving to that direction. The opportunity here for development of supply chain is to take advantage of large scale to reduce cost and extend network to expand service coverage. As we can see that Damco works close with HEB and understand the operation of customer, so the strong connection makes it easy for Damco to offer a appropriate logistics and supply chain strategy for HEB.

Second, "overall information system" may be a important tool for reducing cost, instant response and efficiency improvement. In 2012, the global freight forwarder like DHL still increases its revenue up to 2.8% in spite of the economic depression, nature disasters, and great loss of major ocean carriers. All the division meets the targets and the implemented strategy for future development is all under good progress. The secret of their strength is providing owners/shippers with innovative, strategic cargo handling sector and efficient IT solution. Bjorn et al.(2012) also empirically explore how the information systems improve maritime logistics from tracking stock level, vessel space allocation, transport and inventory cost reduction. The utilization can support the decision making from operational, tactical, and strategic levels within maritime logistics. Therefore, implementing advance information system could effectively support the customer and enhance the efficiency. Also, Hutchison Port Holding's introduction of next generation terminal management system (nGen) with increasing supports the improvement of efficiency and streamlines the global transportation through new technology innovations. The nGen increases total throughput by 28.5% three years after its implementation.

Third, regarding "service point and network", according to the press of UASC (United Arab Shipping Co) strengthen its brand reputation with new vessels, partnership agreements to expand the service network. Shipping would be much cheaper than rail when oil price rising and increasing vessel size may help achieve

scale economics and significant cost savings. Thus, forwarders may expand its service coverage and network through more partnerships with major carriers or local logistics service providers. Many global freight forwarders play the role as a local company, so the local knowledge and expertise becomes a barrier for market entry. When service and network of forwarder business expands globally, the important of reliable local partner is indispensible factor for business success.

	HoQ of Customer Satisfaction							Maximize ( $\blacktriangle$ ), Minimize ( $\triangledown$ ) and Target (x)							
			Direction of improvement												
Row No.	Max. value in row	Relative weight		Overall information system	Paperless and simple procedure	Quality manual and certificate	Customer clearance manual	Service point and network	Customer relationship management	IT implementation	Human resource management	Strong intermodal ability	Marketing strategy	Free consulting service	Green shipping policy
1	9	0.15	Instant response	*	•			▲		-	•			•	•
2	5	0.19	Cheaper agency fee	•	•	•		•	<b>A</b>						
3	9	0.09	Global service ability		•		<b></b>								
4	5	0.12	Tailor-made service		•		٠	•	▲	•	•	•		•	
5	9	0.16	Door to door ability						•	•	•		•		•
6	9	0.07	Schedule reliability			•	•	•	•	•	•		•	•	
7	5	0.07	Consult service	•		•		•	•	•	•	•	•		
8	9	0.06	Excellent reputation		•		•			•	•	•	•	•	
9	5	0.05	Stable space supply	•		•		•	•	•		•	•	•	
10	9	0.02	Fast document handling			•			•		•		•	•	
11	9	0.01	Instant cargo tracking			•	•		•						
12	9	0.01	Regular visit		•	•								•	
			Max. value in column	9	9	5	9	9	9	9	5	9	5	9	5
			Sum product	5.27	0.8	2.72	3	5.09	5.72	3.52	1.67	4.1	2.83	1.56	0.61
			Relative weight	0.14	0.02	0.07	0.08	0.14	0.16	0.1	0.05	0.11	0.08	0.04	0.02
			Rank	2	11	8	6	3	1	5	9	4	7	10	12

 Table 5: House of quality matrix for customer's requirements

The combination of FAHP and QFD is an appropriate methodology for decision making which provide the decision maker the direction of improvement and importance or relative weight of selected items by quantifying the selected customer requirement and technical measures. The rank of customer requirement and technical measure could provide meaningful information regarding to understand "what" customer wants and "how" to improve them. However, this methodology could not explain "how much" to improve the technical measures since HoQ matrix only contains "what" and "how " without explaining "how much". This approach successfully provides decision makers right direction of improvement and related business practices but could not answer how much to improve for each technical measure. Future studies may further discuss this gap by applying input and output analysis techniques. On the other hand, the process and strategy for enhancement of customer satisfaction may change drastically because of the advance technology and emerging of potential competitors in the forwarder business. The continuous and periodic research for customer service is still necessary for forwarders to adjust strategies in the fast changing and dynamic shipping market.

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# A Slot Reallocation Model for Containership Schedule Adjustment

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### Abstract

Containership slots are the main sale resources for shipping lines. This study addresses the slot reallocation planning for the schedule adjustment of a containership. Shipping lines always confront some situations that have to change ship schedules, such as ship delay, port close, dock inspection, phase-in of new ships, fleet shifts, etc. These cases will result in some containers that have been on board and prepared to be loaded onto the ship altering original delivery plan. This study proposes an integer programming model for slot reallocation when the alternated schedule has been sure. The model aims to maximize the company's profits in considering which consignments have to be altered delivery and the possible approaches, as well as the benefit from empty container repositioning. The available slots are possibly subject to the change of port rotation, cutoff of loading operation, and ship capacities in volumes, deadweights and the number of plugs for reefer containers. The decision of empty container repositioning plan is also involved to cope with the reallocation results. The test results present optimal slot reallocation and empty container repositioning plans of an ocean going loop.

Keywords: Slot reallocation, Integer programming model, Empty container repositioning, Ocean going loop

### 1. Introduction

Slot allocation is one of the vital issues in revenue management. In the international freight transportation, carriers are relatively difficult to benefit from the customer selection by competitive prices than the passenger business because shippers and forwarders are long-term cooperation partners. Their unsatisfied experience on the price bid scheme may result in consignment losses of carriers. Container shipping lines also confront the same situation. In particular, this industry always emerges a phenomenon of slot supply excess. Their service routes are normally planned to visit many ports for serving more trade markets. The tactics of slot management for increasing carrier's profits and sufficiently using slot resources become much critical.

Container shipping lines always preplan the seasonal slot allocation of service markets for each loop. This plan will be the targets as well as resources that local sale agents allot their home export shipments (Ang et al., 2006; Lu et al., 2010a). However, shipping lines must confront some situations that must change ship schedules, such as ship delay, port close, dock inspection, phase-in of new ships, fleet shifts, etc. These cases will result in some containers that have been on board and prepared to be loaded onto the ship altering original delivery plan. The company must rapidly reallocate the use of ship capacities for reducing the impact of slot resource reduction as possible. In practice, shipping lines will publish the transferring guideline for on-board containers and the information for stopping the consignment receiving of affected service markets, when the adjustment of ship schedule has been sure.

The decision of slot reallocation concerns with the ship loading constraints as well as the countermeasures of affected containers. On-board containers with a variety of sizes occupy the limited ship capacities. The total weights of containers must be less than the allowed deadweights that might be reduced by some sailing conditions, such as the draft limitation caused from the berth, channel or even the tide. The number of laden reefer containers is also restricted by the available quantities of electrical plugs. For sufficiently using slot resources, shipping lines must take into account the occupation of any consignment between its loading and unloading ports. Containers with longer delivered passages will occupy the capacities on more sailing legs and

reduce the availability for other containers that are possibly loaded before they are discharged. Sometimes, the plan of schedule adjustment may include the reduction of available operational durations at ports. Besides the treatment for laden containers, the repositioning plan of empty containers can be adjusted simultaneously with the slot reallocation for handling the possible repositioning chance.

Shipping lines may have different alternatives for the affected on-board containers caused by the schedule adjustment. Each choice will generate extra expenses for container transfers, such as extra stevedoring operation and the usage of common feeder services. Of cause, shipping lines can consider to choose available deliveries by own service network, but delays are unavoidable. Affected containers that have been promised to deliver but not yet to be loaded can wait for the next voyage or follow transferring processes. Shipping lines require an ideal countermeasure for reducing the impact to its benefit.

The purpose of this study aims to formulate a mathematical programming model for shipping lines to optimally plan the slot reallocation subject to a known schedule adjustment alternative.

# 2. Literature Review

Although revenue management methods are still rarely used in the liner shipping industry, previous studies discussed from different perspectives. These perspectives are classified into seasonal planning, alliance planning and booking decision in this paper.

# 2.1 Seasonal slot allocation planning

The planning of seasonal slot allocation belonging to a tactical level aims to allocate slot quotas for different markets. It can facilitate local agents to know their performance targets in acquiring consignments and to assign available slot resources for various shipments departed from the local ports. Normally, academic research assumes the demands of different container types in various markets (or port pairs) have been known. Decision models maximize the possible profits subject to the constraints on ship slot capacity, available deadweights, and others for specific container types.

Ting and Tzeng (2004) stated the slot allocation problem of the liner service and proposed an integer programming model to obtain ideal allocated results for single directional traffic flows. This model can be conducted on the case with the same characteristics of a traffic pattern.

Feng and Chang (2008) formulated a slot allocation model for the containership operation. However, this model ignores the plug constraint of reefer containers for satisfying an Asian short sea loop. The calculation of load weights also seems not exact as the practical concept in this application. Feng and Chang (2010) extended their previous research to include the consideration of empty containers. The possible influence of empty container repositioning to the slot allocation of laden containers is reported in the case application.

Lu et al. (2010a) addressed the slot allocation planning problem of the container shipping company for satisfying the estimated seasonal demands on a liner service. An integer programming model is proposed to maximize the potential profits per round trip voyage for a liner company. Analysis results for a short sea service reveal that containers with the higher contributions like reefers and 40 feet dry containers have priorities to be allocated more than others. Using model solution not only provides a higher space utilization rate and more detailed allocation results, but also helps the ship size assessment in long-term planning.

Ang et al. (2007) presented a yield maximization problem in considering cargos with various consigned periods from one origin port to multiple destination ports. Their formulation is a multi-dimensional multiple knapsack model limited by the available empty containers, volume capacities and weight capacities. Heuristics are developed to solve large-scale cases. From the practical perspective, this model can apply to the outbound slots distribution for a specific port, while the available slots for distribution at this port are given.

# 2.2 Alliance slot allocation planning

Alliances between shipping lines, regardless fleet sharing, slot chartering, and slot exchanges will affect the slot allocation decision. However, previous research contributes to this field is relatively limited. Lu et al. (2010b) explored the slot allocation planning for an alliance service with ship fleet sharing. The decision contexts contain the optimal number of contributed ships, allocated slots for different container types of service markets, and the possible repositioning flow for different empty containers. Because the available slots for each cooperated partner depend on the contributed number of ships, the estimated profits must take into account the input costs of ships. This is what the difference between the planning for ship fleet sharing and owned operation routes on the topics of slot allocation. The research results reveal that shipping lines must reduce the contribute number of ships when the estimated delivered quantities cannot reach a demand threshold.

Lu et al. (2010) illustrated a case of slot exchange and purchase planning for short sea services between two companies, based on the fair exchange principle. Because the voyage durations of every involved routes are different, to directly calculate exchange slot in TEU violates the fair rule. These two companies accepted to exchange equal sum of TEU-days, i.e., exchange slots in TEU on a loop multiplying its round voyage days, each other. This study formulates an integer programming model for one of companies to optimize exchanging TUE-days and slot allocation on all involved routes subject to given conditions.

# 2.3 Booking decision for slot allocation

The issues of revenue management stem from train and airline operations for passenger seat allocation. Their main decision in these industries focuses on the determination to accept or deny passengers at seat bookings for maximizing the final revenue or yield. Several studies applied the same concept to deal with shippers' consignments. Lee et al. (2007) introduced a heuristic for the shipping company to decide if accept consignments, ad hoc or contractual cargo, to load onto a specific voyage or to postpone in a single leg service. The formulated model is to determine the stationary threshold policy. Lee et al. (2009) further formulated a stochastic dynamic programming model only allowing contract cargo to postpone. Their tests reveal that this policy can benefit the shipping company for more revenue. These models did not take into account the heterogeneous benefits and constraints for different types of containers.

Li (2008) proposed a stochastic model for the dynamic allocation of ship capacities limited on the available volumes and weights. This model aims to either accept or reject a booking request. The concept of model formulation stems from the air transportation, but its application to the shipping lines appears a slight difference with the practical operation. In particular, 20' and 40' dry containers are the main delivered objective of shipping lines, but the allocation policy is to reject them because of their low marginal revenues. Further, the reefer prices set by the weight are not the practice of the liner industry.

Zurheide and Fische (2011) proposed a discrete-event simulation model to decide accepting or rejecting a booking request for determining the best strategy of a shipping company. They conclude the booking limit strategy is better than a first-come-first-serve strategy in comparison with the optimal solutions of bookings known. However, the base in decision depends on the delivered areas and container types of bookings rather than the major properties of bookings, such as revenues and quantities. Zurheide and Fische (2012) extended the model to the bookings of the whole service network. This model also takes into account the possibility of container transferring. The booking requests are also divided into emergence deliveries or not and distinguished their service priorities.

# 3. Mathematical Model

# 3.1 Formulation concept

When the adjusted alterative for ship schedule has been sure, there must be a part of voyage which slot allocation will be affected. This study assumes the scope of affected ship journey has been known. Then, the voyage between previous and next visiting ports of this part is sliced as the decision planning horizon. As shown in Figure 1, nodes 1 to n express the affected sector which slot allocation requires to be changed.  $s_o$  is the previous visiting port of this sector, while  $s_t$  the next visiting port of this sector. The former represents all

preceding journey and the beginning node for on-board containers. The latter expresses the consecutive journey and the ending node for containers keeping consecutive journey. Four categories of markets can be divided as follows.

- (1) Category 1 represents those containers have been on board and will been unloaded at ports outside the affected sector, i.e., containers flowing from  $s_o$  to  $s_t$ .
- (2) Category 2 represents those containers have been on board and will been unloaded at ports among the affected sector, such as containers flowing from  $s_o$  to one of ports among 1 to n.
- (3) Category 3 represents those containers will be loaded at ports among the affected sector and also been unloading at preceding ports among the affected sector, such as containers flowing from one of ports among 1 to n 1 to one of ports among 2 to n.
- (4) Category 4 represents those containers will be loaded at ports among the affected sector and unloaded at preceding ports outside the affected sector, such as containers flowing from the port among 1 to n to  $s_t$ .





The practical tactics in treating schedule adjustment include bypassing some visiting ports and cutting off the port operational duration. The slot reallocation at these situations must decide which consignments should be changed the delivery plan, rather than only choosing container types as the planning in the seasonal horizon. Each shipper may consign multiple containers with different types and same loading and unloading ports, as well as taking the same action in the reallocation plan.

The selection of possible countermeasures for consignments can affect the results of slot allocation besides in considering the basic and necessary limitation of ship conditions in capacities, load weights, and plugs for reefers, It is assumed that possible alternatives, including waiting for the next voyage and transferring services, and incurring costs and slot occupation of these alternatives are known. However, the decision results must make sure that each shipper's consignment can only choose one alternative among the original delivery method and other available alternatives.

### 3.2 Model

The main part of formulated model is to ensure the limits of allowance capacity for every involved sailing leg in the adjusted schedule. Each sailing leg indexed by *s* has its departure port s(d) and arrival port s(a). The notation of variables and parameters is defined as follows.

#### Sets

- **K** = set of consignment indexes.
- **E** = set of category indexes for empty containers.

- **X** = set of consignment indexes that have been sure impossible to be delivered by the original way.
- **XW** = set of port pairs for empty containers that have been sure impossible to be delivered.
- $\mathbf{T}^k$  = set of possible alternatives for consignment *k*.
- $\mathbf{A}_b$  = set of ports requires to positioning empty containers of category *b* in.
- $\mathbf{L}_b$  = set of ports that can position empty containers of category *b* out.
- $\mathbf{H}_{s(d)}^{k}$  = set of possible alternatives that load or unload consignment k at the departure port of leg s.
- $LU_{s(d)}$  = set of consignment indexes that load or unload consignment k at the departure port of leg s in the original plan.

## Decision variables

- $x^{k} = 0-1$  variable to express if consignment k follows the original way or not; 1 for yes, 0 otherwise.
- $\mathcal{Y}_{od}^{b}$  = quantities of type *b* containers repositioned from port *o* to port *d*.
- $z_j^k = 0.1$  variable to express if consignment k is performed  $j^{\text{th}}$  alternative or not; 1 for yes, 0 otherwise.

## Parameters

- $p^{k}$  = revenues obtained from handling consignment k.
- $c^k$  = costs to handle consignment k by original delivery way.
- $e_{j}^{k} = \text{costs to handle consignment } k \text{ by } j^{\text{th}} \text{ alternative.}$
- $v_{ad}^{b}$  = estimated benefit to reposition one empty type b container from port o to port d.
- $\alpha_s^k$  = incident parameter to represent if consignment k occupies the capacities of leg s in the original delivery way, 1 for yes, 0 otherwise.
- $\delta_{sj}^{k}$  = incident parameter to represent if consignment k occupies the capacities of leg s in j<sup>th</sup> alternative, 1 for yes, 0 otherwise.
- $t^k$  = total volumes in TEU of consignment k.
- $w^k$  = total weights in ton of consignment k.
- $r^k$  = numbers of reefer containers in consignment k.
- $q^k$  = numbers of containers in consignment k.
- $teu^b$  = capacities occupied in TEU per empty container of category b.
- $ept^{b}$  = empty weights in ton per container of category b.
- $n_o^b$  = maximal number of empty containers of category b that can be repositioned out from port o.
- $m_d^b$  = maximal number of empty containers of category b that requires to be repositioned into port d.
- U =ship capacities in TEU.
- R = number of plugs on board for laden reefer containers.
- $D_s$  = maximum available deadweights in ton on leg s.

 $Q_s$  = maximum available operation moves at the departure port of leg s.

$$Max. \quad \sum_{k \in \mathbf{K}} (p^{k} - c^{k}) x^{k} + \sum_{k \in \mathbf{K}} \sum_{j \in \mathbf{T}^{k}} (p^{k} - e_{j}^{k}) z_{j}^{k} + \sum_{b \in \mathbf{E}} \sum_{(o,d)} v_{od}^{b} y_{od}^{b}$$
(1)

$$\sum_{k \in \mathbf{K}} \alpha_s^k t^k x^k + \sum_{k \in \mathbf{K}} \sum_{j \in \mathbf{T}^k} \delta_{sj}^k t^k z_j^k + \sum_{b \in \mathbf{E}} \sum_{(o,d)} \beta_{od,s} teu^b y_{od}^b \le U \qquad \forall s$$

$$\tag{2}$$

$$\sum_{k \in \mathbf{K}} \alpha_s^k w^k x^k + \sum_{k \in \mathbf{K}} \sum_{j \in \mathbf{T}^k} \delta_{sj}^k w^k z_j^k + \sum_{b \in \mathbf{E}} \sum_{(o,d)} \beta_{od,s} ept^b y_{od}^b \le D_s \qquad \forall s$$
(3)

$$\sum_{k \in \mathbf{K}} \alpha_s^k r^k x^k + \sum_{k \in \mathbf{K}} \sum_{j \in \mathbf{T}^k} \delta_{sj}^k r^k z_j^k \le R \qquad \forall s$$
(4)

$$\sum_{k \in \mathbf{LU}_{s(d)}} q^k x^k + \sum_{k \in \mathbf{K}} \sum_{j \in \mathbf{H}_{s(d)}^k} q^k z_j^k + \sum_{b \in \mathbf{E}} \sum_{\substack{o = s(d) \\ d = s(d)}} y_{od}^b \le Q_s \qquad \forall s$$

$$(5)$$

$$x^{k} + \sum_{j} z_{j}^{k} = 1 \qquad \forall k \in \mathbf{K}$$
(6)

$$\sum_{d \in \mathbf{L}_{a}} y_{od}^{b} \le n_{o}^{b} \qquad \forall b \in \mathbf{E}, o \in \mathbf{A}_{b}$$

$$\tag{7}$$

$$\sum_{o \in \mathbf{A}_{b}} y_{od}^{b} \le m_{d}^{b} \qquad \forall b \in \mathbf{E}, d \in \mathbf{L}_{b}$$
(8)

$$\sum_{k \in \mathbf{X}} x^k + \sum_b \sum_{(o,d) \in \mathbf{XW}} y^b_{od} = 0$$
(9)

$$x^k \in \{0, 1\} \qquad \forall k \in \mathbf{K} \tag{10}$$

$$z_j^k \in \{0, 1\} \qquad \forall k \in \mathbf{K}, j \in \mathbf{T}_k$$
(11)

$$y_{od}^{b} \ge 0 \text{ and integer}, \quad \forall b \in \mathbf{E}, (o, d)$$
 (12)

The objective function of Equation (1) maximizes the sum of the possible profits and the benefits caused from empty container repositioning. The estimated benefit of repositioning empty containers will be discussed in the next section in detail. In the constraints, Equation (2) enforces the sum of containers on board on each leg cannot be over the maximum capacity in volumes. Equation (3) restricts the loaded weights on each leg cannot be larger than the maximum available deadweights. Laden reefer containers need electronic power to keep suitable temperature on the way, but the number of power plugs installed on board is limited. This constraint is expressed in Equation (4). Equation (5) can make sure that the loading and unloading operation can finished within the allowable duration for each visit. Equation (6) restricts each consignment to follow the original deliver way or to select one alternative. Equations (7) and (8) ensure that possible carriage of empty containers cannot exceed the maximum number of empty containers that can be repositioned out from port o and repositioned into port d, respectively. Equation (9) prohibits the delivery due to special cases, such as cancelling some port visits. Equations (10) to (12) are the nonnegative and integer constraint of variables.

### 4. Cases Analysis

#### 4.1 Background of test loop

We use an Asia/Europe loop of Yang Ming Marine Transport Corp., i.e., NE1, to create the test case. Its port rotation starts from Ningbo (CNNGB), then visiting Shanghai (CNSHA), Nansha (CNNSA), Hong Kong (HKHKG), Suez (EGSUZ), Hamburg (DEHAM), Rotterdam (NLRTM), Felixstowe (GBFLX), Antwerp (BEANR), Suez, Singapore (SGSIN), Nansha and turns back to Ningbo. The long-term schedule of this loop with 70 days of cycle time is shown in Table 1. Yang Ming contributes 1 full-container ships, with 8,626 TEU, 103,235 tons of maximal deadweights and 700 plugs for reefer containers, to operate with other 9 same type ships contributed by the alliance partners.

> West bound											
East bound>   >East bound											
CNNGB		CNS	HA	CNI	NSA	HKHKG		EGSUZ		DEHAM	
ETB	ETD	ETB	ETD	ETB	ETD	ETB	ETD	ETB	ETB	ETD	ETB
THU	FRI	SAT	SUN	TUE	WED	WED	THU	FRI	WED	THU	THU
18:00	12:00	04:00	16:00	21:00	10:00	19:00	11:00	01:00	19:00	17:00	02:00
`	West bound>										
			East	bound -							
NLR'	ГМ	GBI	TXT	BEA	NR	EGS	SUZ	SG	SIN	CNI	NSA
ETB	ETD	ETB	ETD	ETB	ETD	ETB	ETD	ETB	ETD	ETB	ETD
WED	FRI	FRI	SUN	MON	TUE	WED	THU	THU	FRI	TUE	TUE
03:00	02:00	21:00	01:00	06:00	06:00	19:00	17:00	02:00	00:00	03:00	15:00

Table 1: Ship rotation and schedule of the test loop NE1

Source: Website of Yang Ming Marine Transport Corp. (http://www.yml.com.tw/)

This loop can load west bound consignments from Ningbo to Antwerp and provide services from Hamburg to Shanghai for the east bound. Except Suez and cabotage prohibits between China's ports, it can generate 16 port pairs each for west-bound and east-bound carriage demands. However, the trade patterns normally make the quantities of west-bound cargo be larger than that of east-bound cargo. The company uses remain capacities to positioning empty containers from European ports to Asian ports. Once any occasional situation has to adjust the schedule, to change the eastern direction voyage can reduce the influence to laden containers.

## 4.2 Basic example and extraordinary situation

For ease to explain the solution results, we design a test case which shipments are all east-bound. This case contains only 20 shippers who consign a variety of containers which types only include 20 and 40 feet dry and reefer. Table 2 displays the consignment data of the basic example. The repositioning plan for empty containers is shown in Table 3. The weights for 20' dry/40' dry/20' reefer/40' reefer empty containers are 2/4/3/5 tons, respectively. According to the schedule in Table 1, we can calculate the port time for each visit. Except Suez, the operation performance of all ports is set as 30 moves per crane hour, while each port deploys 3 cranes. The total available operation moves in ports, thus, can be estimated. This original loading plan can satisfy all load constraints and port operation and obtain the revenue of \$3,596,000. Regardless of laden or empty containers, the handling costs of a container are assumed as \$50 in Chinese ports and \$80 in Singapore and European ports, respectively.

We assume that the shipping company confronts a special situation and makes a countermeasure of adjusted schedule. The visit of NAS will be bypassed and the loading operation in ANR should be cut off 12 hours from original 24 hours. This plan reduces the upper bound (2,160 moves) of crane operation in ANR to 1,080 moves. The planning horizon is cut from RTM to NGB. For executing our model, some parameters are set as following concept and data.

# 4.2.1 Benefit of empty containers

Because the general trade directions make the excess of empty containers in European ports, shipping lines always use the rest capacities on board to reposition empty containers from European ports to Asian ports. It has been a principle in the carrier's operation strategy. Therefore, in considering the benefit of altering the original plan for repositioning empty containers, we take into account the extra leasing costs and the extra storage costs in the loading port for waiting the next voyage. The benefit of repositioning an empty container k is set as Equation (13).

$$v_{od}^{k} = c * l_{d}^{k} + \tau * s_{o}^{d}$$
(13)

where c is the cycle time of a round voyage,  $l_d^k$  is the leasing cost per day starting at port d,  $\tau$  is the duration

of two voyages, and  $s_o^k$  is the storage cost per day at port *o*. This concept results from that the aim of repositioning an empty container is to replace a leasing in the port of lacking containers. The costs of leasing an empty container for loading cargo contain the mentioned costs plus the handling costs at loading and unloading ports. However, to reposition empty containers still spends the handling costs. The net benefit of repositioning an empty container can thus be easily represented by Equation (13).

Chinnon	Load	Unload	Revenue		Numbers of		Total gross	Total	
Shipper	port	port	(\$)	20' dry	40' dry	20' reefer	40' reefer	weight (tons)	TEUs
1	HAM	SHA	240,000	200	200	0	0	8,000	600
2	HAM	SHA	120,000	100	100	0	0	4,000	300
3	RTM	SHA	280,000	300	200	0	0	9,700	700
4	RTM	NGB	200,000	100	200	0	0	6,300	500
5	FXT	NSA	120,000	100	100	0	0	4,000	300
6	ANR	NSA	240,000	0	300	0	0	6,900	600
7	ANR	NGB	240,000	200	200	0	0	8,000	600
8	ANR	NGB	200,000	100	200	0	0	6,300	500
9	ANR	SHA	200,000	100	200	0	0	6,300	500
10	ANR	SHA	140,000	150	100	0	0	4,850	350
11	SIN	SHA	240,000	0	300	0	0	6,900	600
12	SIN	SHA	200,000	0	250	0	0	5,750	500
13	SIN	NGB	280,000	100	300	0	0	8,600	700
14	SIN	SHA	280,000	0	350	0	0	8,050	700
15	SIN	SHA	40,000	100	0	0	0	1,700	100
16	ANR	SHA	108,000	0	0	50	20	1,310	90
17	ANR	SHA	120,000	0	0	0	50	1,150	100
18	ANR	NGB	108,000	0	0	50	20	1,310	90
19	FXT	NGB	120,000	0	0	0	50	1,150	100
20	FXT	NSA	120,000	0	0	50	25	1,425	100

Table 2: Consignment data of the basic example

 Table 3: Repositioning plan of empty containers

(20' dry, 40' dry, 20' reefer, 40' reefer)	То	Upper bound for repositioning in)		
From (Upper bound for repositioning out)	NGB (100, 100, 50, 50)	SHA (500, 500, 100, 100)	NSA (200, 200, 50, 50)	
HAM (500, 500, 100, 100)	(0, 0, 50, 50)	(0, 0, 50, 50)	Х	
RTM (200, 200, 50, 50)	Х	(0, 0, 50, 50)	Х	
FXT (200, 200, 50, 50)	Х	Х	(0, 0, 50, 33)	
ANR (200, 200, 50, 50)	Х	Х	Х	

In the test cases, the cycle time of a ship round voyage is 70 days, and the duration between two voyages is 7 days for a weekly service loop. We assume the leasing costs of a 20'/40' dry container are \$0.7 and \$1.1 per day and of a 20'/40' reefer container are double. The storage costs are \$1 and \$2 per day for a 20'/40' container, respectively.

# 4.2.2 Transferring alternatives

Besides waiting at the original loading port for the next voyage, all shipments loading before SIN can be transferred at SIN by common feeder services. The penalty of waiting for the next voyage is tested by two fifths (scenario 1) and four fifths (scenario 2) of revenues for each shipment. The costs transferring a 20'/40' dry container from Singapore to China are set as \$260/\$360, respectively, which have contained the port handling costs. Reefer containers are not available for transferring.

### 4.3 Solution Results for Schedule Adjustment

When the penalty of waiting for the next voyage is set as two fifths of revenues for each shipment, the optimal solution makes shipments of shippers 5, 6, 7, and 20 stay at the original port for next loading chance. No other shipments are transferred at SIN. Cargo of other shippers can be delivered as usual. Although the destination of the cargo of shipper 7 is not NSA, the reason of staying at the original port is caused by the reduction of allowed operation moves at ANR. This decision is a least impact to the objective. The repositioning plan of

empty containers is changed as Table 4 for sufficiently using the rest capacities. We can find that containers, regardless of laden or empty, which destination is NSA are all altered the loading plan.

Tuble in the repositioning plan of empty containers for section of									
(20' dry, 40' dry, 20' reefer, 40' reefer)	To (Upper bound for repositioning in)								
From (Upper bound for repositioning out)	NGB (100, 100, 50, 50)	SHA (500, 500, 100, 100)	NSA (200, 200, 50, 50)						
HAM (500, 500, 100, 100)	(100, 0, 0, 0)	(0, 261, 100, 100)	Х						
RTM (200, 200, 50, 50)	(0, 100, 50, 50)	(0, 9, 0, 0)	Х						
FXT (200, 200, 50, 50)	Х	X	Х						
ANR (200, 200, 50, 50)	Х	Х	Х						

 Table 4: New repositioning plan of empty containers for scenario 1

Once the penalty of waiting for the next voyage is set as four fifths of revenues for each shipment, the cargo of shipper 5 should be transferred at SIN and shipments of shippers 6, 7, and 20 keep staying at the original port for next loading chance. Cargo of other shippers can be delivered as usual. The repositioning plan of empty containers is changed as Table 5. The numbers of repositioning empty containers for different types are not changed, but the allotment of 40' dry containers. More containers are loaded onto the ship at RTM.

### Table 5: New repositioning plan of empty containers for scenario 2

(20' dry, 40' dry, 20' reefer, 40' reefer)	To (Upper bound for repositioning in)					
From (Upper bound for repositioning out)	NGB (100, 100, 50, 50)	SHA (500, 500, 100, 100)	NSA (200, 200, 50, 50)			
HAM (500, 500, 100, 100)	(100, 0, 0, 0)	(0, 170, 100, 100)	Х			
RTM (200, 200, 50, 50)	(0, 100, 50, 50)	(0, 100, 0, 0)	Х			
FXT (200, 200, 50, 50)	Х	Х	Х			
ANR (200, 200, 50, 50)	Х	Х	Х			

The above integer programming problems were solved in 0.03 seconds on a Duo T5670 personal computer under the Microsoft XP operation system by calling the commercial software package CPLEX 10.1.1. The number of variables is 109, while the number of constraints is 76. The test summary is listed in Table 6.

	Tuble 0. Summary for cuse tests								
Case	Objective	Number of delivered	Number of undelivered	Number of transferred					
	Objective	containers	containers	containers					
Original plan	3,645,144	4,865	0	0					
Scenario 1	3,386,140	3,890	975	0					
Scenario 2	3,132,010	4,090	775	200					

### Table 6: Summary for case tests

### 4.4 Test for more shippers

A critical factor to affect the scale of test instances for the proposed model is the number of shippers. Based on the same background of test loop, we design some cases with different numbers of shippers as shown in Table 7. The objective values for reallocation slot resources reduce because of transferring and waiting at the original loading ports. Empty containers can keep a flexible buffer to sufficiently utilize the rest slots. The case with 800 shippers can be solved within 1 second with the same package CPLEX as shown in Table 8. These results show our model is promising to solve more real-world instances.

 Table 7: Background of test cases

Case	Number of	Number of	f Variables	Number of	Number of Consigned Containers					
	shippers	Binary	Integer	Constraints	20' Dry	40' Dry	20' Reefer	40' Reefer	Total TEUs	
1	20	40	30	44	1550	3000	150	330	8030	
2	50	150	80	76	581	2070	189	600	3440	
3	200	600	80	270	2297	3999	991	949	10190	
4	500	1500	80	570	1975	3317	876	910	11305	
5	800	2400	80	870	2132	3325	880	875	11412	

	Original Obj.	Adjusted Obj.	Obj. Difference	Alterna	Change in	CPU				
Case				Shippers for	Shippers for	20'	40'	20'	40'	Time
				Transferring	Waiting	Dry	Dry	Reefer	Reefer	(sec.)
1	3,593,400	3,113,790	-14.0%	5	0	+220	+460	-5	-100	0.00
2	1,454,400	1,451,100	-1.0%	12	0	0	0	+33	-20	0.05
3	15,592,706	14,798,361	-5.1%	30	18	-376	-129	-39	0	0.09
4	24,078,894	23,115,738	-3.9%	96	57	0	0	-20	0	0.28
5	24,030.562	23,152,039	-3.8%	126	78	0	0	-5	0	0.76

 Table 8: Solutions of test cases

### 5. Conclusions

Through effective slot management, container shipping lines can avoid wasting the ship slot capacities and increase the efficiency of container deliveries. This study addresses an extraordinary topic for slot reallocation at the ship schedule changed. The formulated mathematical model can decide the optimal delivered way for each consignment and new repositioning plan of empty containers. We have presented a detailed analysis result for the case of ocean going loop with few consignments. In the future research, this model can be applied to more instances with different consignment scales, service properties and special situations.

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# **Empirically Modeling on Characteristics of Logistics Flexibility**

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### Abstract

To succeed in the environment of increasingly uncertain customer needs, firms are requested to view flexibility from a supply-chain perspective. Acting as a linkage of every section in supply chains logistics also need to become flexible to meet the uncertainty. However, flexibility with complex components might be hard to work out. Although some researchers paid attention to the definition of logistics flexibility and components of it, it is still unclear. Moreover, most of the researchers explored it theoretically, and little evidence was from practical experts. This paper focuses on characteristics, which significantly contribute to logistics flexibility for logistics service providers, and data are from the experts who are working at logistics business via Delphi Technique. We identify forty-seven characteristics as significant ones, of which seven items are new findings, and one of them might be special due to the mechanism in China. Based on testing very important and extremely important characteristics, models on characteristics of logistics flexibility are proposed. Furthermore, we explore the relationships among the ten items to make more understanding of logistics flexibility.

Keywords: Logistics Flexibility, Supply Chains, Delphi Technique

### 1. Introduction

As customers' expectations are changing, manufacturers are trying to move from make-to-stock to make-toorder production systems to meet the uncertainty (Bish et al., 2005). Therefore, products with short life cycles are increasingly becoming significant sources of profits for manufacturing companies, as they may potentially generate greater profits than more commodity-like products (Milner and Kouvelis, 2005). Choosing or designing right supply chains becomes more and more influential in the uncertain environment. Because flexibility has both proactive and reactive uses to target new opportunities or respond to uncertainty generated by the supply chain (Sawhne, 2006), and increasing the supply chain flexibility can reduce or avoid uncertainty (Fisher, 1997), making or choosing a flexible supply chain becomes a key for the firm to meet uncertain customer demand.

However, it seems a great challenge for both managers and researchers to make supply chain flexible. Previous researchers have paid much attention to manufacturing flexibility to hedge against demand uncertainty (Holweg and Pil, 2004), and some researchers have explored dimensions of supply chain flexibility (Vickery et al., 1999; Sánchez and Pérez, 2005; Lummus et al., 2005), but there is a little research that addresses the issue of flexibility outside of the manufacturing plant (Sánchez and Pérez, 2005; Slack 2005).

Lummus et al.(2003) mention that flexibility of the entire supply chain is a result of the flexible components at each node of the supply chain and their interrelationships. Particularly, logistics which is about linking the whole production chain to the dealers and ultimately the customers tend to be overlooked (Holweg and Pil, 2004). Accordingly, improving logistics flexibility is meaningful for making the flexible supply chains. The question remains what kind of logistics is flexible to enable response to uncertainty quickly and effectively. Previous researchers have concerned about conceptual discussions about logistics flexibility (Perry, 1991; Davis, 1993; Day, 1994; Daugherty and Pittman, 1995; Andries and Gelders, 1995; Van Hoek, 2001), components of it (Day, 1994; Naim et al, 2006; Kress, 1999; Closs and Swink, 2005; Barad and Sapir, 2003),

and few researchers discuss the relationship between flexible logistics and customer satisfaction or firm performance(Zhang et al., 2005; Closs and Swink, 2005). Considering flexibility is a complex, multidimensional, and hard-to-capture concept (Sethi and Sethi, 1990), logistics flexibility with complexity might be difficult to understand and achieve. In fact, most of the previous studies are conducted theoretically. It still needs more empirical work to make it clearer.

In this paper, we aim to explore the characteristics of logistics flexibility with an empirical research as an effort to address this notable concern. In this way we may develop a framework of characteristics of logistics flexibility. In particular, we attempt to recognize the key characteristics in them. Furthermore, we explore the relationships among the extremely important items to achieve more understanding of logistics flexibility.

# 2. Logistics Flexibility

Logistics flexibility is a firm's ability to respond quickly and efficiently to needs for delivery, support, and services (Day, 1994; Davis, 1993; Perry, 1991). It enables superior customer service by synchronizing product delivery with customer demands (Van Hoek, 2001; Daugherty and Pittman, 1995).

In the literature, much effort is devoted to figure out components of it theoretically. Day (1994) indicates that logistics flexibility has four components: physical supply flexibility, purchasing flexibility, physical distribution flexibility and demand management flexibility. Naim et al (2006) identify key components of transport flexibility in the logistics provision, and evaluate the degree of flexibility of a third party logistics provider (Naim et al, 2010). Kress (1999) mentions that the military logistics flexibility has to cope with: the quantities of the needed resources, their mix, timing and location, and distinguishes between intrinsic flexibility and structural flexibility. Barad and Sapir (2003) utilize the rich manufacture oriented literature and decision-making flexibility in logistics systems, and they are basic flexibility, system flexibility and aggregate flexibility. The basic flexibility types are product flexibility, requirement's flexibility, flexibility of a transportation tool, and flexibility of a transportation network. System flexibility types are trans-routing flexibility and product-postponement flexibility. Aggregate flexibility types consider long-term decisions in logistic systems.

Furthermore, Zhang et al. (2005) prove there is strong, positive, and direct relationship between flexible logistics and customer satisfaction, and distinguished between flexible logistics competence and capability. Closs and Swink(2005) assumes information connectivity plays an important role in making flexible logistics programs, and flexible logistics programs are strongly related to all performance dimensions.

# 3. Study Method

In this study Delphi technique is applied to identify significant and key characteristics of logistics flexibility. In the standard version, the experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' judgments from the previous round as well as the reasons. Thus, experts are encouraged to revise their earlier answers in light of the responses of other members of the panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, stability of results) and the mean or median scores of the final rounds determine the results (Rowe and Wright, 1999).

Some researchers mentioned this method takes advantage of strengths and circumvents the weaknesses of committee interaction and group problem solving (Strauss and Zeigler 1975). Generally experts who are considered qualified to give expert opinions in that field (Lummus et al. 2005). Delphi study is suitable when the problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis (Linstone and Turoff, 1975). So we assume this method is suitable for this study.

Previous researchers recommended two or four rounds survey within this method (Linstone and Turoff, 1975; Martino, 1983). Lummus et al. (2005) selected three rounds considering about time bound, iterative refinements of ideas, and feedback controlling. We plan to take two or more rounds until responses become consistent.

The survey for this research is conducted online via emails, and the questionnaire is sent to experts separately. After every round, we take consensus analysis and simple statistics to show how many people give how much score for each item. To show experts how others rate the items in the last round we present the percentage of different scores for each item in the next round questionnaire. With the population selection, we have considerations as below to make experts be able to identify the items and give reliable scores which correspond to reality.

- (1) They should be very familiar with logistics business (they are able to understand logistics process factors and information factors, which are playing what a role in the logistics process),
- (2) They have the overall view to organizational behaviors (They are able to understand organizational factors),
- (3) They have successful experience with conducting logistics business (they know what is right logistics services for meeting customers' needs),
- (4) They have a global perspective (they can give reasonable judgments with less bias through reducing domestic limitations).

We assume that with the above four characteristics experts enable to identify items with logistics flexibility, and rate them. Therefore, we choose senior managers who work at logistics operation management for logistics service providers with multinational business and good performance. The demographics of participants' companies are shown in appendix A.

In order to make the survey more efficient and effective, during questionnaire design we undertake to list as many characteristics related to logistics flexibility as possible based on literature. To determine what initial items to list in the questionnaire, we interviewed five senior managers from different logistics service providers in the local, and they were instructed to keep, modify each item, or add new items if they feel the existing ones do not cover the entire content domain. These managers also participated in the further questionnaire survey. The items were examined and revised. Finally, 40 initial characteristics of logistics flexibility are listed in the questionnaire (showed in Table 1).

# 4. Round Survey and Results Analysis

### 4.1 Round 1 to Round 2

Introductory emails with a closing date two weeks later were sent to 46 potential participants who are from 15 logistics service providers located in Beijing, Tianjin, Dalian, Qingdao, Rizhao, Xiamen and Ningbo. The questionnaire includes introduction, forty initial items, and short explanations of some terms, for instance, flexibility, logistics flexibility, product postponement, and inventory/customer demand visibility, etc. which specialists might misunderstand. The questionnaire is open-ended, and the specific question posed is:

"Which of the following characteristics do you think to have significant contribution to logistics flexibility? Please, add other items on the bottom, in case there are some left out. Additionally, please, provide further information about particular aspects/elements which in your view are of distinct importance regarding logistics flexibility."

The respondents were requested to respond to the questions by giving weighted responses for each of the factors. The weights are as per the importance to the factor to realizing logistics flexibility (1=not important, 2=moderately important, 3=important, 4=very important, 5= extremely important and 0= don't know).

By the end of the second week, 32 participants had responded. In this round the respondents added nine characteristics that they feel also contributed to logistics flexibility. After discussion with some specialists

who added items we canceled two items, which seem similar with others, and revised one to make it clearer. Finally, seven characteristics are kept. They are: effectively implement the strategy of the company, implement integrative strategies with partners, have employees understand objectives, have employees cooperate positively, have an effective motivation system, respond to emergency quickly and effectively communicates and coordinates with related functional departments of government. So we have a total of 47 characteristics after analysis of round 1 response.

It is seen from round 1 result that the top rated 4 out of 8 characteristics are information related. This seems that the respondents have the opinion that information factors highly contribute to flexibility of logistics. Top priority characteristics are "have accurate and timely data", and "build successful relationship with key customers" is the second. Standard deviations ranged from 0.8424 to 1.5398, showing varied level of consensus in rating the characteristics. The respondents seemed to have highest consensus in this round regarding the top rated characteristic.

To show experts how others rated the items in the first round we present the percentage of different scores for each item, and revised the introduction in the second round questionnaire. In the same way the 32 experts are requested to reply in two weeks.

The results from round 1 to round 2 almost all original items show decrease of standard deviation except "make employees learn organization". We can conclude that the responses became less dispersed in round 2 than in round 1, showing that the respondents reconsidered the importance of the items to logistics flexibility after seeing how others generally responded.

# 4.2 Round 3

In this round survey we show experts the second round results through the same method, and the third round questionnaire is formed with the correspond revision to introduction. It is sent to the same experts with two weeks limitation.

From round 3 results the higher rated items with mean of 4.5 and above are: achieve good internal communication; top management support; have accurate and timely data; have employees cooperate positively; have excellent communication skills and tools; have an effective motivation system; vary transportation modes; build successful relationship with key customers; have employees understand objectives and improve information quality. The characteristics having lower means less than 3.25 are: adjust warehousing, empower employees, effectively use other logistics service providers, centralize inventory availability, introduce product postponement and, least rated, consolidate shipments from multiple locations.

We test for a population mean to indentify very important items using z-stat.(for sample size  $\geq$  30). The null and alternate hypotheses are:

$H_0: \mu = 4$	(1)
$H_1: \mu > 4$	(2)

	Descriptive Statistics							
Characteristics of Logistics Flexibility	Mean	Std. Deviation	<b>z-stat.</b> ( $\mu = 4$ )	<b>z-stat.</b> ( $\mu = 4.25$ )				
Achieve good internal communications <sup>gh</sup>	4.6875	0.6927	5.6144*	3.5728**				
Top management support <sup>h</sup>	4.6563	0.6530	5.6850*	3.5193**				
Have accurate and timely data <sup>fhij</sup>	4.6250	0.6599	5.3576*	3.2146**				
Have employees cooperate positively	4.6250	0.6091	5.8048*	3.4829**				
Have excellent communication skills and tools <sup>gh</sup>	4.5938	0.4990	6.7311*	3.8970**				
Have an effective motivation system	4.5625	0.5040	6.3133*	3.5074**				
Vary transportation modes <sup>bdghij</sup>	4.5313	0.6214	4.8365*	2.5605**				
Build successful relationship with key customers <sup>abh</sup>	4.5313	0.9153	3.2834*	1.7383**				
Have employees understand objectives	4.5313	0.7613	3.9473*	2.0897**				
Improve information quality <sup>fhij</sup>	4.5000	0.5680	4.9800*	2.4900**				
Adjust delivery locations based on demand <sup>egh</sup>	4.4688	0.8026	3.3039*	1.5418				
Respond to emergency quickly	4.4688	0.8026	3.3039*	1.5418				
Implement quick response beefgh	4.4375	0.7594	3.2592*	1.3968				
Effectively implement the strategy of the company	4.4063	0.6148	3.7377*	1.4376				
Deliver quickly and effectively befgh	4.3438	0.7874	2.4697*	0.6735				
Synchronize information systems with partners <sup>fhij</sup>	4.3125	0.8958	1.9734*	0.3947				
Focus on change <sup>h</sup>	4.3125	0.9651	1.8317*	0.3663				
Have distinct company strategy <sup>h</sup>	4.3125	0.6927	2.5520*	0.5104				
Effectively communicates and coordinates with related functional departments of government	4.2813	0.7289	2.1828*	0.2425				
Adjust to global requirements <sup>fh</sup>	4.2813	0.7289	2.1828*	0.2425				
Develop employee capabilities <sup>gh</sup>	4 2813	1 0234	1 5546	0.1727				
Achieve inventory visibility <sup>hij</sup>	4 2188	0.6082	2.0344*	-0.2906				
Coordinate external activities in supply chains <sup>agij</sup>	4 2188	1 0697	1 1 5 6 9	-0.1653				
Perform efficient and seamless information flow <sup>abhij</sup>	4.1875	0.7803	1.3593	-0.4531				
Have competitive knowledge <sup>h</sup>	4.1250	0.7931	0.8916	-0.8916				
Implement integrative strategies with partners	4.1250	0.7931	0.8916	-0.8916				
Achieve visibility of customer demand <sup>bfh</sup>	4.0938	0.7344	0.7221	-1.2036				
Interface internal processes <sup>gh</sup>	4.0313	0.9327	0.1895	-1.3267				
Have flexible planning system <sup>fh</sup>	3.9688	0.7399	-0.2389	-2.1504				
Focus on reducing lead time <sup>bfgh</sup>	3.9375	0.9483	-0.3728	-1.8642				
Forecast customer requirements <sup>bh</sup>	3.8750	0.7071	-1.0000	-3.0000				
Making supply chains short <sup>hj</sup>	3.8750	0.8328	-0.8491	-2.5472				
Vary transportation vehicles <sup>bdgij</sup>	3 7813	0.7507	-1 6484	-3 5324				
Carry out end-to-end performance measures <sup>h</sup>	3 6875	0.8958	-1 9734	-3 5522				
Conduct effective training program <sup>ah</sup>	3 6563	0 7874	-2 4697	-4 2658				
Share information with partners <sup>thij</sup>	3 6250	0.8707	-2 4364	-4.0607				
Change human resource practices <sup>gh</sup>	3 5625	1 1341	-2 1821	-3 4291				
Have an extensive distribution network <sup>acgi</sup>	3 5000	0.9158	-3 0884	-4 6327				
Make employees learn organization <sup>h</sup>	3.4063	0.7976	-3.0004	-5.98/15				
Change organizational culture <sup>h</sup>	3 2813	0.7289	-5 5783	-7 5186				
Start cost-saving initiatives with partners <sup>h</sup>	3 2500	0.9504	-4 4641	-5 9522				
Adjust warehousing <sup>abceghij</sup>	3 1875	0.7378	-6 2296	-8 1/63				
Empower employees <sup>h</sup>	3 1875	0.8958	-5.1309	-6.7097				
Effectively use other logistics service providers <sup>ah</sup>	3 1875	0.9980	-4 6055	-6.0226				
Centralize inventory availability beehij	3 1 8 7 5	1 1760	-3 9082	-5 1107				
Introduce product postponement <sup>dgh</sup>	3 1250	0.8707	-5 6850	-7 3093				
Consolidate shipments from multiple locations <sup>gh</sup>	3.1250	0.0707	5 /828	6 8078				
Consolituate simplifients from multiple locations	5.0515	0.7773	-J.4020	-0.07/0				

 Table 1: Mean, standard deviation and one sample z-statistics of round 3 responses

Sources: <sup>a</sup>Experts who revised listed items in this research; <sup>b</sup>Day(1994); <sup>c</sup>Vickery et al.(1999); <sup>d</sup>Barad and Sapir(2003); <sup>e</sup> Kress(1999); <sup>f</sup> Closs and Swink(2005); <sup>g</sup> Sánchez and Pérez(2005); <sup>h</sup>Lummus et al(2005); <sup>i</sup> Naim et al(2006); <sup>j</sup> Bask(2001); Experts in this research (items not being marked).

Because the alternate hypothesis states a direction, a right tail test is applied. The critical value of z with onetailed test and 95% confidence is 1.65(Lind et al, 2002). The computed z values of a total of 21 items (see table 1 with one asterisk) are greater than 1.65, so the null hypotheses is rejected. We conclude 21 items are very important characteristics to logistics flexibility. All items are conceptually categorized as organizational issues, information factors, logistics process factors, communication and coordination factors. The model of very important characteristics for logistics flexibility is built as Figure 1.

Items	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Improve information quality(V1)	1.00									
Build successful relationship with key customers(V2)	.34	1.00								
Vary transportation modes(V3)	.41	.51	1.00							
Have accurate and timely data(V4)	.34	.55	.42	1.00						
Top management support(V5)	.39	.53	.23	.22	1.00					
Achieve good internal communications(V6)	.08	.88	.55	.44	.40	1.00				
Have Excellent communication skills and tools(V7)	.40	.42	.20	.50	.35	.27	1.00			
have employees understand objectives(V8)	.11	.69	.54	.28	.31	.75	.33	1.00		
have employees cooperate positively(V9)	.47	.20	.37	.20	.56	.02	.23	.10	1.00	
have an effective motivation system(V10)	.34	.52	.46	.36	.41	.52	.43	.46	.18	1.00

 Table2: Correlation Matrix of the extremely important factors

In the same way, with the null hypotheses  $\mu = 4.25$  and the alternate hypotheses  $\mu > 4.25$  we tested the other 10 items are extremely important items (see table 1 with two asterisks). Thus the model of extremely important characteristics is available as Figure 2. It is important to explore how one item relates to others to achieve a better understanding of those items. We analyze the relationship of each other among the extremely important factors, and the correlation matrix is showed in Table 2. All items have positive relationship. There are three coefficients (marked with the blocks) are bigger than 0.6. This means the corresponding items have stronger positive relationship, of which "Achieve good internal communications" has strongest relationship with "Build successful relationship with key customers". Improving the effectiveness of internal communication is not only fairly meaningful for building external relationship successfully, but also for making employees keep track of business goals. Furthermore comprehending business goals is very helpful for Building successful relationship with key customers either.

# 4.3 Changes from round 2 to round 3

Developing group consensus concerning the subject matter is an important aspect of the Delphi process (Lummus et al, 2005). From the second round to the third round, there are 23 items (48.94%) increased in insanity mean, 6 items (12.76%) have the same means in both round 2 and round 3. A total of 18 characteristics (38.30%) have lower mean in round 3 than in round 2. Table 3 illustrates these changes.

There is no one item with statistically significant difference in expert respondent ratings from round 2 to round 3, judging from z-stat values at 0.05 significance level. It means the responses tend to be reliable. Issues of interest that can be seen in the survey results are that common characteristics or groups of attributes important to logistics flexibility were identified. Moreover, respondents appear to change their rating of characteristics after viewing the summary of group responses. In some cases, this can not change the respondents' views, or it is hard to change their views and further rounds responses are needed to reduce the variability.



Figure 1: Model of very important characteristics for logistics flexibility

	Ro	und 3	Ro	und 2		
Characteristics of Logistics Flexibility	Std.			Std.	Mean	
	Mean	Deviation	Mean	Deviation	Difference	z-stat
Introduce product postponement	3.1250	0.8707	2.6563	0.9708	0.4688	1.9540
Change human resource practices	3.5625	1.1341	3.1875	1.2811	0.3750	1.3650
Have an extensive distribution network	3.5000	0.9158	3.1563	1.1670	0.3438	1.3474
Empower employees	3.1875	0.8958	2.8750	1.0080	0.3125	1.2812
Effectively implement the company strategy	4 4063	0.6148	4 1563	0.8839	0.2500	1 1552
Implement quick response	4 4688	0.8026	4 2500	1 0776	0.2188	0.9024
Forecast customer requirements	3 8750	0.7071	3 6875	0.8958	0.1875	0.8378
Have an effective motivation system	4 5625	0 5040	4 3750	0.6599	0.1875	0.0370
Implement integrative strategies with partners	4 1250	0.7931	3 9688	0.8608	0.1563	0.5051
Have employees cooperate positively	4 6250	0.6091	4 4688	0.6713	0.1563	0.7811
Carry out end-to-end performance measures	3 6875	0.8958	3 5625	0.8007	0.1250	0.5429
Have employees understand objectives	4 5313	0.7613	4 4063	0.7976	0.1250	0.5663
Improve information quality	4 5000	0.5680	4 4063	0.7121	0.0938	0.5605
Effectively communicates and coordinates with	1.5000	0.5000	1.1005	0.7121	0.0750	0.1007
related functional departments of government	4.2813	0.7289	4.1875	0.7378	0.0938	0.4379
Coordinate external activities in supply chains	4 2188	1.0697	4 1563	1 1670	0.0625	0 2364
Start cost-saving initiatives with partners	3 2500	0.9504	3 1875	1 1198	0.0625	0.2304
Centralize inventory availability	3 1875	1 1760	3 1250	1 1846	0.0625	0.2457
Top management support	1 6563	0.6530	1 5938	0.6652	0.0625	0.2301
Make employees learn organization	3.4063	0.0550	3 3/38	1 23/2	0.0625	0.3077
Adjust to global requirements	1 2813	0.7970	4 2500	0.8700	0.0023	0.2460
Develop amployee capabilities	4.2013	1.0234	4.2500	0.0837	0.0313	0.1394
Conduct effective training program	4.2013	0.7874	4.2300	0.9837	0.0313	0.1240
Have competitive knowledge	4 1250	0.7874	1 0038	1.0273	0.0313	0.1336
Very transportation vahicles	4.1230	0.7507	4.0938	0.7025	0.0313	0.1310
Focus on reducing load time	3.7013	0.7307	3.7613	1 1622	0.0000	0.0000
Have accurate and timely data	4 6250	0.5485	1.6250	0.7031	0.0000	0.0000
A chieve good internal communications	4.0230	0.0399	4.0230	0.7931	0.0000	0.0000
Have excellent communication skills and tools	4.0073	0.0927	4.0073	0.5500	0.0000	0.0000
Passened to amarganey quickly	4.3930	0.4990	4.3930	0.5399	0.0000	0.0000
Effectively use other logistics service providers	4.4575	0.7394	4.4575	0.0189	0.0000	0.0000
Derform efficient and ecomless information flow	3.1075	0.9960	3.2100	0.9730	-0.0313	-0.1239
Deliver quickly and effectively	4.1873	0.7803	4.2100	0.8701	-0.0313	-0.1570
Vom transportation modes	4.5458	0.7874	4.4003	0.6652	-0.0625	-0.2933
A divert delivery leastions haved on demond	4.3313	0.0214	4.3938	0.0032	-0.0625	-0.5117
Adjust derivery locations based on demand	4.4000	0.0020	4.3313	1.0090	-0.0023	-0.2737
A divet werehousing	4.5125	0.9031	4.5730	1.0080	-0.0023	-0.2317
Adjust wateriousing	3.1873	0.7378	3.2813	0.9240	-0.0938	-0.4114
Active visibility of customer demand	4.0938	0.7344	4.1873	0.8200	-0.0938	-0.4233
Share information with north and	4.5125	0.0927	4.4003	0.7970	-0.0938	-0.4544
Share information with partners	3.0250	0.8707	3.7500	0.8032	-0.1250	-0.5405
Build successful relationship with key customers	4.5313	0.9153	4.6563	0.6530	-0.1250	-0.5646
Making supply chains short	3.8750	0.8328	4.0000	0.8424	-0.1250	-0.5463
Consolidate shipments from multiple locations	3.0313	0.9995	3.1875	1.0906	-0.1563	-0.6114
Change organizational culture	3.2813	0.7289	3.4688	0.8793	-0.1875	-0.8364
Inventory visibility	4.2188	0.6082	4.4063	0.5599	-0.1875	-0.9814
Have flexible planning system	3.9688	0.7399	4.1875	0.7378	-0.2188	-1.0180
Interface internal processes	4.0313	0.9327	4.3438	0.7453	-0.3125	-1.3647
Synchronize information systems with partners	4.3125	0.8958	4.6875	0.5351	-0.3750	-1.7734

 Table 3: Changes from round 2 to round 3 by mean difference

At p<0.05 significance level (-1.96  $\leq z \leq$  1.96)



Figure 2: Model of extremely important characteristics for logistics flexibility

# 5. Conclusions and Discussion

In this paper, we identified characteristics of logistics flexibility. It is carried out by conducting the survey of three rounds to senior managers from logistics service providers in China. 47 characteristics are identified to contribute to logistics flexibility, of which seven new items are found during the survey.

The model on very important characteristics for logistics flexibility within 47 items is built. From round 3, and 21 items are tested to be very important characteristics of logistics flexibility. It is recognized that the strategy should favor the achievement of flexible logistics. This implementation needs support from top managers and the active participation of human resources through effective motivation and communication. Furthermore, the item of "effectively communicates and coordinates with related functional departments of government" added by respondents is tested as one of the very important characteristics. It is assumed to be a key factor for logistics flexibility in China, and it might be very special item related with the social mechanism.

The 10 characteristics are realized extremely important characteristics, which need to be paid close attention to. Interestingly 7 of the 10 items have to do directly or indirectly with communication's effectiveness except "Top management support", "Have effective motivation system" and "Vary transportation modes". For communicating effectively is valued greatly by practitioners, we can deduce that effective communication is playing the most important role in logistics flexibility, and it is proposed a key to increasing logistics flexibility and improving customer service. So companies must focus on information flow to make material flow more effective, efficient, and flexible. Importantly, practitioners pay more attention on internal characteristics rather than external ones. However customers value the manifestation of these internal characteristics, that is to say they care the logistics process flexibility, with which companies are able to provide the right product with correct quantity and quality at the right time. The practitioners might think improve the internal flexible capability is the necessary condition for achieving process flexibility. Meanwhile exploring the relationships of the extremely important items makes logistics flexibility more distinct. We reveal the ten items have positive relationship with each other. There are three stronger relationships (coefficient is larger than 0.6) within the ten items, and achieving internal good communication has greatest effect on the customer relationship.

Above all, the main contributions in this study are:

- (1) A framework about 47 characteristics of flexible logistics is constructed, of which 7 new items are found.
- (2) 21 items are realized to be very important for flexible logistics, and the conceptual model of very important characteristics for logistics flexibility is built.
- (3) 10 items are assumed extremely important ones, which need to be paid close attention to, and accordingly, the model of extremely important items for logistics flexibility is proposed.
- (4) The relationships of the extremely important items are revealed, and three stronger relationships are marked. Thus a greater understanding of logistics flexibility is achieved.
- (5) The research results are meaningful for logistics service providers to develop a comprehensive view of logistics flexibility, and managers may focus on those very important items to improve logistics flexibility, and give a closer attention to those extremely important factors. The frameworks of key characteristics are also helpful for manufacturers to choose right logistics service providers for designing flexible supply chains. They can not only be used to examine logistics flexibility in an organization and but also to compare logistic flexibility across organizations. So manufacturers evaluate those items of logistics service providers to measure if they are right ones or the better one for the supply chain.

There are some issues need to be further investigated. Flexibility seems to have negative relationship with costs (Fisher,1997). So if regarding with the cost-effective of logistics flexibility, characteristics might be changed. Accordingly, for logistics service providers, the degree of logistics flexibility should meet what kind of supply chains, the efficient or responsive, which they are serving. How adjust the degree of logistics flexibility according to the degree of uncertainty of environment and what is the right degree of flexibility for companies to meet the uncertainty might need more research. Sample size may be another issue as 32 practitioners revolved in this study. In this respect, our research was limited by available resources and the number of practitioners who could be confirmed to participate in the 3 round surveys. However, to achieve a broader representation of practitioner views upon this topic, more practitioners and companies need to be included in the study.

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ID	Number of Experts	Title of experts	Number of employees	Domain
1	2	Vice general manager, Operation manager	300	International maritime logistics
2	2	Vice general manager, Operation manager	400	Global ocean fright, air fright and warehousing
3	3	Vice general manager, Distribution manager, Project manager	1200	International integrated logistics for containers
4	2	Vice general manager, Operation manager	300	Distribution, international shipping, warehousing
5	2	Vice general manager, Operation manager	150	International shipping, and warehousing
6	3	Vice General Manager, Operation manager, Project manager	150	Port logistics, warehousing, integrated logistics for Chinese apparel Brand Youngor
7	1	General Manager	63	Multimodal transport, international container logistics
8	2	General Manager, Operation Manager	100	Ocean fright to Southeast Asia, Middle east, India
9	2	General manager, Operation Manager	40	International container shipping, Ocean freight, and domestics lateral shipping for export
10	2	Operation manager, project manager	1300	International project logistics, large-scale equipments transport, logistics for engineering
11	2	Vice general manager, Operation manager	220	International container shipping and integrated logistics
12	2	Operation manager, Project manager	1800	International air freight, ocean freight road and rail freight, warehousing, supply chain solutions
13	3	General manager, Operation manager, Distribution manager	330	large-scale equipment logistics, road /railway freight, and supply chain solutions
14	2	General manager, Vice general manager	96	Air freight, international ocean freight, road and rail freight,
15	2	General manager, Operation manager	120	large-scale equipments transport, international ocean freight, road and rail freight, warehousing

# Appendix A: Demographics of experts' companies

# Port Hinterland Intermodal Network Optimisation for Sustainable Development: A Case Study of China

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### Abstract

Shipping lines increasingly face the challenge of sustainable development in the global fierce competitive environment like many other industries. Shipping lines have ventured into inland transport to offer door-to-door supply chain solutions to improve their competitiveness. There is a growing need of optimization of port hinterland intermodal container flows due to the requirement of door-to-door solutions. In view of rising environmental concerns on greenhouse gas emissions, shipping lines must also consider cutting down their carbon footprints in their strategic and tactical planning. Based on the above background, this paper develops a bi-objective model to minimize cost and transit time for the tactical planning of intermodal container flows with constrained carbon emission. A case study of China is used to illustrate this model. The results and analysis offer managerial insights on the impact of trade-offs between cost and transit time, and the effect of different carbon footprint requirements on transport planning. Port hinterland infrastructure development in China is also discussed, and the policy implications drawn are useful for those countries with a large hinterland area.

Keywords: Intermodal transport, Container network optimization, Port, Sustainable development, China

## 1. Introduction

It is widely accepted that the container invented sixty years ago has brought intermodal transport into a new stage. It can drive different transport modes towards greater transportation seamlessness (Thill and Lim 2010). The definition of container intermodal transport can be well-described as container transport in multimodal chains which link the original nodes of consignors to the destination nodes of consignees so as to offer door-to-door services to customers. Intermodal container transport needs to use more than two transport modes to deliver the containers from consignors to consignees (Barnhart and Laporte 2007). There are three major transport modes in inland to link shipping transport in the sea leg, including railway, barge and truck. These three major transport modes incur different costs, transit times and carbon emissions. How to manage the trade-offs among these three aspects is a big challenge to the decision makers in transport operators, because their corresponding management objectives may conflict with each other in most of the time (Notteboom 2010).

The deeper integration between logistics services has been brought about by the rapid development of supply chain management. The demarcation between previously exclusive logistics markets is now unclear. The maritime industry is involved in such changes in global supply chains without exception (Lam et al. 2012). Competition among shipping lines is highly aggressive at the present time. Beyond traditional port-to-port waterborne services, increasingly shipping lines offer value-added door-to-door services to shippers and explore their marketplaces (Heaver et al. 2001). Such door-to-door solutions are well welcomed by their customers, which can help shipping lines to gain a competitive edge. Hence many shipping lines are eager to obtain a bigger piece of cake in a competitive environment to achieve the loyalty of their customers
(Perez-Labajos and Blanco 2004). Thus only focusing on waterborne transport operation and its relevant optimization is not enough for these shipping lines. They must organize and optimize intermodal container network in both sea and land legs between their traditional strong services in shipping and newly developed business in inland transport.

Currently, the issue of environmental protection has become a key concern in sustainable development in the maritime industry. Hence there is a growing need to consider carbon footprint in transport planning. Intermodal network development offers great potential to improve sustainability in supply chain and transportation because railway and inland barge transport incurs much lower carbon emissions than trucking which is now dominant in inland transport. This explains why green transport solutions suggest seaports linked with inland dry ports by railway especially double-stack train application, inland barge connections, and using shortest possible initial and final journeys by truck in intermodal container networks (Rahimi, Asef-Vaziri et al. 2008; Liao, Tseng et al. 2009; Shintani, Konings et al. 2010).

The design of container transport network has attracted increasing interest in academia. A literature review paper written by Lam and Gu (2012) has analysed the existing peer works about the relevant mathematical models. They have noted that many research works focused on container routing and empty container repositioning in the sea leg. However, very few papers considered both sea and land legs together (Min 1991; Kim, Chang et al. 2008; Imai, Shintani et al. 2009; Infante, Paletta et al. 2009). Most optimization models assessed a single objective of cost. Only few models integrated transit time as another objective (Jula, Chassiakos et al. 2006; Zhang, Yun et al. 2009; Yang, Low et al. 2011), or included multiple objectives (Erera, Morales et al. 2005; Wong, Lau et al. 2010). In general, environmental issues have been extensively researched, but quantitative models developed to address such significant issues are relatively few (Rahimi, Asef-Vaziri et al. 2008; Shintani, Konings et al. 2010).

Lam and Gu (2012)'s review paper has helped us to identify these research gaps. Thus in this paper, a novel optimization model for the tactical planning of port hinterland intermodal container flows is developed to fill such gaps. There are two objectives in this model. The first objective is transportation cost minimization, and the other is transit time minimization. This reflects the need of a diversified market as some customers prefer lowest freight rates while some others would rather pay more for a faster delivery. Carbon footprint issue exists in this model as a constraint to fulfill the environmental protection requirement. A case study on China's intermodal container flow optimization is used as a computational experiment to test our model. It should be noticed that the model is non-deterministic polynomial-time hard (NP-hard) due to the existence of integer variables (Lodi 2010). However, small and medium problem sizes can be solved directly and efficiently through the off-the-shelf commercial solver CPLEX. For large scale cases, some meta-heuristic algorithms are needed, such as Genetic Algorithm. In this study, CPLEX 12.4 is employed to practise the numerical test.

The rest of this paper is organized as follows: Section 2 describes the detailed problem and presents model formulation. Section 3 applies the model for a case study on China and reports the numerical results. Section 4 discusses policy implications. Section 5 concludes this research.

# 2. Problem Description and Model Formulation

#### 2.1 Port hinterland intermodal container transport problem

A growing number of shipping lines now provide door-to-door services to their land-locked end-customers as stated above. Different shipping lines have different business operation modes. Some shipping lines operate their own inland transport network, while some others prefer outsourcing part or all their transport operations. In the latter case, shipping lines also need to understand how to optimize transport planning based on customer requirements and infrastructure settings. Usually shipping lines' first concern is to minimize their transportation cost. However under market driven business environment, they also need to meet transit time requirements given by customers. At the same time, they need to comply with carbon footprint restrictions.



Figure 1: Port hinterland intermodal container transport network

Source: Drawn by the authors

Our model is used for the tactical planning of port hinterland intermodal container flows. The detailed network is illustrated in Figure 1. Containerized freights are shipped from many foreign seaports to many domestic seaports. After containers are discharged at domestic seaports, customs clearance is required before they can be routed through an inland transport network to end-customers' distribution centers at domestic inland cities. There are three available inland transportation modes could be chosen, including truck, railway and barge. Where there are available rail linkages or barge ports nearby, line-haul may be done by rail or barge before last mile delivery by truck. Without such facilities, containers could also be transported from domestic seaports to end-customers all the way by truck.

#### 2.2 A novel optimization model with bi-objectives

This model has two objectives: transportation cost minimization and transit time minimization. Bi-objective optimization is more reasonable and realistic than single objective optimization. In real-life situations, decision makers often need to deal with conflicting objectives. Cost and transit time are the two most common considerations in transport planning problems. This model is formulated with the assumption that a major shipping line is the decision maker. We also assume that there is no capacity constraint for container transport in the sea leg. Transit times are assumed to be deterministic at all transportation modes. Carbon emission restrictions are set by the government for transport operations.

This section presents the model formulation and corresponding explanations are given as follows.

#### **Model Formulation**

Set 1	Description
N z	A set of nodes, let $N = F \cup P \cup R \cup B \cup C$ , while F stands for foreign seaports, P stands for domestic seaports, R stands for dry ports linked by railway, B stands for barge ports, C stands for inland cities.

A A set of arcs, let

$$\begin{split} A &= A_{\scriptscriptstyle FP} \cup A_{\scriptscriptstyle PF} \cup A_{\scriptscriptstyle PR} \cup A_{\scriptscriptstyle PP} \cup A_{\scriptscriptstyle PB} \cup A_{\scriptscriptstyle BP} \cup A_{\scriptscriptstyle PC} \cup A_{\scriptscriptstyle CP} \cup A_{\scriptscriptstyle RC} \cup A_{\scriptscriptstyle CR} \cup A_{\scriptscriptstyle BC} \cup A_{\scriptscriptstyle CB} \,, \\ \text{For each} \, (i,j) \in A_{\scriptscriptstyle XY}, \ (i,j) \ \text{ denotes the arc from } i \in X \ \text{ and } j \in Y \,, \text{ and } X, Y \in \{F,P,R,B,C\} \,. \end{split}$$

# Decision Variable Description

<b>Parameter</b> <i>G</i>	<b>Description</b> Average carbon footprint limitation of this network per TEU in kg
vnum <sub>ij</sub>	Number of deployed inland vehicles from node $n_i$ to $n_j$ , $(i, j) \in A$ while $n_i, n_j \notin F$
$lcm_{ij}$	Laden container transport quantity from node $n_i$ to $n_j$ in TEUs, $(i, j) \in A$
ecm <sub>ij</sub>	Empty container transport quantity from node $n_i$ to $n_j$ in TEUs, $(i, j) \in A$
$tcm_{ij}$	Total container transport quantity from node $n_i$ to $n_j$ in TEUs, $(i, j) \in A$

0	The fuge carbon rootprint minitation of this network per The in Kg
CIMCS	Customs clearance cost for import laden container per TEU
CEXCS	Customs clearance cost for export laden container per TEU
CIMO	Other cost for import container per TEU
CEXO	Other cost for export container per TEU
$EX_{ij}$	Container quantity per vehicle on the arc $(i, j) \in A$
FIX <sub>ij</sub>	Fixed cost per vehicle on the arc $(i, j) \in A$
$SPM_i$	Container supply quantity of node $n_i$ in TEUs, $n_i \in F \cup C$
$DMM_i$	Container demand quantity of node $n_i$ in TEUs, $n_i \in F \cup C$
$SPEM_i$	Empty container supply quantity of node $n_i$ in TEUs, $n_i \in F \cup C$
$DMEM_i$	Empty container demand quantity of node $n_i$ in TEUs, $n_i \in F \cup C$
$CAP_i$	Container throughput capacity of node $n_i$ in TEUs, $n_i \in P \cup R \cup B$
$CHC_i$	Container handling cost in node $n_i$ per TEU, $n_i \in P \cup R \cup B$
$THT_i$	Container handling time in node $n_i$ per TEU, $n_i \in P \cup R \cup B$
$CST_i$	Container storage cost in node $n_i$ per hour per TEU, $n_i \in P \cup R \cup B$
$TST_i$	Container storage time in node $n_i$ per TEU, $n_i \in P \cup R \cup B$
$CTP_{ij}$	Transportation cost from node $n_i$ to $n_j$ in US\$ per TEU, $(i, j) \in A$
$TTP_{ij}$	Transportation time from node $n_i$ to $n_j$ in hours, $(i, j) \in A$
$GTP_{ij}$	Transportation carbon footprint from node $n_i$ to $n_j$ in kg per TEU, $(i, j) \in A$
AVNUM <sub>ij</sub>	Available vehicle number from node $n_i$ to $n_j$ , $(i, j) \in A$ while $n_i, n_j \notin F$

# **Objective functions:**

Minimize Cost= (

$$\sum_{(i,j)\in A} CTP_{ij} \times tcm_{ij} + \sum_{(i,j)\in A} 2 \times (CHC_i) \times tcm_{ij} + \sum_{(i,j)\in A, n_i \notin F \cup C} (CST_i \times TST_i) \times tcm_{ij} + \sum_{(i,j)\in A_{FF}} (CIMCS + CIMO) \times lcm_{ij} + \sum_{(i,j)\in A_{FF}} (CEXCS + CEXO) \times lcm_{ij} + \sum_{(i,j)\in A_{FF}} CIMO \times ecm_{ij} + \sum_{(i,j)\in A_{FF}} CEXO \times ecm_{ij} + \sum_{(i,j)\in A, n_i \notin F, n_j \notin F} FIX_{ij} \times vnum_{ij} + \sum_{(i,j)\in A_{FF}} (SPM_i + DMM_i)$$

$$(1)$$

Minimize Time= (

$$\sum_{(i,j)\in A} TTP_{ij} \times tcm_{ij} + \sum_{(i,j)\in A} 2 \times (THT_i) \times tcm_{ij} + \sum_{(i,j)\in A, n_i \notin F \cup C} TST_i \times tcm_{ij}$$

) 
$$\div \sum_{i \in F} ((SPM_i + DMM_i) \times 24)$$
 (2)

#### **Constraints:**

$$\sum_{\substack{(i,j)\in A\\(i,j)\in A}} (GTP_{ij} \times tcm_{ij}) \div \sum_{i\in F} (SPM_i + DMM_i) \le G$$

$$(3)$$

$$\sum_{\substack{(k,i)\in A}} tcm_{ki} = \sum_{\substack{(i,j)\in A}} tcm_{ij}, \forall n_i \in P \cup R \cup B$$

$$(4)$$

$$\sum_{\substack{(i,j)\in A}} tcm_{ij} = SPM_i, \forall n_i \in F \cup C$$

$$(5)$$

$$\sum_{\substack{(i,j)\in A\\F}} tcm_{ij} = DMM_j, \forall n_j \in F \cup C$$

$$(6)$$

$$\sum_{\substack{(i,j)\in A_{FF}}} ecm_{ij} = SPEM_i, \forall n_i \in F$$

$$(7)$$

$$\sum_{\substack{(i,j)\in A_{FF}}} ecm_{ij} = DMEM_j, \forall n_j \in F$$

$$(8)$$

 $vnum_{ij} \le AVNUM_{ij}, \forall (i, j) \in A, n_i \notin F, n_j \notin F$ 

 $tcm_{ij} \le EX_{ij} \times vnum_{ij}, \forall (i, j) \in A, n_i \notin F, n_j \notin F$ (10)

(9)

$$\sum_{(i,j)\in A} tcm_{ij} \le CAP_i, \forall n_i \in P \cup R \cup B$$
(11)

$$tcm_{ij} = ecm_{ij} + lcm_{ij}, (i, j) \in A_{FP} \cup A_{PF}$$
(12)

$$tcm_{ij} \in \mathbf{Z}^+, \forall (i,j) \in A$$
(13)

$$ecm_{ij} \in \mathbf{Z}^+, \forall (i, j) \in A_{FP} \cup A_{PF}$$
(14)

$$lcm_{ij} \in \mathbf{Z}^+, \forall (i,j) \in A_{FP} \cup A_{PF}$$
(15)

$$vnum_{ij} \in \mathbf{Z}^+, \forall (i,j) \in A, n_i, n_j \notin F$$
(16)

#### **Corresponding Explanations:**

The objective function (1) minimizes total costs of laden and empty containers flowing through the transport network. They include transportation cost, terminal handling cost, storage cost, customs clearance cost and fixed cost of using inland vehicles (trucks, trains and barges). The objective function (2) minimizes total transit times including transportation time, terminal handling time and storage time. Constraint (3) represents the carbon footprint restrictions set by the governments or the society. Constraint (4) balances container in-flows and out-flows at transport nodes. Constraints (5) and (6) are supply and demand constraints of total containers. Constraints (7) and (8) are supply and demand constraints of empty containers. Constraint (9) sets the number of available vehicles in each inland arc. Constraint (10) defines the relationship between container transport quantity and the number of available vehicles in each inland arc. Constraint (11) is a capacity constraint of transport nodes. Constraint (12) defines the relationship of total container transport quantity and empty container transport quantity in transport arcs. Constraints (13) - (16) define the non-negative characteristics of decision variables.

#### 3. Model Application and Case Study

### 3.1 Case description

In this section, we use a numerical example about China to illustrate this model. China is a big economy with rapid development and a country with large continent area. China's continued economic rise has caused significant repercussions for the global economy in terms of trade patterns and orientation. Some researchers use their quantitative results to show that Australian logistics sector would potentially benefit significantly from China's rise (Tongzon and Nguyen 2009). On one hand, China's rapid economic growth has brought about the prosperity of its maritime industry. On the other hand, its maritime industry development speeds up and promotes its global competitiveness. Particularly, we select the hinterland area of Yangtze River in Central China as our focus. Yangtze River is the longest river in China and is one of the main arteries of waterway container traffic. Shanghai Port sits at the mouth point of Yangtze. Not far away from Shanghai Port, Ningbo-Zhoushan Port is a new rising port. Shanghai Port and Ningbo-Zhoushan Port are chosen as two domestic seaports in the case study. Both ports have achieved extraordinary container traffic growth in the past ten years. Shanghai Port has become the world's busiest container port in terms of throughput since 2010. Ningbo-Zhoushan Port was ranked as the 6th container port since 2010 (Marine Department, 2012).

Twenty-five foreign seaports are included in this case study. These 25 foreign seaports are heavily involved in Mainland China's international trade. They are Los Angeles, Long Beach, Seattle, Oakland, New York, Boston, Miami, Rotterdam, Antwerp, Hamburg, Le Havre, Kobe, Tokyo, Yokohama, Osaka, Tanjung Pelepas, Port Klang, Singapore, Hong Kong, Busan, Inchon, Gwangyang, Kaohsiung, Keelung and Taichung. Regarding the hinterland setting, three main inland transport modes are included which are truck, rail and barge. Since we apply our model to Yangtze River and its hinterland, hence barge transport is available under this background. The selected hinterland area of Shanghai and Ningbo-Zhoushan ports includes Shanghai Municipality, Jiangsu Province, Zhejiang Province, Anhui Province, Jiangxi Province, Totally, there are 30 selected inland cities. Based on the current infrastructures situation in Mainland China, we consider five railroad dry ports in Suzhou, Hangzhou, Nanjing, Wuhan and Changsha and three barge ports in Suzhou, Nanjing and Wuhan.

We assume that there are 80% and 20% empty containers for import and export containers in Mainland China (Rodrigue 2007). Customs clearance cost per TEU is \$120 and \$100 respectively for import and export laden containers. Other port handling cost per TEU is \$165 and \$85 respectively for import and export containers. We suppose one truck carries two TEUs, one rail can carry 100 TEUs, and one barge can carry 500 TEUs per trip. Every selected inland city has a demand of 1,500 TEUs and such demand follows a uniform distribution in the planning period. Other main parameters are shown in below Table 1.

Table 1.	Table 1.Main Parameters			
	Ship	Rail	Barge	Truck
Variable transportation cost (\$/km)	0.19	0.5	0.17	2
Average speed (km/hour)	40	70	30	70
Carbon footprint (Kg/km)	0.084	0.205	0.084	0.472
~				

Sources: Compiled from the technical report (TEMS 2008), "BLM-Shipping" professional software, the website of Ministry of transport of China, and (Maersk Line, 2012).

#### 3.2 Three scenarios with different optimization objective portfolios

Table 2 presents the results corresponding to different optimization objectives. There are three scenarios as follows:

#### Scenario 1:

If we only concern one objective optimization ("Min Cost"), the results are presented in column 1. In this scenario, 44% of containers should be delivered by truck directly from domestic seaports, and 33% and 23% of containers should be transported by barge and railway respectively.

#### Scenario 2:

If we only do "Min Time" optimization, results are in column 2. In this scenario, 67% of containers should be

delivered by truck directly from domestic seaports, and 33% of containers should be transported by railway. Barge is not used due to longest transit time.

### Scenario 3:

The column 3 shows the bi-objective optimization results. In such scenario, 55% of containers should be delivered by truck directly from domestic seaports, and 8% and 37% of containers should be transported by barge and railway respectively.

Table	Table 2.         Three Scenarios with Different Optimization Objective portfolios									
Min Cost Min Time Bi-objectives (Min Cost+ Min Tim										
	(Scenario 1)	(Scenario 2)	(Scenario 3)							
Truck (%)	44%	67%	55%							
Barge (%)	33%	0%	8%							
Railway (%)	23%	33%	37%							

# 

Source: Compiled by the authors from numerical results

When cost minimization is the only objective, barge transport mode is the most encouraging. When transit time minimization is the only objective, trucking is the most preferred transportation mode. When we consider these two objectives together, there is a trade-off for the transportation mode choice.

In the sea leg, optimization objectives also affect cargo routing. Shanghai Port is an established international shipping hub. For import routes to the region, many shipping lines call Shanghai Port first and then Ningbo-Zhoushan Port, or link Shanghai and Ningbo-Zhoushan ports with feeder services. The transit time for a ship/barge between Shanghai and Ningbo-Zhoushan ports is about one day. If a customer in Ningbo wants lowest transportation cost, his containers should be discharged at Ningbo-Zhoushan Port. However, if he needs to receive his cargoes fast, containers must be discharged at Shanghai Port and then trucked to Ningbo within several hours.

#### 3.3 Sensitivity analysis in carbon footprint requirements

According to Section 2.2, G represents average carbon footprint limitation per TEU which reflects policy makers' restriction on cargo emission. When G is less than 530kg, there is no feasible solution. In order to illustrate the impact of G value, we obtain modeling results at three sets G values when a feasible solution exists. In Carbon Requirements I and II, G values are set as 530kg and 560kg respectively. In Carbon Requirement III, G value is set as 590kg or above. Scenario III means that when G value is greater than 590kg, the change of G value will not impact the range of Pareto Frontier.

Figures 2 to 4 present the numerical results at these three Carbon Requirements. In each figure, Pareto Frontier is on the left side and container distribution chart by transportation modes is on the right side. Pareto Frontiers are obtained by plotting 100 dots which represent different trade-offs between costs and transit times. We use fixed time dots to optimize cost objective. For example, following a uniform distribution, 100 transit times are selected from within the feasible solution space, and they are then set as a model constraint to obtain cost optimal results. Container distribution chart by transportation modes is summarized as the average of optimal results.

Based on the analysis, it can be noted that the usage of barge increases when G value decreases. The usage of truck increases when G value increases. This finding is in line with the common understanding that barge is the most environmentally friendly and truck is the least environmentally friendly tool. For sustainable development, the government has the responsibility to promote the usage of inland railways and waterways where the geographical conditions allow. This will help reduce last-mile trucking mileage in order to build green intermodal supply chains.

Figure 2. Modeling results at Carbon Requirement I (G=530kg)



Source: Drawn by the authors from numerical results



Figure 3. Modeling results at Carbon Requirement II (G=560kg)

Source: Drawn by the authors from numerical results

Figure 4. Modeling results at Carbon Requirement III (G=590kg and above)



Source: Drawn by the authors from numerical results

We can also find that a small change in G value will have significant impact on the Pareto Frontier range. The reason is that the most contribution to the carbon footprint is from the sea leg transport. Its transport distance is of a major share of the total intermodal chain's mileage. However, it does not mean that it is meaningless to

address environmental concerns for inland transport planning. Reducing the trucking mileage for inland transport is not only good for the environment protection, but also saves cost because it is cheaper to transport cargoes over long distance by railway or waterway. To realize the benefits, however, there must be substantial improvement in inland intermodal transport infrastructures, including not only inland railways and waterways (as links), but also dry ports and barge ports (as nodes).

# 4. Policy Implications

Table 3 presents transport quantity via inland railroad and barge ports in Carbon Requirements I and III. These two settings are the two extreme situations in this case study. Carbon Requirement I has a G value of 530kg, which represents a very stringent carbon footprint limit. Carbon Requirement III has a G value greater or equal than 590kg, which represents a very loose carbon footprint requirement that does not impact transportation mode choices.

	Table 5. Iral	isport quantity via miano ranroad a	and barge ports
		Carbon Requirement III (G>=590kg)	Carbon Requirement I (G=530kg)
	City	Usage (TEU)	Usage (TEU)
	Suzhou (D0)	2,587	4,559
	Hangzhou (D1)	1,632	3,186
Railway dry	Nanjing (D2)	4,110	1,676
port	Wuhan (D3)	11,339	0
	Changsha (D4)	13,552	15,000
	Subtotal	<u>33,220</u>	24,421
	Suzhou (B0)	419	1,639
Dance next	Nanjing (B1)	1,394	7,126
Barge port	Wuhan (B2)	5,109	15,000
	Subtotal	<u>6,922</u>	23,765
Total by dry po	orts and barge ports	40,142	48,186

 Table 3.
 Transport quantity via inland railroad and barge ports

Source: Compiled by the authors from numerical results

In Carbon Requirement I, there are more containers handled by inland railroad and barge ports on the whole because of a tighter carbon footprint requirement. However, total containers transported by railroad decrease as barge becomes dominant for long distance transport. For example, no more containers are transported via Wuhan railroad port (D3) in Carbon Requirement I. However, containers transported via Wuhan barge port (B2) surge dramatically to 15,000 TEUs.

In Carbon Requirement III, Wuhan (D3), Changsha (D4) and Wuhan (B2) are the nodes with the longest transport distances to the two domestic seaports of Shanghai and Ningbo-Zhoushan. They handle a much larger amount of containers than transport nodes which are nearer to domestic seaports. This result means that there is a higher demand for the use of railroad dry ports and barge ports in locations which are far from coastal seaports, even if there are loose restrictions on greenhouse gas emissions.

Policy implications for sustainable development can be drawn from these findings. First of all, barging is the most environmentally friendly and cost effective. Governments should give first priority to develop barge ports if the geographical conditions allow. For Mainland China's case, the Yangtze River is a natural corridor linking Western China and Eastern China. It can provide huge potentials to reduce the pollution in transport sector in Mainland China if the Chinese government can utilize and explore it better from a sustainable development purpose. The Chinese government has been promoting the development of Western and Central China by offering various investment incentives. In fact, the Chinese government has realized that inadequate transport infrastructure is a bottleneck to its economic development. Yu et al. (2012) discover that since 1994 the transport infrastructure growth of Mainland China has surpassed its GDP growth and such gap is bigger from then on. Barge intermodal along the Yangtze River from the upstream Chongqing to downstream Shanghai will deserve more attention. More satellite barge terminals will be established along Yangtze River, while some maintenance works will be improved, such as dredging, widening and deepening the waterway channels accordingly. In comparison with railways and highways, the development of the Yangtze River

waterways would require much less time and capital investment. Such a development will also bring about substantial economic benefits for export oriented manufacturers in the hinterland, because it is most cost effective to barge containers from inland provinces to coastal seaports. In Europe, the Rhine River has greatly benefited the transport and economic development of the Rhine-Scheldt Delta region (Notteboom 2007). Similarly, the development of the Yangtze River waterways and barge ports could play a strategic role to stimulate the economic growth of Western and Central China (FHWA 2007).

Where natural waterways are not available, governments need to consider the development of the railway links and dry ports as a priority. Unlike in European countries and USA, the railway system in Mainland China is state-owned and has little involvement of private investment. Although some scholars had recommended to introduce private investment into Chinese Railways in order to strengthen competition many years ago (Rong and Bouf 2005), till now Chinese Railway still remains its own operation pattern. China has a huge population size. A large portion of railway capacity is used for passenger transport, and thus limited capacity can be deployed for freight transport. To overcome the capacity constraint with railways, the Chinese government may consider partial privatization of its railway system to speed up the pace of its railway development. In recent years, the Chinese government has made many efforts to build its "High Speed Rail" system to relieve the pressure of passenger transport and release more rail capacity to its freight transport. Similar as inland waterways, such a development will not only help reduce environmental pollution, but also helps businesses to lower transport costs. Although the railway link development is controlled by Chinese central government, dry port development in Mainland China is opened. In order to incite local economic development, many local governments would like to build dry ports themselves. A lot of dry ports have sprung up in Mainland China. Over-development of dry ports is not always a good thing. The local governments should manage the planning systematically for sustainable development. India's case draws reference that government has a great influence in shaping its industry's competitive structure, especially in developing economies (Ng and Gujar 2009).

# 5. Conclusions and Future Research

This research provides an optimization solution to the intermodal container transport problem from tactical level. Shipping lines have ventured into inland transport to offer door-to-door supply chain solutions to improve their competitiveness. This has resulted in an increasing need of simultaneous optimization of container flows in both sea and land legs. The freight market is diversified. Some shippers want lowest cost while some others need a fast delivery. Shipping lines also need to address carbon footprint requirements in view of rising environmental concerns. To handle these challenges, this research proposes a bi-objective optimization model to minimize cost and transit time for port hinterland intermodal container transport. The carbon footprint requirement is handled as a constraint in this model.

The model is applied to a case study of import and export container flows to and from inland China and suggests several key findings. First, as long as inland waterways are available, barge is the most preferred transportation mode to lower cost and carbon emissions. Second, for railway container transport, it is more beneficial to build dry ports where it is relatively far away from coastal seaports. Third, trucking has shortest transit time, but incurs highest cost and carbon emissions. Unless transit time is a major concern, trucking should not be encouraged for long distance transport. Fourth, barge or railway intermodal transport provides opportunities to reduce the ratio of last-mile trucking mileage to the total transport mileage. This not only brings about economic benefits, but also better preserves the environment. Finally, tighter environmental regulations on carbon emissions favor barge and rail transport. However, more environmentally friendly transport modes require the development of supporting infrastructures including inland waterways, barge ports, railways and dry ports.

There are several contributions made by this paper to not only the academic circle but also the industry. First, this model is original and fills the gaps in the literature. The model optimizes port hinterland intermodal container flows. It measures not only transportation cost but also transit time. More importantly, it is one of the few attempts which quantifies the impact of carbon footprint requirements on transport planning. Second, model application suggests managerial insights and policy implications. These results not only answer

essential questions about container transport planning in China, but are also relevant for other countries with a large continent area, e.g., India. The main contribution of this paper is that this model is beneficial not only to shipping businesses and one-stop logistics service providers, but also can offer insights for government policy makers to develop inland transport infrastructures.

This research has its limitations and future extensions could be done. First, it can be extended to consider sailing speed and bunker consumption in the sea leg. Second, in reality, transit times are not always definite. It is thus necessary to incorporate stochastic features in the model if uncertainties are a major concern in transport planning. Third, it is also beneficial to run more experiments with the inclusion of more end-customer demand nodes. Fourth, for the transport planning at an operational level, we are extending the model to consider the routing of individual container origin-destination pairs to meet their cost and transit time requirements.

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# **Optimization of Resource Allocation Dedication on a Liner Shipping Company's Container Terminals – An Application of Centralized Data Envelopment Analysis**

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### Abstract

This paper presents an application of centralized data envelopment analysis (CDEA) to analyze the performance of a number of container terminals supervised by one liner shipping company. The contribution of this paper is that it provides a systematic and centralized perspective of resource reallocation based on one company's perspective. Many liner shipping companies have set up exclusive container terminals in the main international harbors for providing stable service as well as gaining advantages over keen competition. The conventional DEA methodology has been widely used for the evaluation of port/terminal performance in the previous literature. While conventional DEA models set targets separately for each DMU, CDEA models consider a centralized decision maker who supervises all the operating units. The decision maker of the liner shipping company has an interest in maximizing the efficiency of individual exclusive container terminals at the same time that total input consumption is minimized and total output production is maximized. That is, instead of projecting each terminal independently, a centralized approach is used.

This paper focuses on the one of the world's top 20 liner shipping companies. The numerical results show that, under the minor adjustment scenario, the liner shipping company can maximize the production of the aggregated output of all terminals by transferring labor from terminal B to terminal E, without reducing or increasing any input. Under the major adjustment scenario, the aggregated adjustable-input is required to be reduced in order to maximize the production of the aggregated output of all terminals. In terminal A, labor is required to be reduced under the short-term and long-term policies, and the slack for the long-term labor level is greater than that for the short-term labor level. However, in the long term, the amount of hauling equipment needs to be increased. Terminal B is the most inefficient terminal under the short-term and long-term policies. To improve the overall efficiency of the five exclusive container terminals, the shipping company should reallocate the resources in terminal B. In terminal C, both the labor and hauling equipment are required to be reduced under the long-term situation. The liner shipping company does not need to adjust any resources in terminal D. In terminal E, labor is required to be reduced, but the hauling equipment is required to be increased. The hauling equipment is required to be double that for the year 2011. This result accurately reflects the empirics, because terminal E was only opened in 2011 and the quantity of inputs needs to be increased.

Keywords: Centralized Data Envelopment Analysis, Resource Allocation, Liner Shipping Company, Dedicated Container Terminal

# 1. Introduction

Container transportation plays a very important role in international transportation services. In order to provide stable service as well as gain an advantage over the keen competition, many liner shipping companies have set up exclusive container terminals in the main international harbors. To maintain their competitiveness in such a competitive environment, shipping lines have to invest heavily in their exclusive container terminals. Thus, it is important to estimate the relative performance of container terminals supervised by one liner shipping company.

The evaluation of port/terminal performance has been widely studied by using the conventional DEA methodology in the previous literature (Roll and Hayuth, 1993; Martines-Budria et al., 1999; Valentine and Gray, 2001; Tongzon, 2001; Itoh, 2002; Wang et al., 2003; Barros, 2006; Cullinane et al., 2006; Lin and Tseng, 2007; Lorena and Monica, 2007; Koster et al., 2009).

DEA is an LP-based, nonparametric method in operations research and economics that is used in evaluating the performance of many different kinds of activities. The DEA method not only estimates the performance, but also helps decision making units (DMUs) remove other sources of inefficiency from the observations. This capability distinguishes the DEA from other decision-making techniques. The DEA method has various models which differ in the criteria based on which projections are made. In addition to the two common approaches: the CCR and BCC models, there are the additive model, cross efficiency, window analysis, Malmquist analysis, the Assurance Region model, and the non-controllable model (NCN model).

Lozano and Villa (2004) created new DEA models for centralized resource allocation in the intra-organizational scenario. The new DEA models consider the situation where there is a centralized decision maker who supervises or "owns" all of the operating units, and the total output and input are more important than the output and input for the individual units. In this paper, we refer to the new model as centralized data envelopment analysis (CDEA). Lozano et al. (2004) and Yu et al. (2013) evaluate performance by utilizing CDEA. Lozano et al (2004) used the CDEA model to analyze the performance of Spanish municipalities' glass recycling operations. Yu et al. (2013) studied the human resource rightsizing problem for Taiwan's airports using centralized data envelopment analysis.

While conventional DEA models set targets separately for each DMU, CDEA models consider a centralized decision maker who supervises all the operating units. The decision maker of the liner shipping company has an interest in maximizing the efficiency of individual exclusive container terminals at the same time that total input consumption is minimized and total output production is maximized. That is, instead of projecting each terminal independently, a centralized approach is used in this paper.

The remainder of this paper is organized as follows. In the next section, the structures of the theoretical models are provided. Section 3 covers the experimental design. Finally, a brief conclusion is given in Section 4.

# 2. Methodology

This paper uses one output and four inputs which have been commonly used in the previous literature. The output variable is container throughput in TEU. Container throughput is unquestionably the most important and widely-accepted indicator of port or terminal output (Wang et al., 2003). The input variables comprise the number of quay gantry cranes, marshalling yards, labor, and hauling equipment. Here quay gantry cranes and marshalling yards are non-adjustable inputs.

Before formulating the models, the notation to be used should be introduced. Let n be the number of DMUs; j, r be the indexes for DMUs; i be the index for input; k be the index for output; xij be the amount of input i consumed by DMUj (x1j: number of quay gantry cranes, x2j: marshalling yards, x3j: labor, x4j: hauling equipment); ykr be the amount of output k produced by DMUj;  $\gamma$  be the aggregated-output expansion; s3r be

the slacks for labor; s4r be the slacks for hauling equipment; and  $\lambda_{1r}, \lambda_{2r}, \lambda_{3r}, \dots, \lambda_{ir}$  be the vector for projecting DMUr.

Two scenarios are proposed: minor adjustment and major adjustment. A minor adjustment assumes that the liner shipping company cannot change the amount of each input at its original level, but allows labor transfer among

terminals only. A major adjustment assumes that both the total amount of labor and hauling equipment can be adjusted (reduced and increased) and transferred among terminals. However, the total amount of the other two inputs remains unchanged.

### 2.1. Minor Adjustment

-

s.t.

This model is built on the assumption of variable returns to scale (VRS) characterizations with increasing returns to scale, constant returns to scale, and decreasing returns to scale. There are two phases in the model. In the first phase, the liner shipping company tries to maximize the production of the aggregated output of all terminals without a reduction or increase in any input. In the second phase, given the optimal solution of the first phase, the minimized slack for labor is pursued.

The proposed models for the minor adjustment are as follows:

Phase I:  

$$Max \ \gamma$$
 (1)

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} x_{ij} \le \sum_{r=1}^{n} x_{ir}, i = 3 \quad \forall r$$
(2)

$$\sum_{j=1}^{n} \lambda_{jr} x_{ij} \le x_{ir}, i = 1, 2, 4 \quad \forall r$$

$$\tag{3}$$

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} y_j \ge \gamma \sum_{r=1}^{n} y_r$$
(4)

$$\sum_{i=1}^{n} \lambda_{jr} y_{j} \ge y_{r}$$
(5)

$$\sum_{i=1}^{n} \lambda_{jr} = 1 \qquad \forall r \tag{6}$$

$$\lambda_{jr} \ge 0, \quad \gamma \text{ is free}$$
 (7)

Eq. 1 pursues the optimum expansion of the aggregated output of all terminals. The adjustable input constraint as shown in Eq. 2 allows the amount of labor to be transferred among terminals. Eq. 3 ensures that the non-adjustable input is no larger than the observed aggregated input. Eq. 4 seeks to non-radially increase each output as much as possible and ensures that each output remains in the feasible aggregated output set. Eq. 5 imposes the restriction that the projected point for each terminal will be no less than the observed output quantities of the terminal. Eq. 6 shows that VRS is adopted in this model and any vector used to project DMU cannot be less than zero, as shown in Eq. 7.

Phase 2:

$$Min\sum_{r=1}^{\infty} (S_{3r}^{+} - S_{3r}^{-}) \quad (3.8.1)$$
(8)

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} x_{3j} = \sum_{r=1}^{n} (x_{3r} + S_{3r}^{+} - S_{3r}^{-}).$$
(9)

$$\sum_{j=1}^{n} \lambda_{jr} x_{ij} \le x_{ir}, i = 1, 2, 4 \quad \forall r$$

$$\tag{10}$$

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} y_{j} = \gamma^{*} \sum_{r=1}^{n} y_{r}$$
(11)

$$\sum_{j=1}^{n} \lambda_{jr} y_j \ge y_r \tag{12}$$

$$\sum_{r=1}^{n} S_{3r}^{+} = \sum_{r=1}^{n} S_{3r}^{-}$$
(13)

$$\sum_{j=1}^{n} \lambda_{jr} = 1 \quad \forall r \tag{14}$$

$$\lambda_{jr}, S_{3r}^+, S_{3r}^- \ge 0.$$
<sup>(15)</sup>

To find the minimum amount of labor that can be transferred, an objective function is provided as shown in Eq. 8. Eq. 9 helps determine whether the current aggregated amount of labor is appropriate in the centralized perspective, while Eq. 13 ensures that the total slack of the  $S_{3r}^+$  labor transferred to all terminals should be equal to the total slack of the  $S_{3r}^-$  labor transferred from all terminals. That is, Eq. 13 implies that the total amount of labor is equal to the original level. Eq. 11 can be seen as using the reallocation perspective to reach the ideal output under the CDEA perspective, and  $\gamma^*$  is the optimum of phase 1. Eq. 15 shows that the slacks and any vector for projecting DMU cannot be less than zero. Eqs. 10, 12, and 14 can be compared with Eqs. 3 and 5-6, respectively.

#### 2.2. Major Adjustment

This paper provides a further discussion regarding the major adjustment strategies of two policies: short term and long term. The short-term model is built on the assumption of the VRS of activities and the long-term model is built on the assumption of constant returns to scale (CRS).

#### 2.2.1 Short Term

There are two phases in the model as well as in the minor adjustment model. In the first phase, the liner shipping company maximizes the production of the aggregated output of all terminals without a reduction or increase in any input. Furthermore, at the maximum aggregated output obtained in Phase I, the slack variables for labor and hauling equipment are found in the second phase.

The proposed models for the short-term major adjustment are as follows:

Phase 1:  

$$\begin{array}{ll}
\text{Max } \gamma & (16) \\
\text{s.t.} & \\
\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} x_{ij} \leq \sum_{r=1}^{n} x_{ir}, i = 3, 4 \quad \forall r & (17) \\
\sum_{j=1}^{n} \lambda_{jr} x_{ij} \leq x_{ir}, i = 1, 2 \quad \forall r & (18) \\
\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} y_{j} \geq \gamma \sum_{r=1}^{n} y_{r} & (19) \\
\sum_{j=1}^{n} \lambda_{jr} y_{j} \geq y_{r} & (20) \\
\sum_{j=1}^{n} \lambda_{jr} = 1 \quad \forall r & (21) \\
\lambda_{jr} \geq 0, \quad \gamma \text{ is free} & (22)
\end{array}$$

This model is similar to the first phase model for the minor adjustment policy, and Eq. 16 and Eqs. 19-22 can be compared with Eq. 1 and Eqs. 4-7, respectively. An adjustable input constraint as in Eq. 17 allows the amount of labor and hauling equipment to move among the terminals. Eq. 18 ensures that the two non-adjustable inputs are no larger than the observed aggregated inputs.

Phase 2:

$$Max \sum_{r=1}^{n} \left(\frac{S_{3r}}{x_{3r}}\right) + \sum_{r=1}^{n} \left(\frac{S_{4r}}{x_{4r}}\right)$$
(23)

s.t.  

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} x_{3j} = \sum_{r=1}^{n} (x_{3r} - S_{3r})$$
(24)

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} x_{4j} = \sum_{r=1}^{n} (x_{4r} - S_{4r})$$
(25)

$$\sum_{j=1}^{n} \lambda_{jr} x_{ij} \le x_{ir}, i = 1, 2 \quad \forall r$$

$$\tag{26}$$

$$\sum_{r=1}^{n} \sum_{j=1}^{n} \lambda_{jr} y_{j} = \gamma^{*} \sum_{r=1}^{n} y_{r}$$
(27)

$$\sum_{j=1} \lambda_{jr} y_j \ge y_r \tag{28}$$

$$\sum_{j=1}^{n} \lambda_{jr} = 1 \quad \forall r \tag{29}$$

$$\lambda_{jr}, S_{3r}, S_{4r} \ge 0 \tag{30}$$

In this phase, given the generation of the maximum aggregated output of the first phase, the liner shipping company tries to maximize the use of the labor and hauling equipment that those terminals can reduce, as shown in Eq. 23. Because the unit of labor is different from that for hauling equipment, this paper divides the slack by each input at its original level. Eqs. 24-25 help determine if the current aggregated amounts of labor and hauling equipment are appropriate in the centralized perspective. Eqs. 26-30 can be compared to Eqs. 18, 11-12 and 14-15, respectively.

#### 2.2.2 Long Term

The proposed models for the long-term major adjustment are similar to the models for the short-term major adjustment. The difference between the long-term model and the short-term model lies in the restrictions imposed by Eqs. 21 and 29 that imply VRS. Because the long-term major adjustment is based on the assumption of constant returns to scale (CRS), the restrictions imposed by Eqs. 21 and 29 should be deleted from phase 1 and phase 2, respectively.

#### 3. Numerical Results and Discussion

#### 3.1. Input and Output Data

This paper focuses on one of the world's top 20 liner shipping companies. The company's container ships call at 109 container terminals in the world and only five of the terminals are supervised by the company. Two (named A and B) of the five exclusive terminals are in America, two (named D and E) in Asia, and only one is in Europe (named C). Data related to the year 2011 are obtained from the five exclusive container terminals.

The output variable is measured by one indicator: annual container throughput in TEU in 2011. The inputs are measured by four indicators: the marshalling yard, quay gantry cranes, labor, and hauling equipment. Here,

the marshalling yard is measured according to design capacity in TEU, because design capacity more reasonably reflects actual container terminal production empirically. For reflecting the actual operational efficiency of a terminal as accurately as possible, the quay gantry cranes input is measured in terms of the number of containers that can be handled per hour (i.e., in TEU/hr). Because there are different types of quay gantry cranes and different types have different efficiency, the efficiency of quay gantry cranes is a better measure than the number of quay gantry cranes. The labor input (which includes epibolic labor and regular employees) is measured in wages. Furthermore, the cost of labor is divided by purchasing power parity (PPP) for the year 2011, because the five exclusive container terminals are in different countries. Hauling equipment, which includes yard gantry cranes, straddle carriers, fork lifts, and container stacking cranes, is measured in terms of the number of such pieces of equipment. The efficiency of hauling equipment is important, but the necessary data are unavailable, and so this paper assumes that the different types of hauling equipment have the same efficiency. The important descriptive statistics related to the sample are summarized in Table 1.

Table 1. Summary statistics for the sample								
Variable		Output						
	Quay gantry crane	Marshalling yard	Labor	Hauling equipment	Container throughput			
Maximum	1040 TEU/hr	1,600,000 TEU	134,000,000 USD	57 items	1,260,000 TEU			
Minimum	320 TEU/hr	12,288 TEU	93,364 USD	19 items	135,000 TEU			
Mean	536 TEU/hr	712,458 TEU	32,936,295 USD	31 items	671,683 TEU			
Standard Error	311 TEU/hr	561,332 TEU	50,773,899 USD	14 items	428,698 TEU			

# Table 1: Summary statistics for the sample

### 3.2. Minor Adjustment analysis

The minor adjustment strategy aims at reallocating the labor among the exclusive container terminals, under the assumption that the labor cost remains unchanged and the other inputs are at their original levels. The results of the minor adjustment analysis are summarized in Table 2.

#### Table 2: Results of minor adjustment strategy

Uni							
Terminal	А	В	С	D	Е	Total	
Slack for labor	0	-81,591	0	0	81,591	0	

From the first phase, the output expansion value  $\gamma^*$  is 1.1045, which means that the aggregated output of the five exclusive container terminals can be increased from 3,358,416 TEUs to 3,709,370 TEUs. Table 2 shows that, without affecting the production of the maximum outputs, only terminal B requires a reduction in labor cost of 81,591 dollars and terminal E should increase its labor cost by 81,591 dollars, with terminals A, C, and D showing no changes in labor.

# *3.3. Major Adjustment analysis*

The major adjustment strategy aims to reallocate the labor and hauling equipment among the exclusive container terminals, so that labor and hauling equipment can be adjusted (reduced and increased) while the other two inputs (quay gantry cranes and the marshalling yard) remain unchanged in terms of the total number.

#### 3.3.1 Short Term

Under the assumption of VRS of activities, the results of the short-term major adjustment analysis are summarized in Table 3. From the first phase, the output expansion value  $\gamma^*$  is 1.1085, which means that the aggregated output can be increased to 3,722,848 TEUs.

Terminal	Slacks for labor	Slacks for hauling equipment		
А	-995 USD	0 items		
В	-11,906,636 USD	-15 items		
С	0 USD	0 items		
D	0 USD	0 items		
Е	0 USD	0 items		
Total	-11,907,631 USD	-15 items		

Table 3: Results for short-term major adjustment strategy

Without affecting the production of the maximum outputs, Table 3 shows that the total amount of the labor cost should be reduced by 11,907,631 dollars, while the number of pieces of hauling equipment needs to be reduced by 15. There is a need for terminal B to reduce its labor cost by 11,906,636 dollars, and terminal A could decrease its labor cost by 995 dollars. Only terminal B requires a reduction of 15 pieces of hauling equipment, while the other terminals have no need for any changes in hauling equipment.

# 3.3.2 Long Term

The results of the long-term major adjustment analysis are shown in Table 4, and are based on the assumption

of CRS for its activities. From the first phase, the output expansion value  $\gamma^*$  is 1.2568, which means that the aggregated output can be increased by 862,509 TEUs to 4,220,925 TEUs.

Tuble III	Tuble if Results for the long term major aujustment strategy							
Terminal	Slacks for labor	Slacks for hauling equipment						
А	-133,696,567 USD	5 items						
В	-11,906,636 USD	-15 items						
С	-12,710,781 USD	-12 items						
D	0 USD	0 items						
Е	-4,535,018	22 items						
Total	-162,849,001 USD	0 items						

 Table 4: Results for the long-term major adjustment strategy

Table 4 shows that the total amount of the labor cost needs to be reduced by 162,849,001 dollars, while the number of pieces of hauling equipment does not need to be changed. There is a great need for terminal A to reduce its labor cost by 133,696,567 dollars, terminal B requires a reduction in its labor cost of 11,906,636 dollars, terminal C should decrease its labor cost by 12,710,781 dollars, and terminal E needs to reduce its labor cost by 4,535,018 dollars.

Although there is no need for the overall number of pieces of hauling equipment to change, the hauling equipment needs to be reallocated among the terminals as shown in Table 4. Terminal A requires an increase of 5 items and terminal E is in need of as many as 22 items. However, terminal B should decrease the number of its items by 15 and terminal C should reduce the number of its items by 12. Only terminal D does not need any changes in hauling equipment.

# 3.4. Summary and Managerial Implications

The numerical results are presented in Table 5 which summarizes the results shown in Tables 2-4. The operations of terminal D are the most efficient, as shown in Table 5. The liner shipping company does not need to adjust any resources in terminal D, based on the minor and major adjustment scenarios.

		Slack for labo	Slack for hauling equipment		
Terminal	Minor	Major A	Adjustment	Major A	djustment
	Adjustment Short-term Long-term		Short-term	Long-term	
А	0 USD	-995 USD	-133,696,567 USD	0 items	5 items
В	-81,591 USD	-11,906,636 USD	-11,906,636 USD	-15 items	-15 items
С	0 USD	0 USD	-12,710,781 USD	0	-12 items r
D	0 USD	0 USD	0	0	0
Е	81,591 USD	0 USD	-4,535,018 USD	0	22 items
Total	0 USD	-11,907,631 USD	-162,849,001 USD	-15 items	0

Table 5: Comparison of the slack values of the different policies

Under the minor adjustment scenario, the liner shipping company can maximize the production of the aggregated output of all terminals by transferring labor from terminal B to terminal E, without any reduction or increase in any input.

Under the major adjustment scenario, the aggregated adjustable inputs (i.e., labor and hauling equipment) need to be reduced to maximize the production of the aggregated output of all terminals. In terminal A, the labor needs to be reduced under the short-term and long-term policies, and the slack in the long-term labor level is greater than that in the short-term labor level. However, in the long term, the amount of hauling equipment needs to be increased. Terminal B is the most inefficient terminal under the short-term and long-term policies, and both the labor and hauling equipment need to be reduced in the short term, but not in the long term. In terminal C, both the labor and hauling equipment need to be reduced in the long term. According to the Input-Output data, the aggregated input of terminal C is a greater than that of terminal D, but the throughput is less than one third of that of terminal D. Terminal C is a joint venture with another company and the cost distribution properly. In terminal E, the labor needs to be reduced, but the hauling equipment needs to be increased to be increased. The hauling equipment needs to be increased to be increased. The hauling equipment needs to be inefficient. The liner shipping company should deal with the cost distribution properly. In terminal E, the labor needs to be reduced, but the hauling equipment needs to be increased. The hauling equipment needs to be double that for the year 2011. This result is real reflecting the empirics, because terminal E only opened in 2011, and its inputs need to be expanded.

# 4. Conclusions

This paper presents an application of centralized data envelopment analysis (CDEA) to analyze the performance of a number of container terminals supervised by one of the world's top 20 liner shipping companies. To maintain her competitiveness in such a competitive environment, the liner shipping company needs to estimate the relative performance of its container terminals, and reallocate the input resources. This paper has utilized the CDEA models in the analysis. The numerical results show that, under the minor adjustment scenario, the optimum annual container throughput is 1.1045 times as large as that for the year 2011. Under the short-term major adjustment scenario, the optimum throughput is 1.2568 times to 4.22 million TEUs. That means that the aggregated-output of the exclusive container terminals can be expanded, while the input resources remain at their original levels.

According to the numerical results, terminal B is the most inefficient terminal under the short-term and long-term policies. In order to improve the overall efficiency of the five exclusive container terminals, the shipping company should reallocate the resources in terminal B. In terminal C, both the labor and hauling equipment are required to be reduced over the long term. As regards terminals A and E, both of them need to increase the amount of work involved in equipment hauling. The liner shipping company does not need to adjust any of its resources in terminal D.

The contribution of this paper is that it provides a systematic and centralized perspective of resource reallocation from one company's perspective. However, this paper has certain limitations. First, the same weights are used to evaluate each terminal. In other words, the importance or non-importance of each terminal is not considered. Second, external environmental factors such as container demand forecasts are excluded in

this study, which might affect the results regarding the reallocation of resources. Third, this paper assumes that the different types of hauling equipment have the same efficiency. Fourth, the cost of transferring labor and hauling equipment for resource allocation planning is ignored. The limitations mentioned above can be considered in future works.

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# A Systemic View of Container Security: A Need for Strategic Cooperative Management

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# Abstract

This paper takes a bird's eye view of our global system of container trade: how we should think about it, how we might measure it, and how we can better secure it together. Though this work is neither the first nor the last collaborative effort on this subject, we believe that existing discussions about container security are almost always tactical, myopic and fragmented. This paper strives to overcome these defects. It does so by answering the three 'how's' above from a systemic perspective, rather than from a ground-level one alone. In that way, this paper is not about securing *a* port or *the* container, but it is about examining the ways in which we can all work together to build a more secure, more resilient global *system* of container trade. By taking a systemic view, we believe that stakeholders in container security will start to think about their task in a new way, and that new, innovative and efficient operational responses will become evident. The paper ends by recommending development of a strategy based on cooperative management.

Keywords: Global Container Trade, Security, Ports, Strategic Cooperative Management and Systems.

#### 1. Introduction

The term "security" has become ubiquitous for contemporary policymaking. This has been a growing trend over the past quarter century, but has increased markedly since the end of the last century. As the gradient of traditional military threats, especially war between major powers – a euphemism for The United States of America and the erstwhile Soviet Union – receded in the minds of many analysts and policy makers, the focus shifted from international strategic matters to domestic mundane issues particularly those concerning economic growth, trade and employment.

To the old idea of collective security were added concepts of common, comprehensive and cooperative security. Confusion is bound to follow if the term is used to describe different things or conditions in differing circumstances. The question is less one of what, exactly, is security? Rather, it perhaps is better phrased as what are the different ways in which to conceive of security? And what are the implications for policy. Because most theorizing about security has not been maritime focused, it is essential to place the development of concepts of maritime security within the context of the wider security debate.

Barry Buzan (1998) has proposed that the concept of security can only be fully understood by integrating the interdependent "levels of analysis" and "issue sectors" or "dimensions" of security. Buzan's levels of analysis are individual, national and international (both regional and system-wide) security, while his issue sectors comprise military, political, societal, economic and environmental security.

International security is concerned with the systemic factors that influence the behavior of states and the consequent implications for security among states. Although states are not the only actors in the international system, they are the bodies that hold primary responsibility for providing security to their respective populations. International organizations may play supporting roles in the provision of security to various communities at different levels. Although states sometimes act under the auspices of organizations, such as

the United Nations for example, in peacekeeping or military observer missions – the forces themselves are provided by states, which maintain a monopoly on the legitimate use of force in the international system.

A majority of the global maritime trade today is conducted in containers. Containers carrying goods that are shipped in oceangoing vessels are of particular concern because they can be filled overseas at many different locations and are transported through complex logistics networks before reaching ports of destination. In addition, transporting a shipping container from its international point of origin to its final destination involves many different participants and many points of transfer. The container, or material in it, can be affected not only by the manufacturer or supplier of the material being shipped, but also by carriers who are responsible for getting the material to a port, as well as by personnel who load containers onto the ships (Burgess, J.P., 2008). Others who interact with the cargo or have access to the records of the goods being shipped include exporters who make arrangements for shipping and loading, freight consolidators who package disparate cargo into containers, and forwarders who manage and process the information about what is being loaded onto the ship (Bernhard, C., 2009).

Several studies of maritime security conducted by federal, academic, nonprofit, and business organizations have concluded that the movement of oceangoing cargo in containers is vulnerable to some form of criminal action. Every time responsibility for cargo in containers changes hands along the supply chain there is the potential for a security breach. As a result, vulnerabilities exist that criminals could take advantage of by, for example, placing a Weapon of Mass Destruction (WMD) into a container for shipment to the United States or elsewhere (OECD, 2002). While there have been no known incidents of containers being used to transport WMD, criminals have exploited containers for other illegal purposes, such as smuggling weapons, people, and illicit substances. There have been a few cases detected in different parts of the world where live explosives were transported in a container from the sea ports to the inland dry ports without the knowledge of either the customs or the dry port operator (Eriksson, Johan., 2001).

The fact that container security is a critical factor in global supply chains is universally accepted. However the methodology to measure it and the means to reduce associated risks is widely disputed (Van der Linden J.A., 2001). The disagreements become even more stringent when the tangible costs and time factors rise sharply without any clearly perceivable benefits of risk reduction. The responsibility and liability for container security failure complicates the issue even further.

Having said this becomes necessary to define what exactly is container security which is what we try to do in the following section followed by a section titled a systemic perspective of container security where in we discuss about the various options available for improvement of container security and argue why we should adopt a systemic perspective about the issue under consideration. Section 4 highlights the importance of standardizing the concept of container security followed by a discussion on developing of a strategic response and policy constraints it faces. Section 6 highlights the changes of technological biases which can creep in while developing strategic responses. Finally the last section concludes with recommending development of a cooperative strategy for container security.

# 2. Definition of Container Security

The word 'security' signifies freedom from danger or highlights the quality or state of being secure. It further denotes freedom from fear or anxiety. As far as maritime container security is concerned the objective of this noun is the cargo stuffed inside a container which is subsequently sealed by the customs/authorities who permit the onward transportation by one or more modes of transport till it reach the consignee.

Container Security has yet to find a universally accepted definition. The concept is subjective and can indirectly be defined as 'retention of safety and security of the containerized cargo as declared in the cargo manifest (in terms of value, quantity and quality) by maintaining the integrity of the Container Seal or Security Device (CSD) and non causal of third party damage.' (OECD, 2004).

The above definition signifies the importance of the following aspects:

Integrity of container seals is paramount to determining the breach of container security. In other words if the seals are intact it would be the onus of the claimant to prove failure of container security.

The cargo details stated in the cargo manifest are critical in proving breech of container security. In short it would not be possible to prove failure of container security until and unless the details of cargo stuffed in the container do not match with those stated in the manifest.

It would be left to the prudence and judgment of the customs officer on the site to decide whether or not the container security has been breached unless the claimant can provide evidence to prove otherwise.

Neither the container nor the cargo has caused third party damage even if the seals are found intact and there is absence of discrepancy with regards to cargo details declared in the manifest.

Container Security would be considered to have failed on the occurrence of any one or all of the three mentioned events viz; tampering of seals, discrepancy in cargo stuffed and manifests and directly causing third party damage.

Lastly the cargo manifest submitted to the customs by the carrier overrides all other documents such as shipping bills, bills of lading, invoices, insurance policies etc.

The maritime transport industry understands and accepts the security strategic decisions of national governments particularly the US that preventing and detecting the possible containerized transportation of unlawful and hazardous material is the number one container security priority but it is unable to build a consensus about the methodology to achieve the stated objectives; for eg: What specific thing must a container security device do? What specific events must be captured and recorded? Should it record the opening of just one door on the container or must it be able to capture either door opening? Is capturing entry through the doors enough or must it detects entry into the container through the walls, ceiling or floor? Does the device have to detect conditions other than entry intrusion?

Given the above, it becomes imperative to develop a holistic definition of container security by taking into consideration the perspectives of not only the five groups of stakeholders but also the public at large. It also becomes necessary to not to ignore the loopholes in the existing laws dealing with container security apart from the uncovered liability regimes. As such we need to review the concept of container security from a broad systemic perspective which will address myriad of issues connected with this concept.

Finally the unique feature of container security needs to be highlighted which is the potential of a seal intact container to cause third party damage to person or property or both due to a range of dangerous/hazardous goods being carried inside the container either surreptiously or blatantly. There are various means and methods to anticipate, minimize and eliminate the happening of such events which is what the following sections are all about.

# 3. A Systemic Perspective of Container Security

At a systemic level, container security is to a large extent a function of the ability of states within the international system to secure access to vital goods and resources not available domestically, through the process of international trade – mostly carried by sea. As we well know the process of trade functions most efficiently when it is relatively free. Essentially there are four broad categories of systemic responses – with a degree of unavoidable overlap - to container security which are common, collective, comprehensive and cooperative, with most emphasis being placed upon the last mentioned cooperative method.

# 3.1 Common Systemic Perspective

The term "common security" was popularized by the 1982 Palme Commission, which promoted arms control and disarmament in Europe. In particular, the Commission's report, Common Security: a Program for Disarmament, focused on ways to reduce risks of conflicts and associated dangers, asserting that the "common

risk" of conflict even nuclear wars would require efforts to "promote our security in common." Based on a working assumption that weapons posed the primary threat to peace, the Commission asserted six principles of common security which are as follows:

All nations have a legitimate right to security. Military force is not a legitimate instrument for resolving disputes between nations. Restraint is necessary in expressions of national policy. Security cannot be attained through military superiority. Reductions and qualitative limitations of armaments are necessary for common security. "Linkages" between arms negotiations and political events should be avoided.

In this context Barry Buzan had suggested that to be of practical utility, the idea "must be accompanied by innovative policy proposals that give a compelling, concrete expression to the realities of security interdependence. According to him strategic perspective "must be designed in such a way as to meet the common security objective of damping down the security dilemma by building into one's own security perceptions and the need to be sensitive to the security concerns of others. Thus the set of proposals envisaged by Buzan may be described, generally, under the broad heading of "defensiveness." The various versions of "defensive" strategies include non-offensive defense, defensive deterrence, defensive defense and, the version most favored by him and others was that of nopprovocative defense (NPD). Buzan went on to propose a novel concept called nonprovocative defense (NPD). NPD consists of making use of "non-offensive" conventional means to make compromising security "difficult and costly". The enhancement of container security could be based on similar assumptions. Implicit in these strategies is the acceptance of the idea of the so-called "offence-defense" balance, which purports to be able to identify whether the technological capability could be converted into deterrent ability. Various container security initiatives are based on such concepts.

# 3.2 Collective Systemic Perspective

Although collective security is not a new idea, the events of 9-11 led to a popular resurgence of the theme of replacing the self regulated security system with externally supervised one. The formation and of the ISPS code is the result of precisely such a thinking. Collective security, whilst acknowledging the continued role of force in world affairs, rejects self regulation and aggressively promotes formation of national alliances aimed against identifiable threats in favor of an inclusive "design for a system of world order," whereby all states, organized by some type of central body (such as the UN/IMO), would be required to resist automatically any breach/compromise/misuse of the container security (Rosenthal et al., 2001).

Such a concert-based collective security system would rely upon "a small group of major nations notably the United States to guide the operation of a regionwide security structure." A concert would, according to its proponents, capture "the advantages offered by collective security". However, the notion of a concert would require the creation of a two class security system, where the importance of maintaining positive, cooperative security relationships between the major nations/states overrides the rights and interests of other particularly smaller nations/states (Russell et al., 2003). It would be pertinent to note here that the definition of 'container security' may have different connotations to different nations/states. It would also indicate subversion of rights of smaller nations.

# 3.3 Comprehensive Systemic Perspective

Comprehensive systemic perspective is an idea that attempts to weld the many levels and dimensions of security into an overarching concept. Security in this view, therefore, must take into account individuals and sub-state communities as well as national, regional and international concerns, including the linkages between domestic and external security, and all the various forms of security covered in the earlier discussion.

However, despite widespread usage, the idea has tended to be vague and poorly defined, with several differing versions on offer and little agreement on its practical applicability across the various aspects of security. The

Council for Security Cooperation in the Asia Pacific (CSCAP) has attempted to better define the idea of comprehensive security. It defines the concept in the following terms:

'Comprehensive systemic perspective is the pursuit of sustainable security in all fields (personal, political, economic, social, cultural, military, and environmental) in both the domestic and external spheres, essentially through cooperative means. Comprehensive perspective posits that security of person, community and state is multifaceted and multidimensional in character. Ultimately security encompasses the security of all the fundamental needs, core values and vital interests of the individual and society in every field. Any significant threat to the comprehensive well-being of man, society and state, whether emanating from external sources or from within a state, is deemed a threat to security (UNCTAD, 2004).

Another common critique of comprehensive systemic perspective is that, even when considered from a purely national perspective, it is simply too broad and unfocused. Stated a different way, a concept such as comprehensive perspective that purports to be about the wellbeing of almost everything renders "security" meaningless as a distinct idea. One could probably make the case that most responsibilities of government can be treated as security issues if individual or national wellbeing is to be affected to any significant degree. Moreover, to do so would hardly aid national policy formulation or coordination: rather, it simply would ensure the meaninglessness of "security" as a policy determinant or indicator of policy prioritization.

#### 3.4 Cooperative Systemic Perspective

The most developed of the alternative concepts of security perspective, cooperative systemic perspective is also the most practical and established version on offer. The concept has been rejected by the United States, which did not wish its system of bilateral alliances weakened. In common with other alternative concepts, the cooperative security perspective concept seeks to replace old security structures with new, multilateral ones possessing the above characteristics. Yet, unlike the formalized cooperative security structure the proponents of cooperative security are of the view that a gradualist approach needs to be adopted, thereby "allowing multilateralism to develop from more ad hoc, informal, and flexible processes until the conditions for institutionalized multilateralism become more favorable." It has been suggested by Desmond Ball that due to the difficulties encountered in establishing multilateral, cooperative structures globally lead to encouragement of bilateralism over multilateralism, and informal, pragmatic and consensual approaches to decision making.

An additional characteristic of cooperative perspective is a requirement for inclusiveness. Furthermore it is deemed necessary that the process of cooperative security activities should include as many relevant actors as possible in order to smoothen the transition to multilateralism. There is little doubt that the absence of big power dominance in the cooperative security process would be a prerequisite condition for a deepening of security multilateralism yet it is impossible to envision any region-wide security system not dominated by at least one or more of the major powers to be of some relevance.

The processes envisaged by cooperative perspective proponents include the gamut of bilateral and multilateral ties not only in the traditional sectors such as security treaties and defense cooperation activities, but also across a wider range of political and economic linkages. The conceptual basis of cooperative perspective has been developed most thoroughly by Van De Voort, M., (2003), who argued that it must be geared toward reassurance, rather than deterrence; it must at best replace or at least co-exist with bilateral alliances; and it must promote both military and non-military security.

Van De Voort's acknowledgement that the idea incorporates "aspects of both common security and comprehensive security," leads to the criticism that it is "attempting to cover all the bases without risking offending anyone."The concept of cooperative security, then, suffers from a degree of ambiguity and, in common with its sister concepts, remains somewhat vague and indistinct despite, or perhaps even because of its attempts to define the concept. Dewitt further confuses the issue by asserting that "any attempt to differentiate between comprehensive, common, collective and cooperative security it runs the risk of drawing artificial boundaries.

In the realm of maritime security this type of activity has been most common with regard to developing or implementing standards, procedures and regulations in the maritime transportation sector, and to help to build capacity in developing states. This may be viewed as a bottom-up approach to security.

### 4. Standardization and Measurement of Container Security

At this stage it becomes relevant and perhaps necessary to ask a few pertinent questions relating to the subject matter under discussion. As discussed earlier the concept of security whether maritime or otherwise is very fairly ambiguous which does not lend itself easily to a precise definition or standardization. Having said that, it follows the necessity to standardize/ measure/evaluate the security systems in place and the procedures adopted as inability to do so would result in inability to benchmark and improve it which would ultimately lead to catastrophic circumstances. In this context some of the questions that come to one's mind are as under:

- Why should the standards of container security be measured?
- If so what methodology should be adopted to measure it?
- Who or which competent authority or person should be encharged with this task?
- What should be considered to be reliable sources for data?
- Which analytical process should be adopted for processing the data?
- What should be considered as a valid time frame?
- Can the inferences so drawn be considered to be standard and used as benchmarks across different geographical and varied time periods. If not then what are the available alternatives?

Assuming that standards of container security should be measured the question arises regarding the methodology that one needs to adopt to evaluate the standards of security systems in place there are, broadly speaking, two methods which are popular amongst scholars. The first method is based on constructing a questionnaire mostly using Delfi techniques or its many variants and using it conduct structured or semi structured interviews with the relevant stakeholders. The responses are then compiled and validated by making use of different structural equation models. The results are then used for evaluating standards, setting up of benchmarks and making recommendations. Though popular, this method is not short of its share of criticisms some of which appear to be fair and reasonable. The other methodology is less empirical and emphasizes the detection of what could be considered as security failures. It statistically evaluates the system as a whole. However the vulnerability of this methodology lies in defining different variables particularly those concerning security failures and availability of necessary real time information.

Coming to the next question regarding competency of persons/institutions who could be assigned the task of evaluating the security standards, there once again appear to be two answers for this question. The first being the evaluation should be conducted by an internal person/department or authority and second being that it should be conducted by an externally designated person or authority. These are a large number of reasonable and valid arguments in favor and against both options. The reasons range from confidentiality to objectivity and need for transparency. The jury is yet to come with a firm recommendation either way.

The subsequent question that begs an answer is with regards to availability of data, its adequacy, its accuracy its timeliness and lastly its verifiability. In the world of information revolution today there is as much information as there is disinformation. The efforts made to conceal information are almost symmetrically matched by efforts made to reveal it. Irrespective of motives behind the actions it can be stated unambiguously that the current environment is not conducive enough for enhancement of security standards. One possible solution could be adoption of procedures that are fairly transparent and placing all the data in the public domain.

The next question is related to the earlier question. The nature and quality of data will influence the analytical process chosen for evaluating the security standards. There are two popular analytical methods in vogue nowadays. The DEA method computes the efficiency and then ranks the facilities in an ascending order whereas the SFA method computes the ideal levels of efficiency that could be achieved with the quantum of inputs deployed and then ranks the facilities. The later method is considered more reliable than the former.

It cannot be anybody's case to suggest that the rules and regulations with regards to container security are not behind the curve. To tell the truth not only they are well behind the curve but are almost in totality reactive in nature rather than being proactive. In such circumstances the question with regards to the validity of a time period for security evaluation suggests two answers. The first being continuous and the second being periodical. In the later case we also need to ascertain the appropriateness of a suitable time frame which would be selected for conducting a periodical evaluation.

However considering the fact that the present security systems are reactive in character and are lagging behind the failure events and are also unable to anticipate and prevent them, the suitable answer for the system evaluation would be the continuous evaluation. But this would also necessitate allocation of significant resources both in terms of time and money.

The question of benchmarking security standards is extremely complex given the fact that the perceptions of individual nations vary in the extreme. Naturally the responses are also bound to fluctuate wildly from one end of the spectrum to another. In spite of this parameters for evaluation security systems beg to be standardized if not completely then at least partially. Different security systems if adopted could also simultaneously be evaluated using another set of parameters which could be based on localized empirical data variables. The inferences drawn on completion of such analysis could then be utilized to develop and implement specialized responses appropriate for the system in question.

The last question that begs an answer is should such security system evaluation be voluntary or compulsory. Considering the present circumstances it would be ideal to opt for the later solution. But considering the fact that consensus building is an extremely time consuming process, it would not be appropriate to rule out the former solution at least in the short term.

# 5. Developing a Policy Response

As part of a new policy, governments all over have added and prioritized national security to the existing portfolio of policy objectives for their respective Customs and Border Patrol (CBP) services. As participants in this wide-ranging security strategy, several CBP services have introduced new policies considered more effective in protecting against perceived existential container security threats.

On a macro basis, a security policy layer was added which did not displace the pre-9/11 policy priorities of revenue collection, conventional anti-smuggling, and trade facilitation. The revenue policy layer was and is the reality prevalent in many developing countries where the principal role of CBP is to raise money to pay for government operations by taxing imports. The anti-smuggling policy layer has the objective of deterring the border crossing of contraband: items such as narcotics and counterfeit goods. The trade facilitation policy layer was and is the notion that CBP controls should have the overriding objective of efficiency so that the flows of legitimate goods are not unnecessarily constrained. The level of emphasis of these different customs policy priorities vary from country to country.

The proposed policy shift broadly addresses expanded trade data submission requirements for economic operators early in the supply chain by opting for the following methodologies viz; enhanced risk management methods geared to security; increased use of non-intrusive container cargo scanning and the introduction of security-oriented compliant and validated trader benefits policies.

Although Al-Qaeda's 9/11 attacks did not use container transport as a delivery mechanism, U.S. policymakers in particular feared that they might in the future. The ensuing U.S. policy initiatives, described by some as "push the border outward" (Bowman 2007), are based on the contention that container and cargo inspection should take place closer to the point of export instead of the traditional import focus. This reflected both a philosophical shift to data submission requirements earlier in supply chain flows and the principle that any violent threat delivered by cargo container should be handled as far as possible from home shores.

Most governments now require container transport operators to supply CBP with cargo information in electronic form well before arrival at the place of importation and in some instances before loading at the

foreign port. CBP administrations have also expanded the list of obligatory data to be supplied for each consignment as a basis for the identification and handling of "high-risk" cargo. These new requirements are frequently sweetened by the use of risk management selectivity (dividing cargo into high security risk and low security risk) that promise trade facilitation benefits to pre-validated container transport operators.

The security-facilitation coupling has occurred because governments and intergovernmental organizations contend that container security could be more effectively pursued by adding only a bare minimum burden and inefficiencies to international trade flows. Considering this constraint the United States and other governments are in the process of developing and implementing similar security policies such as the European Commission's advance cargo information regulation called Pre-arrival / Pre-departure (2011) and the EU Authorized Economic Operator program (2008). Japan too has an advance filing regulation in respect of cargo, crew and passenger information (2007) which covers cargo arriving by sea or air to Japan. China has a 24-hour Advance Manifest Rule (2009) which mandates that for all export, import, and transshipped cargo to any Chinese port, ocean carriers must provide the manifest or the bill of lading to Chinese Customs 24 hours before loading.

Discussions continue on what and how many data elements are justifiable by CBP for effective container security analysis. Global businesses use an enormous range and volume of operational data. On the other hand there are obvious advantages to all stakeholders if procedural processing can be limited to just the minimum necessary while implementing container security policies In addition, precise risk management is a demand of the private sector, which seeks predictable, simple, and fast formalities for container transport operators who are generally compliant with international trade norms and regulations.

In response to such constraints the CBP assesses risks by selectivity, profiling, and targeting which has the potential to reduce the volume of consignments requiring intervention and thus reduce the time needed for clearance by assignment of goods and consignments to high-risk (red lane) and low-risk (green lane) categories. But selectivity becomes a non-issue if compliance nears 100% or inadequate if compliance nears 0%. In such circumstances risk minimization can be strengthened by the quality and relevance of available historical data. In reality collecting and analyzing international trade data in order to minimize the risk of container security failure is challenging because of the infrequency of relevant detections or seizures (OECD, 2004). Yet while risk minimization can be seen as a necessary foundation for CBP procedures it is our opinion that it should be fuelled not just from data gleaned from manifest and customs declarations, but also by making extensive usage of human intelligence.

# 6. Technological Bias

Use of non-intrusive inspection (NII) equipment or scanners for cargo is a prominent component of the container security paradigm. The ostensible reason for using scanners in the trade security context is to identify contraband concealed in cargo containers. Scanning equipment is expensive to acquire and maintain. Effective application also requires expert trained staff. Moreover, unless compliance is pitiably low, scanning should only be used to complement an existing risk management system that includes selectivity. There are several examples where 100% scanning is being used not for purposes of security or trade facilitation, but as a revenue generator for the state or for destination inspection companies where in some instances a fee is paid by the transport operator for every scanned container, even if it does not contain any cargo. To successfully use a scanner there should be a comprehensive understanding of its meaning, and its relationship with screening and physical inspection.

A U.S. law known as the Implementing Recommendations of the 9/11 Commission Act of 2007 (U.S. Public Law 110-53, 2007) mandates, among other things, 100 percent scanning of all U.S. bound ocean-going containerized cargo before loading the transport vessel starting in 2012. This policy in our opinion is incompatible to a great extent with the principle of selectivity in customs security controls and is contrary to balancing security and trade facilitation. 100 percent maritime cargo scanning is a distraction from policy utility and a purblind opinion that "ultimate security" is attainable.

Governments, particularly in developing countries, have expressed apprehension about the cost implications. Other concerns include maintaining the operational functioning of scanners in difficult weather conditions and logistical or spacing difficulties in certain port environments; data privacy concerns; and possible retaliation by U.S. trading partners requiring scanning of exports from the U.S. The regulation is an unfunded mandate in that no budget is allocated to compensate foreign governments and port authorities for the heavy expense of purchasing, operating, and maintaining the scanners or the private sector for the heavy costs they will suffer from the increased controls. Such impediments make it highly likely that implementation of the legislation will be indefinitely deferred, selectively enforced, or repealed.

CBP administrations have established in principle Authorized Economic Operator programs where they validate or accredit ostensibly compliant and low-risk economic operators who have met special requirements in respect of physical security of premises, hidden camera surveillance, and selective staffing and recruitment polices. In return AEOs are promised benefits, such as faster clearance of goods and fewer physical inspections. The sustainability of AEO programs faces some risks. Logic suggests that building and keeping mutual trust between customs and trade is essential in the application and sustainability of AEO programs. Trust is a requisite ingredient for collective action in any inter-sectoral relationship (Judt 2010) and for finding mutual solutions to divergent interests. Thus both sides must be perceived to be living up to the bargain for such programs to be sustainable. If the promised benefits are not perceived to be provided the bargain also runs the risk of breaking down. The eventual outcome of security-oriented AEO programs will probably depend, over time, on evaluations of their perceived successes and failures, and ultimately the strength of political and public concerns with conventional international trade operations as a likely target and instrument for nefarious elements.

In the recent past the World Customs Organization (WCO) based in Geneva has published instances of different kinds of contraband being detected in containers at various locations of the globe. According to the WCO the enforcement officers on the ground used Interface Public Member (IPM) a software tool developed by the WCO to enhance the ability of the officials to identify contraband being transported in a container by accessing key information provided by various stakeholders. This enables the officials to take smart decisions aimed at curbing transportation of contraband in containers.

However based on such success stories one cannot draw comfort of the problem of contraband transportation in containers being successfully resolved once and for all. It ironically proves exactly the opposite as the detection of a few such containers highlights the security vulnerabilities of the entire container transport system as a whole. In such circumstances one may ponder upon the number of containers that might have escaped detection. As such one needs to study the complexities within the system while attempting to diagnose the causes and their relationship with the effect apart from the precise impact on the business environment.

The Interface Public Member tool to a large extent depends on the ability of the system to transmit real time information. But this very ability to generate real time information could also be its Achilles heel as unverified and blatantly false information could get transmitted thus helping in creation of fake databases with disastrous consequences for global trade apart from wastage of valuable resources. As such the integrity of the entire system could be adversely affected and a so called smart system could not only become dumb but worse as there is a danger of being abused and manipulated.

From above it is obvious that the healthy functioning of the security system depend almost entirely on the cooperation that is extended by individual member countries. For that to happen the threat perception of individual member need to be recognized by others if not shared. Until and unless this happens it is difficult to imagine how the risks could be minimized and the security system be improved.

# 7. Conclusion

Business in the 21st century will be conducted with shifting borders as most borders will be removed through the globalization of economies, technologies and communication. Its focus will also shift as the concern for global issues is turning inward to a concern for organizational development and organizational learning.

International partnerships will become standard business practice as the uncertainties increase and immediate events demand attention.

While the developments of new approaches in container security are going swiftly, development in the conceptualization of cooperative management within international partnerships is lagging. With maritime trade becoming increasingly globalised, alliances not only between multinational firms but also institutions such as customs, railways, ports, airlines and security agencies are becoming popular. To enhance management effectiveness within international partnerships, firms and institutions need to develop their management strategies as well as their cooperative strategies.

An integrative model is proposed by developing a contingency theory using well-known theories of organizational integration. The proposed integrated model will enable multinational institutions to face critical issues and create a global strategy and a global vision, which will be necessary to operate in highly complex and rapidly changing maritime environment. This particular form of joint venture is not only important for its strategic use but also because of its ability to lower risk.

However, despite their increased popularity and strategic importance, global institutions have a high record of failure in terms of the strategic objectives of their parent countries. Many of these performance problems are found that to be related to the unique managerial requirements of such ventures. The complexity of the venture is caused by the presence of two or more parent countries or groups of countries usually of different cultures, which may be competitors as well as collaborators. It is obvious those to gain a competitive advantage by utilizing international joint ventures, parent countries need to identify the linkage and the contribution of each partner and carefully structure the multinational institutions in ways that strengthens the cooperation.



Figure 1: Conceptual model of the cooperative strategy

Beamish (2005) (as shown in the figure 1 above) has pointed out that avoidance of interest conflicts and prospects of increasing mutual benefits are important instruments to enhance the successful performance of the joint cooperative ventures. It has also been pointed out by several scholars that, an evidence of increase of the mutual benefits is able to encourage more partner cooperation. In addition, the perspectives of the joint multinational cooperative system and the influencing behavior among the partners need more attention in order to systematically understand what the sources of the cooperation problems are. The future research should proceed in this direction by emphasizing the mutual gains which can be availed by all by developing a container security system which precisely addresses such issues.

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# Redistribution of Truck Arrivals to Minimize Congestion at Container Terminals

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### Abstract

The growth of container traffic has created many problems including high traffic congestion and  $CO_2$  emission in terminal areas. Especially,  $CO_2$  emission resulting from the long waiting time of trucks at the gate and the yard of container terminals has become a serious environmental problem in most port cities. One of the operational measures to solve this problem is the truck appointment system. In the appointment system, when the truck companies send their arrival plan to the terminal, the terminal operator considers the possible congestion at the terminal and suggests changes of the submitted arrival times of trucks. This study proposes a mathematical model for optimally allocate the arrival times of trucks in a way of minimizing the total cost of trucking companies and the terminal.

Keywords: truck appointment system, container terminal, mathematical model, congestion, CO<sub>2</sub> emission

#### 1. Introduction

The growth of container throughput has led terminal operators to many challenges in using terminal facilities. The equipment is over-utilized and the storage yard in terminal is over-congested. Therefore, outside trucks have to wait at the gate or at the container yard for a long time. Especially,  $CO_2$  emission resulting from the long waiting time of trucks at the gate and the yard of container terminals has become a source of serious environmental problems in most port cities. Because of the high investment requirement, there are many obstacles in increasing the throughput and storage capacity of a terminal.

The truck appointment system is a computer software for adjusting truck appointment considering the service capacity of both the container terminal and truck companies (Figure 1). By analysing the data of the storage or retrieval containers plans, the truck appointment system estimates the workload of each yard block and adjusting truck appointment times. Every truck company has the most preferable schedule for their trucks. Therefore, if the adjusted time for a truck is not same as the originally scheduled time, the corresponding trucking company may experience inconvenience for dispatching the truck. The inconvenience is considered as one of cost terms in the objective function. The truck appointment adjusting algorithm must minimize the waiting cost of trucks and the inconvenience cost. By adjusting arrival times of trucks, the terminal aims at the reduction of the congestion in the terminal gate and yard blocks.

This paper is organized as follows: section 2 introduces the background of this study. Section 3 presents the truck appointment system. Section 4 shows results of numerical experiments. Section 5 provides conclusions.



#### Figure 1: Truck appointment system

#### 2. Background

Nowadays, a growing number of studies have been concentrated to the gate congestion at container terminals. In these studies, there are two typical approached: expanding gate capacity and managing truck arrivals. Dekker et al. (2010) proposed the concept of a chassis exchange terminal, which means an outside container storage yard where truckers can drop off and pick up containers during peak times as they do inside the terminal. The container movements between the outside yard and the terminal can be done during off-peak times. The other approach is managing truck arrival to reduce the gate congestion. Morais and Lord (2006) suggested a truck appointment system. In this paper, they considered import containers that are associated with hinterland operation in the terminal. The terminal operator announces opening hours and entry quota within each hour for arrival times of truck companies. They introduced the successful application at Port of Vancouver. However, Giuliano and O'Brien (2007) stated that "there is no evidence to suggest that truck appointment system reduced queuing at terminal gates and hence heavy diesel truck emissions".

Some authors introduced the impact of terminal operation and truck company activities to the truck appointment system. Zhao and Goodchild (2010) used a simulation to evaluate the usefulness of the information on truck arrival times in the reduction of container remarshaling. It showed that the significant benefit can be obtained even with a small amount of arrival time information. Sharif et al (2011) explored the effect of applying predictive strategies various truck dispatching for realizing steady arrivals of trucks and hence less queuing of trucks at the seaport terminal gates. Results demonstrated that the congestion at seaport terminal gates can be significantly reduced by using the provided real-time gate congestion information and some simple logics for estimating the expected truck wait time.

One of policies supporting the application of the truck appointment system is the road/toll pricing. Chen et al. (2011) reviewed about the Pier Pass Program in the Port of Los Angeles and the Port of Long Beach. The program aims at reducing the truck traffic during peak periods on major highways around the ports. A traffic mitigation fee with a fixed toll rate is charged to trucks that enter or exit the terminal gate during Monday through Friday between 3:00 AM and 6:00 PM. Chen et al (2011) used that idea to propose a two-phase optimization approach. The mathematical model in their paper is used to compute a system-optimal truck arrival pattern, and then find a desirable pattern of time-varying tolls that leads to the optimal arrival pattern. Chen et al (2013) proposed a 'vessel dependent time windows' method involving three steps to control truck arrivals. These steps are: (1) predicting truck arrivals based on the time window assignment; (2) estimating the queue length of trucks; and (3) optimizing the arrangement of time windows to minimize the total cost in the system. They used three algorithms (Genetic Algorithm (GA), a multi-society GA, and a hybrid algorithm using GA, and Simulated Annealing) to solve the optimization problem. In these papers by Chen et al. (2011, 2013), the non-stationary queuing model was applied to estimate the queuing length of trucks.

The time-dependent queuing model subdivides the time period of interest into shorter time intervals, and then applies a steady-state queuing theory formula for each queue (Chen et al, 2011). Stolletz (2008) developed a "stationary backlog-carryover approximation" approach for time-dependent queuing systems with Markovian arrivals and exponentially distributed service times (see Figure 2). Each node shows a system state  $x_t$ , the average number of customers at one time interval t. The horizontal arcs maintain the fluid balance between consecutive intervals. The customer arrival rate that is represented by (vertical) incoming arc is  $\lambda_t$  from the Poisson process. The customer discharge rate  $v_t$  is the (vertical) outgoing arc. The actual discharge rate  $v_t$  is determined by the maximum service rate  $s_t$  and the capacity utilization ratio  $\rho_t$ . An important assumption of the fluid-based approximation model is that the capacity utilization ratio  $\rho_t$  depends on the prevailing system state and the pre-specified variation coefficient of the service time distribution  $C_s$ . The analytical fluid-based approximation model is comprised of three major components, namely, a flow balance function, an exit flow function, and a time-dependent capacity utilization ratio function with a general service time distribution (M/G/1 queues), which are expressed as follows:

Flow balance function:  $x_{t+1} = x_t + \lambda_t - v_t \quad \forall t$ 

Exit flow function:  $v_t - s_t + \rho_t \le 0$   $\forall t$ 

Time-dependent capacity utilization ratio function:

$$\rho_{t} = \frac{x_{t} + 1 - \sqrt{(x_{t})^{2} + 2(C_{s})^{2} x_{t} + 1}}{1 - (C_{s})^{2}} \quad \forall t$$

#### Figure 2: Illustration of fluid-based approximation scheme (Chen et al, 2011)



Chen et al (2011) compared the traditional stationary queuing model that is applied separately to each time interval with the fluid-based model. The stationary model fails to capture the transitions in system state (i.e., queue length) between the different demand rates, and it overestimates the maximum queue length during the short congested period. Thus, while the stationary model is more suitable for estimating the queue length when the analysis horizon is long, the fluid-based approximation model more effectively represents the queue length during dynamic conditions.

This study also uses the non-stationary queuing model. This paper considers the terminal with only one outbound gate and assumes that the yard allocations of outbound containers are known. The decision-making model in this study will suggest the arrival time window for trucks to minimize the sum of the time adjustment cost and the waiting time cost.

#### 3. Mathematical Formulation

This study assumes that the berthing schedule of each vessel is known in advance. Outbound containers are delivered to the terminal before the arrival of the corresponding vessel. Outbound containers (or tasks) are transported from the shippers to the terminal by trucks. A task group is defined to be the set of delivery tasks with the same preferable delivery time window, which may be delivered to or picked up from the same yard block and are to be moved by the same trucking company. Each task group has a preferred arrival time window considering the dispatching schedule for trucks of the truck company. This paper considers the congestion in the yard. Therefore, when the yard crane in a block is busy, road trucks have to wait in the queue of the yard block. The waiting time of a truck depends on the queue length.

Considering the dispatching schedule of trucks, each trucking company submits delivery tasks and their most preferable time windows to the terminal. Then, the truck appointment system estimates queue lengths at each time interval and at each yard block and suggests the new time window for each task to minimize the change of its arrival time from the most preferable time window and the waiting cost of road trucks.

The input data and decision variables in the truck appointment system are listed here.

Notations

- *i* : index for a task group;
- *j* : index for a yard block;
- : index for a trucking company, k = 1, 2, ..., n;
- $\tau$  : index of time window
- *t* : index of time interval. Note that multiple time intervals exist in a time window.
- $b_i^l$  : earliest possible (lower) bound of the time window for task group *i*;
- $b_i^u$  : latest possible (upper) bound of the time window for task group *i*;
- $d_i$  : number of tasks to be done for task group *i*;
- $s_{k\tau}$  : number of available trucks of company k during time window  $\tau$ ;
- $p_i$  : most preferable time window at which containers of task group *i* to be stored or retrieved;
- $\mu_{jt}$  : maximum service rate of yard block j at time interval t;
- $\sigma$  : number of (approximation) interval times in one appointment time window;
- $e_i$  : coefficient of variance of service time distribution at yard block *j*.

- $a_{ij}$  : number of containers of task *i* that can be allocated to yard block *j*. Note that outbound containers for the same vessel may be allocated to more than one yard blocks;
- $w_i^+$ : unit time cost of late arrival time compared with the most preferable time window of task *i*
- $w_i^-$ : unit time cost of early arrival time compared with prefer time window of task i

 $w^y$  : unit time cost for waiting truck at yard block.

```
Sets
```

G(k) : set of task groups for trucking company k;

 $T(\tau)$  : set of time interval included in time window  $\tau$  .

Decision variables

 $\sum_{i}\sum X_{ij\tau} \ge d_i$ 

 $X_{ii\tau}$ : number of trucks for task group *i* which are deployed to yard block *j* at time window  $\tau$ ;

- $V_{it}$  : number of trucks departing from yard block *j* at time interval *t*
- $W_{it}$  : average number of trucks at block *j* at time interval *t*
- $V_{ijt}$  : number of trucks for task group *i* departing from yard block *j* at queuing model time interval *t*
- $W_{ijt}$  : average number of trucks for task group *i* at block *j* at queuing model time interval *t*

The centralized decision-making mathematical model for finding the optimal solutions of truck arrival time window is present below. (Truck Redistribution Model: TRM)

Minimize 
$$\sum_{k} \sum_{i \in G(k)} \sum_{j} \left[ w_i^* \sum_{\tau} X_{ij\tau} (\tau - p_i)^* + w_i^* \sum_{\tau} X_{ij\tau} (p_i - \tau)^* + w^y \sum_{t} (W_{ijt} + \frac{\lambda_{ijt} - V_{ijt}}{2}) \right]$$
(1)  
subject to

for all 
$$i$$
 (2)

$$\sum_{i \in G(k)} \sum_{i} X_{ij\tau} \le s_{k\tau} \qquad \text{for all } k \text{ and } \tau \qquad (3)$$

$$\sum_{\tau} X_{ij\tau} \le a_{ij} \qquad \qquad \text{for all } i \text{ and } j \qquad (4)$$

$$b_i^l \sum_j X_{ij\tau} \le \tau \sum_j X_{ij\tau} \le b_i^u \sum_j X_{ij\tau} \qquad \text{for all } i \text{ and } \tau \tag{5}$$

$$\lambda_{jt} = X_{ij\tau} / \sigma \qquad \text{for all } j, \tau \text{ and } t \in I(\tau)^{c}.$$

$$W_{j(t+1)} = W_{jt} + \lambda_{jt} - V_{jt} \qquad \text{for all } j \text{ and } t \qquad (7)$$

$$V_{jt} \le \mu_{jt} \frac{W_{jt} + 1 - \sqrt{\left(W_{jt}\right)^2 + 2\left(e_j\right)^2 W_{jt} + 1}}{1 - \left(e_j\right)^2} \qquad \text{for all } j \text{ and } t \tag{8}$$

$$\lambda_{it} = X_{it} / \sigma \qquad \text{for all } i, i, \tau \text{ and } t \in T(\tau)^{\frac{1}{2}} \tag{9}$$

$$W_{ij(t+1)} = W_{ijt} + \lambda_{ijt} - V_{ijt}$$
 for all *i*, *j* and *t* (10)  

$$V_{ijt} = V_{jt} \frac{W_{ijt} + \lambda_{ijt}}{W_{jt} + \lambda_{jt}}$$
 for all *i*, *j* and *t* (11)

$$X_{ij\tau}, \Box_{j} \Box Y_{jt}, \quad \underset{ij\tau}{?} V_{ijt} \ge \qquad \text{for all } i, j, t \text{ and } \tau \tag{12}$$

Eq. 1 is the objective function. It minimizes the lateness and the earliness cost when trucks of task group *i* arrive at yard block *j* at time  $\tau$  which may be later and earlier than the most preferable time window  $p_i$ . At each time interval *t*, the system state, which is the number of trucks waiting at each block, is considered to estimate the waiting time of each truck at each block. At each time interval *t*, the system state is affected by the length of the waiting queue,  $W_{ijt}$ , at the beginning of time interval and the arrival rate,  $\lambda_{ijt}$ , and the service rate,  $V_{ijt}$  (Figure 3).

In this mathematical model, the total number of delivered containers must satisfy the delivery demand of task group *i* (Eq. 2). The sum of trucks used by each company at any time window cannot be larger than the number of available trucks (Eq. 3). Eq. 4 ensures that the number of containers for task group *i* to be located at yard block *j* cannot be not greater than the amount of space allocated to the task group. With each task group, the terminal or truck companies may have upper bound or lower bound for time window (Eq. 5). Eq. 6 represents the relationship between decision variables and input data on the arrivals. In each time interval  $\tau$ , there are  $\sigma$  time intervals. Eqs. 7-8 are the equations from the B-PSFFA model. Stolletz (2008) proposed the time-dependent analysis of stochastic and non-stationary queuing systems. Based on a stationary backlog-carryover approximation of the time-dependent expected utilization, different approximations of the time-dependent expected queue length and the number of customers in the system are proposed in the paper.

#### Figure 3: Queuing system state



Eqs. 9-10 are used to calculate the arrival rate and the queue length of each task group. It is assumed that the service rate at a yard block for each task group depends on the queue length and the arrival rate of the corresponding task group and all the task groups at that yard block (Eq. 11). Eq. 12 indicates the domain of each decision variable.

#### 4. Computational experiments

In this section, we provide computational examples to demonstrate the performance of the TRM model. The examples are solved on a personal computer equipped with Intel® Core 2 Quad CPU and 3GB memory space. The computer code uses Lingo 11.0 as its optimization engine.

	F F					0 · · · r	-			
Task group <i>i</i>	1	2	3	4	5	6	7	8	9	10
$d_i$	5	4	6	3	3	4	5	6	3	3
$p_i$	2	3	2	2	4	1	1	3	3	4
$b_i^l$	1	2	2	1	1	1	1	2	2	2
$b_i^u$	4	4	4	4	4	2	3	4	4	4

#### Table 1: Input parameters of ten task group in the problem 2

Table 1 shows some data about ten task groups in problem 2 in Table 6. It shows the number of containers in each task group,  $d_i$ , the most preferable time window of task group  $p_i$ , the lower bound,  $b_i^l$ , and the upper bound,  $b_i^u$ , of the arrival time window. It means that the arrival time window of each task group cannot be later than the upper bound and earlier than the lower bound of the time window.

Tuble 2. If fundble number of trucks in the truck companies					
Time window		1	2	3	4
Truck company	1	3	5	6	4
	2	7	4	1	5
	3	6	1	2	4
	4	3	4	3	4

 Table 2: Available number of trucks in the truck companies

In this problem, there are 4 truck companies and 5 yard blocks, and 4 time windows as the planning horizon. The number of available trucks in each truck company at each time window is presented in Table 2. Table 3 shows the yard allocation for every task group. Values of input parameters such as the service rate of yard
blocks, and various cost parameters are listed in Table 4. The set of task groups of company k, G(k), and set of time interval included in time window  $\tau$ ,  $T(\tau)$ , are given below.

 $G(k) = \{1, 5, 9\}, \{2, 6, 10\}, \{3, 7\}, \{4, 8\}, \text{ for } k = 1, 2, 3, 4, \text{ and}$  $T(\tau) = \{1, 2, 3, 4\}, \{5, 6, 7, 8\}, \{9, 10, 11, 12\}, \{13, 14, 15, 16\}.$ 

Table 5: 5	pace anoc	cated to	each ta	аѕк дгоі	ıp
Yard block	1	2	3	4	5
Task 1	5	0	0	0	0
2	0	4	0	0	0
3	4	0	2	0	0
4	0	0	0	3	0
5	0	3	0	0	0
6	0	0	4	0	0
7	0	2	0	3	0
8	0	0	1	0	5
9	1	2	0	0	0
10	0	0	0	3	0

## Table 3: Space allocated to each task group

#### Table 4: Input parameters for problem 2

Input parameters	Value
$\mu_{_{jt}}$	2
σ	4
$e_i$	0.01
$W_i^+$	1
W <sub>i</sub> <sup>-</sup>	4
$w^{\mathcal{V}}$	3

To derive an optimal solution for problem 2, the nonlinear programming model, TRM, of section 3 is solved. The computational results for problem 2 are summarized in Table 5. The optimal solution  $X_{ij\tau}$  is the number of trucks for task group *i* which are deployed to yard block *j* at time window  $\tau$ . In the table, the number of trucks that transports containers for task group 10 and are deployed to yard block 4 at time window 4 is 3. With task group 9, there is one arrival truck in yard block 1 and two arrivals of trucks at yard block 2 at time window 3. The objective value was 134.55 and the computer time (CPU time) is 565 seconds.

To compare the performance of the optimization model with that of the traditional approach, we estimated the performance of the system in which each truck company sends their trucks to the terminal without information from the other truck companies and the terminal. For the traditional approach, it is assumed that the truck companies submit their applications of the arrivals at the terminal based on the preferable time windows. If the number of available trucks at a truck company is not enough to satisfy the demand of customers, then some tasks have to be performed later or earlier than their most preferable time windows. The appointment time of each task is adjusted in a way of minimizing the cost increase from delaying or advancing the arrival time each task group and satisfying the constraint about the maximum number of available trucks, the latest possible bound, and earliest possible bound of the time window for each task group. The truck arrival rate and the truck service rate at each yard block are estimated by the same method as in the TRM model.

Table 5 compares the solution of the traditional approach with that of the TRM model. Both solutions satisfy the constraint on the number of available trucks but are different from each other. Table 6 compares the cost of adjusting arrival times cost and the queuing cost of two solutions. In this problem, the cost of delaying and advancing the arrival time by one hour,  $w_i^+$  and  $w_i^-$ , are set to be 1,000 Korean won/truck/hour (won) and 4,000 won/truck/hour, respectively. The waiting unit cost  $w^y$  of truck at yard block is set to be 3,000 won/truck/15 minutes. The total cost of the solution for 42 arrival trucks (10 task groups) with traditional approach is 155,310 won and the objective value from TRM's solution is 134,550 won. The traditional

approach incurs lower costs of delaying or advancing arrival times of trucks but a higher waiting cost of trucks than the TRM model because the traditional approach does not consider the number of trucks from other trucking companies. Note that the total cost was reduced by 13% by applying the TRM model. The TRM model provided the solution reducing the total cost by about 20,000 Korean won for 42 arrival trucks in 4 hours.

	Traditio	nal approach		Optimal solution from TRM					
Task i	Yard j	Time window $\tau$	window $\tau$ $X_{ij\tau}$ Task <i>i</i> Yard <i>j</i> Time window $\tau$						
1	1	2	5	1	1	2	2		
				1	1	3	3		
2	2	3	1	2	2	2	1		
2	2	4	3	2	2	3	1		
				2	2	4	2		
3	1	2	1	3	1	4	4		
3	1	3	2	3	3	2	1		
3	1	4	1	3	3	3	1		
3	3	4	2						
4	4	2	3	4	4	2	3		
5	2	4	3	5	2	4	3		
6	3	1	4	6	3	1	2		
				6	3	2	2		
7	2	1	2	7	2	1	2		
7	4	1	3	7	4	1	2		
				7	4	3	1		
8	3	3	1	8	3	3	1		
8	5	3	2	8	5	3	2		
8	5	4	3	8	5	4	3		
9	1	3	1	9	1	3	1		
9	2	3	2	9	2	3	2		
10	4	2	1	10	4	4	3		
10	4	4	2						
	Objective	value: 155.32			Objective	e value: 134.55			

Table 5: Comparison between the solutions of the traditional approach and the TRM model for
problem 2

Table 6: Com	paring the	objective val	ue of tradition	al solution and	<b>TRM's solution</b>	for problem 2

Cost terms	Traditional approach	Solution from TRM
Cost of delaying arrival time	14.0	23.0
Cost of advancing arrival time	8.0	4.0
Waiting cost	133.3	107.5
Total cost	155.3	134.5

Table 7 shows the features of five problems solved as numerical experiments, which are different from each other in the problem size and the computational time. The computation time for Lingo solver increased exponentially with an increase in the problem size. Problem 5 assumed 5 truck companies, 10 yard blocks, 20 task groups, 8 time windows, 32 time intervals, and the maximum number of containers in one task of 10. The computation time for problem 5 was around 28 hours. Lingo solver would not be a practical tool to solve the larger sized problems. The results of solving 5 problems are summarized in Table 8. The objective value was improved by 15% on average by applying TRM model compared with the traditional approach.

No.	Number of	Number of	Number of	Number	Number	Max. no. of	CPU time
	truck	yard blocks	time	of time	of task	containers per	(seconds)
	companies	-	windows	intervals	groups	task group	
1	3 1	4	4	8	7	2	401
2	4 4	5	4	16	10	6	565
3	4 5	5	4	16	10	6	524
4	4 3	6	5	20	10	8	17,982
5	5 2	10	8	32	20	10	102,129

**Table 7: Computational times for various problems** 

## Table 8: Comparing the objective value of traditional solution and TRM's solution

No.	Traditional solution	Optimal solution from TRM	% of improvement
1	66.4	41.3	38
2	155.3	134.5	13
3	154.0	126.1	18
4	341.5	332.1	3
5	483.0	460.9	5
		Average	15

#### 5. Conclusions

The traffic congestion in container terminal areas is becoming a common problem in most of ports. As one of effective methods to reduce the gate and yard congestion, the truck appointment system has been suggested. This paper addressed a problem formulation for suggesting changes of appointment times for trucking companies. Our approach utilizes a non-linear mathematical model for the terminal operator. The model supports the reallocation of truck arrival times in a way of minimizing the total cost including the cost of adjusting arrival times and the waiting cost of trucks in the yard. The method in this study attempts to realize the situation where the arrival times for trucks are uniformly distributed and the congestion in terminal gates and yard blocks are minimized.

A non-linear integer programming model was developed and a numerical experiment was done for evaluating the mathematical model. The numerical experiment showed that the mathematical model in this study can improve the objective value by about 15% compared with a traditional approach in which each trucking company applies the appointment times independently.

The mathematical model in this study is a non-linear integer programming model. It is difficult to get optimal solution in a short time by using Lingo commercial software. Therefore, finding a suitable algorithm to solve the model in a reasonable time even for larger practical problems is one of future research topics.

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# Indexing Container Freight Rates: A Step towards a Market Pricing Stability Mechanism

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#### Abstract

Container freight rates have become increasingly volatile in recent years due to a mix of exogenous market factors (e.g. swings in the global economy) and endogenous factors (e.g. vessel capacity strategies of shipping lines). The risks and uncertainty linked to persistent freight rates volatility are a clear incentive for container shipping lines to consider alternative forms of shipper-carrier contracting arrangements and new measures to face such volatility. We argue that index-linked service contracts along with hedging strategies and the use of derivatives markets could help the container shipping industry to face market uncertainty. Such tools could help carriers to focus more on service levels than freight rates. However, without a credible and concrete freight benchmark, such step could prove to be troublesome. The introduction of Shanghai Containerized Freight Index (SCFI), followed by the World Container Index (WCI) and other container indices was a necessary step towards a new container freight market mechanism; although a lot of arguments exist against the way some of these indices are constructed. So the indices will have to reach a stage of maturity in the coming years, thereby opening the way to a broader applicability of the benchmarks in shipper/carrier relations. This paper aims to critically discuss the index-linked service agreements models, their effectiveness in dealing with freight rates volatility, the recently emerged freight indices and their methodologies. We do so by examining the Indexed-Linked Container Contracts (ILCCs) models, variants used along with the ILCCs models to mitigate freight volatility exposure, and container freight indices. The critical analysis particularly focuses on the base data collection methods used and the aggregation methods deployed to obtain overall indices.

Keywords: Container freight rates volatility - Indexed-Linked Container Contracts - Freight Indices - Hedging, Derivatives

#### 1. Introduction

Some industry analysts suggest that container freight rates extreme volatility will continue to be a feature of container shipping, given the uncertain economic outlook and changing characteristics of the industry. Old tools such as fixed price service agreements used by the industry have failed to face the turbulent nature of the business.

A clear example was when the global economic crisis hit the world in late 2008. Fixed price service agreements faced a tremendous pressure due to the collapse in freight rates. From that point onward a need for new measures was felt. The introduction of the Index-Linked Container Contracts along with the use of hedging techniques started to draw the attention of industry players. The introduction of the first container freight derivative market by early 2010 was a sign that the industry was about to change. The first step was taken by Clarkson Securities (CSL). In January 2010, the first trade of what it calls the Container Freight Swap Agreement took place between Morgan Stanley and Delphis, a container ship operator that owns a

European feeder line. The swap agreement was settled against the Shanghai Containerized Freight Index (SCFI) of average weekly spot rates.

The aim of the paper is to critically discuss (1) Indexed-Linked Container Contracts (ILCCs) models; (2) variants used along with the ILCCs models to mitigate freight volatility exposure, and (3) container freight indices.

The critical analysis particularly focuses on the base data collection methods used and the aggregation methods deployed to obtain overall indices. In particular, the paper is structured as following. After an introduction on the recent volatility in the container freight market, the paper is divided into two sections. The first section discusses the basic Indexed-Linked Container contracts (ILCCs) models. Then, we highlight the existing variants used along with the ILCCs to mitigate freight volatility. In the second section, we critically discuss the emerging container freight indices such as the Shanghai Containerized Freight Index (SCFI), the World Container Index (WCI) and their methodologies. The paper ends with conclusions and avenues for future research.

## 2. Freight Rates Volatility in Container Shipping

The shipping industry, including the container liner shipping, is a cyclical business. History shows such cycles typically last four to six years. However, more recently cycles seem to have shortened to only 6 to 18 months (see Figure 1).



Source: SCFI - Shanghai Shipping Exchange (SSE)

Between the years 1997 and 2008, global container trade witnessed an average growth of 9% per year, with 6 years of consecutive double digit growth between 2002 and 2007. This boom which carriers enjoyed abruptly ended in late 2008 when the global economic and financial crisis started to unfold. The 20 billion USD carriers' losses in 2009 clearly demonstrate to what extent shipping lines have been affected by the economic crisis.

Due to measures taken by carriers, such as cutting down capacity, postponement or cancelling of new building orders and slow steaming, a relative recovery has been witnessed in 2010. The aggregate earnings in container liner shipping, 17 billion USD in 2010, tempted many carriers to redeploy most of their idle capacity and to resume vessel orders, thereby increasing the risks for a downward pressure on freight rates. In early 2011 carriers engaged in a rate war especially on the Asia-Europe trade. The resulting sharp fall in freight rates particularly at the end of 2011 pushed carriers to a joint loss of an estimated 8 billion USD. In 2012 carriers introduced a series of general rate increases (GRI) that pushed freight rates up by more than 200 percent on the Asia-Europe trade and 80 percent on the eastbound trans-pacific trade by the beginning of the summer.

The year 2013 started promising for carriers with high spot rates and low bunker prices than a year earlier. However, shipping lines still have to face a weak demand due to the continuing economic slowdown and significant new vessel capacity entering the market in the coming years. According to Drewry Annual Container Market Review published in October 2012, the world container fleet is estimated to increase by 7.3 percent in 2013 after scrapping and delays in deliveries. The new vessels that are brought into the market mostly have a unit capacity of over 10,000 TEU, which will primarily be deployed on the Asia-Europe trade, while Europe and the US are struggling from the recessionary conditions leading to a fall in demand in these markets.

The measures taken by carriers to restore freight rates to profitable levels, such as the reduction of excess capacity and slow steaming, appear not to be sufficient to overcome the dramatic market volatility of the past few years.

Recent extreme market volatility cannot be treated as a short term phenomenon; some of the industry analysts such as Alphaliner, Clarkson and Drewry suggest it will be a trade mark for the container shipping for the coming decade. They predict that the market lows will be worse than in the past and the peaks period will become shorter and shorter. Such extreme and increasing volatility is a product of exogenous factors and developments (e.g. world economic conditions, trade dynamics, and political conditions) and endogenous factors (e.g. investment and allocation decisions by shipping lines), see Randers and Goluke (2007).

Container freight rates depend on the balance between supply and demand of shipping capacity. Whenever demand exceeds supply, capacity tightens pushing up freight rates and vise versa. Historically, supply and demand rarely have been in balance as it is difficult for carriers to predict the demand needs over the lengthy vessel building cycle. During that period demand conditions can change dramatically.

Traditionally, service contracts are one of the commercial tools used by carriers and shippers to shield themselves from freight rates volatility. These fixed rate agreements have existed as the best method for both sides to secure forward freight rates and also secure shipping capacity and equipment/cargo volumes.

However, during the economic crisis which hit in late 2008 freight agreements proved not to be watertight enough to achieve the objective of securing stable revenue streams for carriers or higher service levels for shippers, whenever freight rates move significantly in either direction. Carriers need to restore rates by imposing surcharges to guarantee space or cargo being rolled-over when rates increase. This practice leads to shippers' frustration as they have a binding contract in hand with certain volumes at a fixed rate. Whenever freight rates decrease, shippers put pressure on carriers to move volumes to competitors offering cheaper rates to stay competitive with their rivals. As a result, rates are amended to lower levels. In turn, carriers become frustrated as they incur lower revenue streams.

Gaps between spot and contract rates put great pressure on service agreements. As such, a need is felt to develop new contractual structures which protect both carriers and shippers from extreme market movements.

Index-Linked Container Contracts (ILCCs) or floating rate freight agreements are a way to avoid such pressure. Shippers and carriers agree to tie their contract rate to one of the recently emerged indices that are publicly available. Such tool allows the rates in the service agreements to follow market fluctuations. In the next section we examine (ILCCs) models and the different variants used to smooth out market fluctuations.

## 3. Index-Linked Container Contracts (ILCCs)

Freight rates volatility is not a new trend in the shipping industry. A key issue is how carriers and shippers react to such volatility. Carriers have to accept a decline in their profits when freight rates are pushed down. On the other hand shippers have to accept to pay more to move their cargo when freight rates move up. They seem to have one common thought: they should be concerned about service levels, not only price. However, none of the parties is doing so under the existing circumstances.

ILCCs in its basic sense allow service contract rate to fluctuate according to a change of an agreed price index, besides any other agreed criteria. Such practice helps to avoid endless price negotiations, to save time and administrative costs, to reduce the risk of parties defaulting. Moreover, ILCCs allow parties to focus on the service level. ILCCs do not exclude price negotiations between carriers and shippers. They just reduce the frequency of such negotiations: the parties involved mainly negotiate the initial or the base price, discount levels off the agreed index, contract duration and volume commitment along with any other service commitments. Afterwards, the parties do not need to get involved in any price negotiation during the contract duration.

ILCCs to a certain extent differ from fixed price service contracts in its negotiation process. Parties initially need to agree on the following:

- Scope of traffic
- Contract period
- External index
- Base rate
- Rate discount and adjustment mechanism
- Parties service commitment



*Source: Drewry Supply Chain advisor* Note: The red line is the contract rate, blue line represents the index

The negotiation starts similarly to fixed price service agreements. Carrier and shipper agree on the trade lane and volume to be moved. The initial rate could be determined according to a tender or one of the external indices. The contract period preferable is longer than one year. The external index to link the price movement to, and the adjustment mechanism will be discussed in a later section of this paper. Figure 2 illustrates the basic mechanism in ILCCs, i.e. the contract rate indicated by the red line follows the index rate evolution indicated by the blue line over the contract lifetime. There are two basic models for ILCCs: the time lag model and the real time model.

#### 3.1 Time Lag Model

The time lag model adjusts the future contract rate based on a past change in the index over an agreed period of time. For example, quarter one will set the rate for quarter two and so on.

Figure 3 illustrates the time lag model mechanism. The carrier and shipper agree on the initial rate which could be determined by a tender or according to an external index. The rate is reviewed on a quarterly basis giving a one quarter lag time. The set rate will be fixed according to the change in the index average.





Source: Drewry Supply Chain advisor



Source: Drewry Supply Chain advisor

## 3.2 Real Time Model

The real time model allows the contract rate to vary with the spot changes in the index. In most cases, a discount on the index price is agreed either in numeric or percentage terms (e.g. US\$100/TEU or -10%).

Figure 4 illustrates the real time model mechanism. The carrier and shipper agree on the initial rate which could be determined by a tender or according to an external index. The rate is reviewed on a monthly basis according to the spot movement of the external index. The set rate will be fixed according to the change in the index average.

## 3.3 Index-Linked Contract Models Compared to fixed price service agreements

Fixed price service agreements have existed for long time as the best method for both sides to secure forward freight rates and also secure shipping capacity and equipment/cargo volumes. However the pressure such agreements faced recently, due to the increased market volatility, revealed the fact their ability to effectively deliver their objective. Moreover, the lengthy and frequent price retender and review process. Fixed price service agreements are determined by complexity and inflexibility.

On the other hand, The Real Time model considered the best approach for securing space/volume as the model allows contract rates to be in almost a perfect synchronization with the spot market rates. Thus, such model eliminates any risk of volume shift to other rival or cargo to be rolled over. Meanwhile, time lag model

is less efficient in terms of the space/volume security as there are always a time lag between the spot rate and the contract rate adjustment. However, both models are easier in terms of their administrative process, simplifying and removing cost from the tender process. Moreover, longer term contracts reduce the need to retender, giving further tender cost reduction for both parties. Real Time model in general is the easiest to administer, thus they more efficient to simplify the on-going contract management process.

Both models allow the contract rate to follow the freight market movements giving more room for a focus on service levels rather than price. However, the risk exposure to market volatility still exists in both models which contradict with their objective in the first place. This effect is greater in the real time model as the contract rate fluctuates instantly with the market rate. Some variants are used to reduce such risk exposure and help to smooth out contract rate variation. These variants are discussed in the next section.

## *3.4 ILCCs Model Variants*

Variants which could be used along with the ILCCs models to help to reduce the risk exposure to freight volatility include dampeners, floor & ceilings, triggers, Drewry's SMART model and hedging.

- *Dampeners* allow a change in the contract rate relative to the change in the external index, e.g. a 50% dampener means a 20% change in the index will allow the contract rate to be adjusted by 10%, helping to smooth out contract rate fluctuation over the contract lifetime.
- *Floor & Ceiling* involves the setting of upper and lower values for the contract rate over the lifetime of the contract. Although such a technique has been very popular, it does not provide predictability of future rate movements. If the difference between floor and ceiling is too wide, a strong exposure to market volatility cannot be avoided. On the other hand, if the difference is too narrow it may lead to an increase in the divergence between the contract rate and spot market.
- *Triggers* imply delays in any contract rate adjustments till the index breaches a pre-agreed threshold. Such a technique could help to reduce the frequency of rate adjustments; however, it does not help enough to avoid extreme market movements.
- *Drewry Stable Market-Adjusted Rate Term (SMART) model* is a model developed by Drewry based on a combination of a floor and ceiling along with trigger points (Figure 5).



#### Figure 5: Drewry SMART model

Source: Drewry Freight rates report 2011

• *Hedging:* carriers and shippers could hedge their positions (which involve a strategy to reduce price fluctuation for an underlying asset) in the derivatives market (which is a market trading financial contract between two parties that settle against a benchmark index of underlying physical market) against freight market seasonal movements (Container freight derivatives seminar, London 2011).

Carriers, who agree on a service contract linked to an index, will hedge their position against a drop in the spot rate market. In the case of a drop, the carrier will offset the cash made from his derivatives contract against the spot rate drop in the physical market.





At the opposite position, shippers will hedge their position against a rise in the spot market. In the case of a rise, they will offset the cash made from the derivative market against the increase in the spot rate in the physical market. However, in order for the hedging approaches to be efficient, the real time model should be applied.





## 3.5 Index-Linked Contract Models' variants Compared

Dampeners and Floor & Ceiling help to reduce risk exposure to market volatility. However, they could cause an increase in the gap between contract rate and spot market. Triggers have almost no effect on the risk exposure, but they reduce the frequency of rate adjustments leading to a higher level of simplicity in the administrative process. In contrast with the above, the Drewry's SMART model can achieve a reduction of risk exposure, but more efforts on the administrative side are needed to manage any risk exposure to freight rates volatility.

Hedging is considered the best approach of the above variants. However, hedging is still less attractive for most of the industry players especially carriers. Carriers' idea about hedging and the use of derivatives is that it could attract speculators to the industry leading to more volatility to the market. We argue that the container trade involves a high number of small and medium-sized shippers, and scores of global liner companies. As the carriers are enjoying the upper hand in terms of business scale, derivatives might challenge their control on freight rates.

The pressure of the increasingly competitive global logistics industry requires higher service levels along with a competitive low cost for shippers. Such pressure created the need for a new risk management tool, other than the fixed rate contracts which were the optimum tool to face freight volatility. The shortcomings of the annual contract system during the global economic crisis highlighted the need for a greater predictability of container shipping rates and the need for hedging. The recent focus on the transition from fixed rate long-term service contracts to ILCCs could help to reduce the pressure on such contracts and accordingly on the carrier/shipper commercial relationship. Such a transition could help carriers to focus more on service levels than freight rates. However, without a credible and concrete freight benchmarking, such step could prove to be troublesome. Few indices have emerged in the last three years such SCFI and WCI among others which will be the focus in the next section highlighting their methodology and role to promote the use of ILCCs and hedging strategies.

## 4. Container Freight Indices

In the last three years a few container freight indices have emerged. Their objective is to reflect the ups and downs in the container freight market and to serve as a reference in decision-making for shipping and trade. In this section we discuss a few of these emerging indices together with their structure and respective methodologies.

#### 4.1 The Shanghai Containerized Freight Index (SCFI)

SCFI is a weekly index produced by the Shanghai Shipping Exchange (SSE). SCFI was launched officially in October 2009 to replace the original SCFI issued on December 7, 2005. It covers 15 major trade lanes ex. Shanghai. Each of these lanes is given a weight in order to calculate the comprehensive index. Each route is given a USD rate per TEU or FEU depending on the trade lane. It represents the current spot market CY/CY rate of exporting TEU/FEU of general cargo, including all possible surcharges, but excluding the Terminal Handling Charges (THC). The SCFI is not influenced by ship type, ship age, carrier or transport volume.

$$P_i = \sum_{j=1}^n P_{ij} / n$$

i = route, j = sampling company, n = number of sampling companies on the route i

$$I = \sum_{i=1}^{m} (P_i * W_i / P_{i0}) * 1000$$

i = route, m = number of the route, Wi = weighting of route i The basis comprehensive index is 1,000 points with October 16th 2009 as the base period

Market assessments gathered from samples of both sides of the market are used in order to make sure the average price is neutral. Sixteen panelists of liner companies and eighteen panelists of Chinese shippers/freight forwarders provide the freight information.

#### 4.2 The World Container Index (WCI)

In September 2011, Drewry Shipping Consultants and Clear Trade Exchange launched the World Container Index (WCI). WCI reports individual market prices for 11 major East-West container shipping routes. A composite index of the 11 routes indices weighted for the volume on each of the routes is reported each week covering trade in both directions between Asia, North America and Europe (Figure 6).



Market assessments are based on the value of actual agreed spot freight rates between major carriers and shippers or freight forwarders excluding rates from quotes, tariffs, estimates, bids or offers. Data is collected from 13 anonymous and volunteering market intermediates panellists (freight forwarders/ NVOCCs) located in Asia (3 panellists), North America (5 panellists) and Europe (2 panellists) besides 3 global companies.

Freight rates are reported per fully loaded standard FEU of general cargo, including BAF and all other applicable surcharges, plus THC when it is a common market practice to include them as the case in US ports,

but excluding any surcharges related to inland transportation. A minimum number of 16 market assessments are gathered for each route per week with validity of not less than 7 calendar days and not more than 1 calendar month from the date the assessment is reported. In practice that means very small or large shipments will be excluded from the assessment.

The median of all rates submitted is calculated. Any rate more than 20% above or below this median is excluded. The complying rates are sorted into reports for the specific carriers monitored. The mathematical average rate for each carrier monitored is reported. The mathematical average of all individual carriers is calculated producing the final WCI rate for that route for that week (Figure 7).



**Figure 7: WCI route index methodology** 

Source: WCI

## 4.3 The Transpacific Stabilization Agreement Revenue Index (TSA)

TSA is a revenue index developed by the Transpacific Stabilization Agreement, released in August 2011. The index tracks the average revenue per FEU from Asia to the US west coast and to the East and Gulf coasts for TSA's membership of 15 major carriers, which account for the major vessel capacity and cargo carried from Asia to the US. The market assessment is based on contracted rates along with NVOCC and 3PL spot shipments. The index includes in its structure all the non-floating surcharges such as THC and documentation. However, it excludes any floating surcharge like the BAF. TSA was developed specifically for shippers to be used as a freight guideline for negotiation and the setting up of long-term service contracts with carriers (Figure 8).



June 2008 has been determined to be the baseline month, with a value of 100 *Source: TSA* 

The market assessment is collected from 12 of 15 TSA carriers. They submit their average revenue per FEU for the total TSA trade scope – with separate totals to the US West Coast and to the US East Coast/Gulf. The average revenue is provided by each carrier in US dollar terms. The collected average revenues are aggregated to develop the index. A weighting is applied to each carrier's submission based upon their relative cargo volume for that month. Such weighting is reviewed monthly.

## 4.4 The Container Trade Statistics Index (CTS)

CTS provides monthly contract and spot rates via Aggregated Price Indices based on the weighted average of the sea freight rates including all surcharges and ancillary charges, but excluding inland haulage per trade route and direction (Figure 9). Moreover the CTS price indices are split by type of equipment, i.e. dry and reefer containers.



## 4.5 Strengths and weaknesses of freights indices

Since the day it was lunched SCFI received a lot of criticism from the industry executives. The inclusion of both sides of the market as panellists raised some serious questions about whether one side is trying to skew the index in its favour. However, submissions of panellists are not shared and only transmitted to the SSE, making collusive behaviour difficult. Any submissions above or below the mean by a certain percentage should be justified and recorded. However, carriers complain about the involvement of a number of anonymous Chinese freight forwarders and about the "speculative nature" of the tool not based on concrete data. We argue that the container freight market does not involve only large carriers and shippers: it accommodates a high number of other medium-sized to small users. Such a sector is more reactive and sensitive to market fluctuations giving the real market essence to the index, besides, the inclusion of only Chinese companies makes a lot of sense as the index represent only exports ex Shanghai to different routes. However, the index represents only a specific market segment, making it somehow difficult for other users to link their business to it or to take it as a guide. They have to ensure a perfect correlation between the freight patterns on their trade routes and the SCFI.

On the other hand, WCI to a certain extent managed to avoid some of the weaknesses of SCFI. Market reporters are based in different countries to ensure a differentiated presentation of market rates. The non-inclusion of carriers among the panellists, make it very difficult for a market reporter to deliberately skew the index to their favour. WCI represents different major east-west routes and is not focused on a specific port of origin. The non-disclosure of the identity of the market reporters plays a key role in avoiding the risk of carriers trying to manipulate the index by agreeing on artificial rates with any of the market reporters. Also, the inclusion of the backhaul routes in WCI provides more practicality. However, the use of only FEU rates in market assessments is not helpful for TEU users if the offsetting between TEU and FEU rates is not constant as is the case on some trade lanes.

While SCFI and WCI depends on the spot rates for constructing their indices TSA and CTS depends on both spot and contract rates data. Many carriers prefer such approach to a certain extent as they believe it is more in tune with the real market as it provides both spot and contract rates. Meantime, the non-inclusion of the

floating surcharges in the TSA such as BAF because they fluctuate along with fuel prices, is a point to be credited to TSA over the other indices including the BAF surcharges in their index figures. We argue that the inclusion of BAF one of the flaws makes the other indices greatly dependent on oil prices. Another point of strength could be taken into consideration; the CTS price indices are split by type of equipment, which give it more practicality to users than other indices.

A few years ago freight indices were not a recognizable word in container shipping. At present, carriers, shippers and logistics service providers can fall on a handful of them. When it comes to index selection we argue the more the index is reflecting the spot market the more it is delivering on its objective. Such opinion may take the side of some indices over others as it suggests that the indices based on spot rates are better than the methods largely based on both spot and contract rates. Market participants do not agree on which index is to be preferred. However, if all parties are well informed about how the index works and what value the index can add to their business, then they can agree on an index to link their contracts to or they can create their own index<sup>i</sup>.

The main objective of freight indices is to reflect freight market highs and lows responding to the supply/demand mechanism. To prove such point we ran a simple analysis on two data sets from WCI and SCFI over the same period of time (Table 1). In spite of the fact that the two indices use a different structure and methodology, both are using spot rates. We found both sets of data are 0.94 correlated (Figure 10) and if we excluded WCI figures in both weeks when SCFI were not published the correlation reaches 0.98. Such simple analysis gives some credit to attempts to benchmark container freight rates; although arguments still exist against the way some of these indices are constructed. We believe the indices will need some time to reach a stage of maturity in the coming years, thereby opening the way to a broader applicability and acceptability of these benchmarks in shipper/carrier relations.

			(WCI)	(SCFI)					
Year	Week	Date	Composite	Date	Composite				
2011	25	23-Jun-11	1538.79	24-Jun-11	1024.77				
2011	26	30-Jun-11	1590.70	1-Jul-11	1030.85				
2011	27	7-Jul-11	1578.20	8-Jul-11	1030.64				
2011	28	14-Jul-11	1587.66	15-Jul-11	1016.87				
2011	29	21-Jul-11	1580.13	22-Jul-11	1009.30				
2011	30	28-Jul-11	1560.39	29-Jul-11	1013.06				
2011	31	4-Aug-11	1598.43	5-Aug-11	1019.16				
2011	32	11-Aug-11	1598.43	12-Aug-11	1033.24				
2011	33	18-Aug-11	1719.84	19-Aug-11	1064.10				
2011	34	25-Aug-11	1745.99	26-Aug-11	1064.26				
2011	35	1-Sep-11	1685.45	2-Sep-11	1057.11				
2011	36	8-Sep-11	1653.42	9-Sep-11	1041.26				
2011	37	15-Sep-11	1624.90	16-Sep-11	1020.38				
2011	38	22-Sep-11	1580.96	23-Sep-11	991.34				
2011	39	29-Sep-11	1542.97	30-Sep-11	973.73				
2011	40	6-Oct-11	1507.24	7-Oct-11	0.00				
2011	41	13-Oct-11	1462.37	14-Oct-11	947.54				
2011	42	20-Oct-11	1460.63	21-Oct-11	939.16				
2011	43	27-Oct-11	1410.04	28-Oct-11	932.62				
2011	44	3-Nov-11	1377.82	4-Nov-11	919.44				
2011	45	10-Nov-11	1342.49	11-Nov-11	898.18				
2011	46	17-Nov-11	1342.10	18-Nov-11	885.38				
2011	47	24-Nov-11	1317.67	25-Nov-11	879.05				
2011	48	1-Dec-11	1217.35	2-Dec-11	868.31				
2011	49	8-Dec-11	1204.56	9-Dec-11	855.54				
2011	50	15-Dec-11	1193.57	16-Dec-11	853.61				
2011	51	22-Dec-11	1194.26	23-Dec-11	856.64				
2011	52	29-Dec-11	1200.57	30-Dec-11	947.58				
2012	1	5-Jan-12	1444.79	6-Jan-12	975.31				
2012	2	12-Jan-12	1459.58	13-Jan-12	981.05				

Table .1

2012	3	19-Jan-12	1488.81	20-Jan-12	982.56
2012	4	26-Jan-12	1477.52	27-Jan-12	0.00
2012	5	2-Feb-12	1453.55	3-Feb-12	970.71
2012	6	9-Feb-12	1435.62	10-Feb-12	965.23
2012	7	16-Feb-12	1423.58	17-Feb-12	949.33
2012	8	23-Feb-12	1426.24	24-Feb-12	977.09
2012	9	1-Mar-12	1966.34	2-Mar-12	1163.96
2012	10	8-Mar-12	1964.28	9-Mar-12	1170.57
2012	11	15-Mar-12	1969.54	16-Mar-12	1223.25
2012	12	22-Mar-12	2027.66	23-Mar-12	1230.18
2012	13	29-Mar-12	2032.94	30-Mar-12	1347.50
2012	14	5-Apr-12	2324.75	6-Apr-12	1374.90
2012	15	12-Apr-12	2317.77	13-Apr-12	1416.87
2012	16	19-Apr-12	2366.03	20-Apr-12	1426.23
2012	17	26-Apr-12	2343.42	27-Apr-12	1488.14
2012	18	3-May-12	2592.39	4-May-12	1501.46
2012	19	10-May-12	2578.92	11-May-12	1464.82
2012	20	17-May-12	2539.05	17-May-12	1426.00
2012	21	24-May-12	2477.78	25-May-12	1408.81
2012	22	31-May-12	2442.17	1-Jun-12	1386.90
2012	23	7-Jun-12	2376.60	8-Jun-12	1414.72
2012	24	14-Jun-12	2478.45	15-Jun-12	1450.23
2012	25	21-Jun-12	2480.30	21-Jun-12	1425.66
2012	26	28-Jun-12	2465.20	29-Jun-12	1460.52
2012	27	5-Jul-12	2590.29	6-Jul-12	1421.94
2012	28	12-Jul-12	2553.26	13-Jul-12	1372.52
2012	29	19-Jul-12	2474.05	20-Jul-12	1327.45
2012	30	26-Jul-12	2424.22	27-Jul-12	1327.08
2012	31	2-Aug-12	2491.42	3-Aug-12	1369.57
2012	32	9-Aug-12	2543.62	10-Aug-12	1363.41
				Ē	

Source: WCI, SCFI





# Source: WCI, SCFI

#### 5. Conclusions

Both carriers and shippers are facing freight rates volatility and cyclicality in the container shipping industry. In recent years, the industry seems to be witnessing more extreme cycles and volatility.

The shortcomings of existing contractual arrangements between shippers and carriers highlighted the need for a greater predictability of container shipping rates and the need for hedging. We argue that the introduction of the Index-linked Container Contracts (ILCCs) along with hedging strategies, and the use of derivatives markets could be a significant step towards a market pricing stability mechanism, giving room to carriers and shippers to focus more on service levels.

The recent transition from fixed rate long term service contracts to spot or floating rate contracts is following a slow pace. However, this transition is drawing a lot of attention from all industry players. We believe it is just a matter of time before some of the industry players will lead other players to embrace spot or floating rate contracts. However, the lack of credibility of existing container freight indices proves to be a burden to promote such a transition.

We argue that the introduction of SCFI at the end of 2009 followed by the WCI and other container indices was a necessary step for such a transition. However, they need some time to develop and reach maturity. Old habits and tools are becoming increasingly impractical for facing the increasing market volatility associated with supply/demand imbalances.

ILCCs along with container freight indices and hedging instruments open avenues for more research on how the derivative hedging models could be properly used in container shipping as they are used in other industries (particularly commodities).

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<sup>&</sup>lt;sup>1</sup> One of the illustrious SRS shippers group, a group of 22 companies based on northern France includes supermarkets, retail chains, specialty retailers, and catalogue merchandisers, aggregating over 125,000 TEU imports mainly from Asia. They developed an index based on average of the monthly spot rates gathered from the top ten carriers collected through a group of freight forwarders such DHL, Expeditors, DB Schenker and Panalpina. SRS group during the crisis published that they will use their index in advance of negotiating 2009 shipping contracts. In 2009, rates were adjusted monthly which was very hard to do so. By 2010, most of their contracts were changed to quarterly review (The Journal of Commerce Online, Dec 26, 2011).

# Sustainability Portfolio Analysis: Study of Logistics Service Providers

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#### Abstract

The concept of sustainable development has attracted significant attention from both the industry and academics in the past decade. In the logistics area, Logistics Service Providers (LSPs) are under stringent pressure from customers, governments and society to achieve sustainability in order to maintain competitive advantages. The purpose of the paper is to research on the sustainability portfolio of the world's top LSPs. The study assesses the LSPs based on their sustainability portfolio, namely economic, social and environmental performance. In particular, the environmental metrics are Efficient and carbon neutral transportation, Inventory and warehouse management, Green value added service, Lean process, Electronic information and communication, Clean technologies, and Alternative energy. The social metrics are indicated by whether the three major stakeholder groups, namely government, employees and community are involved in LSP's environmental initiatives. In terms of the economic aspect, the analysis focuses on whether the environmental policy enhances the economic indicators of the LSPs. Systematic literature review methodology is applied to eliminate researcher bias and maximize reliability. The study presents knowledge on why sustainability is important to LSPs. The paper also analyzes sustainability strategies adopted by the current top LSPs and how sustainability can contribute to the competitive advantage to the firms. Finally the research seeks to understand the trend of sustainability strategies and provide practical suggestions.

Keywords: Logistics; Logistics service provider (LSP); sustainability; environmental; sustainability portfolio

#### 1. Introduction

Due to growing public concerns on global warming, Greenhouse Gas emission and resource depletion, sustainability issues have gained increasing attention over the past several years (Corbett & Klassen, 2006). In response to legislation requirement, ethical motives, economic opportunities and especially stakeholders' pressure, companies have accelerated in developing sustainability initiatives (Bansal & Roth, 2000; Dey, LaGuardia, & Srinivasan, 2011). Even though recent research has growing interest in pursuing sustainability analysis in relation to Logistics Service Providers (LSPs) (Halldórsson & Kovács, 2010; Nicole & Thorsten, 2012), there are still gaps existing that need to be covered in order to develop better model of sustainability initiatives. A LSP is defined as a provider of logistics services that performs the logistics functions on behalf of their customers (Coyle, Bardi, & C. John Langley, 2003). Due to the increasing importance of sustainability, it is necessary to closely analyze how current sustainability strategies adopted contribute to competitiveness of LSPs.

This present research aims to provide an in-depth portfolio analysis on three aspects of sustainability performance of LSPs, namely environmental, social and economic. Unlike previous studies, our research focuses on integration of the three aspects of sustainability as opposed to looking at isolated function of a single portfolio. Among the three aspects, the focal point of this research is on environmental sustainability. The research also explicitly examines social and economic aspects to present the relationships with and contribution on the environmental initiatives. Social aspect in sustainability is mainly about the involvement

of internal as well as external stakeholders in the present research. The metrics are indicated by whether the government, employees and community are involved in the environmental sustainability initiatives.

The scale of economic sustainability in this paper takes a specific stand, which is defined as the direct economic influence on environmental initiatives, such as direct capital investment on clean technology. In many cases, the expenditures and investment on the environmental strategies also benefit other aspects of business performance, such as reducing operating cost, improving customer satisfaction and building up better corporation image (Lee & Lam, 2012). However, it is nearly impossible to get the separate financial figure with respect to environmental investment because the influence is largely intangible. Thus, in this research, the direct economic performance on environmental initiatives is presented instead of the firm's overall financial performance.

In this study, the cases of world's top 20 Logistics Service Providers (LSPs) are investigated to build a coherent and reliable approach to analyze sustainability practices that current LSPs have adopted. The research is built on previous literature plus publication from current LSPs by examining sustainability as an entirety, investigating the current adopted sustainability practices, and analyzing the contributions from different portfolios. By comparison and analysis of the data from the 20 LSPs, the research aims to address the question about how each sustainability initiative contributes to the overall sustainability performance. It also provides insight to the trend of sustainability practices in the logistics industry.

## 2. Literature Review

The widely accepted definition of sustainability defines it as the integration of environmental, social and economic portfolios and keeping the balance of the three aspects (Carter & Rogers, 2008; Sarkis, 2010). However, the previous studies mostly discuss sustainability in logistics in terms of one isolated portfolio, particularly the environmental aspect, and there is a lack of integration of each portfolio's contribution to the holistic sustainability performance. Previous studies mostly focus on the design of sustainable logistics network to introduce better management strategies for logistics firms (Der-Horng, Meng, & Wen, 2010; Halldórsson & Kovács, 2010; Pagell & Wu, 2009). There is a gap of how the combination of the three sustainability aspects affects the overall sustainability performance of LSPs. In this section, we present relevant literature on sustainability regarding to LSPs in the three portfolios, namely environmental, social and economic in order to set the scene in our research.

#### 2.1 Environmental sustainability

Since logistics service is an integral activity in supply chain management, environmental concerns can significantly affect various logistics decisions of LSPs (P. R. Murphy, Poist, & Braunschweig, 1995; Paul R. Murphy & Poist, 2000; Wolf & Seuring, 2010). To achieve a firm's success to become environmentally friendly, LSPs play an important role in the provision of green products and services to customers and society. What's more, companies would be able to produce greener and more ecological products if the corresponding LSPs could offer green logistics service (Wu & Dunn, 1995).

The importance of integrating environmental sustainability into the LSPs has been emphasized in previous studies. For example, the survey conducted in 2008 to 2009 (Lieb & Lieb, 2010) shows that almost all LSPs have launched a broad range of formal sustainability programs that have had quite positive impacts on their customers. Most of them have made formal environmental sustainability statement and commitments including the goals and the approaches to achieve the goals (Lieb & Lieb, 2010). However, the outcomes of the nine case studies in Wolf and Seuring (2010) indicate a lack of evidence showing the environmental issues constituting a buying criterion for LSPs. Most studies still focus on traditional criteria like quality and cost to choose and evaluate LSPs without or with limited consideration of environmental sustainability criteria (Hakan & Bülent, 2007; Meade & Sarkis, 2002). Other studies mainly emphasize on improving the environmental sustainability strategies rather than uncovering the integrated relationship of the three aspects of sustainability in LSPs (McKinnon, Browne, & Whiteing, 2012). Thus there is a need to investigate the impact of applying environmental sustainability related to the social and economic portfolios (Carter & Jennings, 2002; Kumar, Teichman, & Timpernagel, 2012).

## 2.2 Social sustainability

Corporate social responsibility has been studied and argued by academics for several decades (Carter & Jennings, 2002). On a corporate level of LSPs, social sustainability means corporations add value to communities by increasing the human capital of individuals and furthering the societal capital of communities (Dyllick & Hockerts, 2002). Activities related to social responsibility include the recruitment of the employees, concerns about the global environment, and the health and safety issues during the work process (Paul R. Murphy & Daley, 1990). However, little research has covered social responsibility of LSPs. Logistics literature in the area of social sustainability includes survey research about logistic managers and sustainability strategies (P. R. Murphy et al., 1995), relationships of reverse logistics and social sustainability (Sarkis, 2010), and designing better framework of social sustainability (Carter & Jennings, 2002).

## 2.3 Economic sustainability

Studies about operations research have a long tradition in improving operations, especially in reducing costs to facilitate industry development. The situation in logistics service provider is that it is crucial to persuade and acquire supports from top management by showing the facts that there is competitive cost advantage potentially to achieve long-term gaining (Aref, Marilyn, & Joseph, 2005; Zhu, Sarkis, & Lai, 2008). Low-cost operational changes are needed to yield sustainable gains, otherwise financial pressures and shareholder concerns will likely to affect LSPs' sustainability decision (Lieb & Lieb, 2010). However, in recent years, most studies results show that environmental sustainability activities can help to make LSPs to be more profitable and competitive, thus achieving economic sustainability (Ameer & Othman, 2012; Chiou, Chan, Lettice, & Chung, 2011; Kumar et al., 2012).

After the literature review, it is clear that sustainability issues in the logistics industry have drawn remarkable attention from researchers over the years. However, most of the studies focus on one aspect of sustainability, and the inter-relationship among environmental, social and economic has rarely been touched and needs further research. The present study aims to use portfolio analysis on 20 LSPs to uncover the relationship among three aspects of sustainability and thus fill the gap.

## 3. Methodology

## 3.1 Data Collection

This research examines the sustainability performance of the top 20 LSPs in the logistics industry in terms of revenue. The top 100 third-party LSPs listed by Inbound Logistics are examined and ranked by gross annual revenue in 2011, and the top 20 are chosen to be exemplars in our research. The total revenues of these 20 LSPs have reached up to \$320,000 million US dollars in year 2011 according to company annual reports. These LSPs are international entities, which should be representative of the major market players in third-party logistics. The fundamental research data for this study is collected from the publicly available information from the official website of exemplars including articles from the business press, certificates issued by reputed third party (e.g. ISO 14001 certificate, EPA's Green Seal), audited carbon print figures and narration of sustainability accomplishment on their websites. The annual reports as well as the sustainability reports are also investigated to provide more objective and comprehensive data. This data collection method was adopted by several literatures to investigate the performance of logistics firms and has been proved as effective (Ameer & Othman, 2012; Pagell & Wu, 2009). Researcher biases are further eliminated by systematic literature review. The research design was based on the recommendations of Pagell and Wu (2009) and Björklund, Martinsen, and Abrahamsson (2012) and took reference from the previous research model on sustainability of LSPs (Lam & Dai, 2013; Pagell & Wu, 2009). The methodology builds up a stable and coherent base for the sustainability portfolio analysis of LSP.

#### 3.2 Systematic Literature Review

Systematic literature review is a process of data collation and management. All literature about the research topic has been collected directly from LSPs' website, annual reports, sustainability reports, scientific journals,

conference proceedings as well as published books. The numerous data was reviewed in a systematic way, by identifying objective practices, comparing similarities and differences, and categorizing literature by characteristics. The method helps to gather comprehensive literature review and reduce researchers' bias.

## 3.3 Cross Case Analysis

Cross case analysis is a research method that identify patterns across the various organizations and facilitates the comparison of commonalities and differences from different cases (Stake, 2005). It helps to reduce the amount of data and to present the data in a more meaningful manner (Miles & Huberman, 1994). The method also outlines the combination of different sustainability initiatives that contribute to the overall sustainability performance of LSPs. Data reduction is preliminarily achieved through the process of categorization and pattern matching (Khan & VanWynsberghe, 2008). Cross case analysis allows comparing different dimensions from various portfolios and companies thus helping to provide a comprehensive view of all the exemplars. This provides opportunities to learn from different LSPs and gather critical evidence to conclude the contribution of each initiative and further modify the sustainability strategies.

In the present research, the sustainability strategies have been categorized in three major portfolios, namely environmental, social and economic. Under each major portfolio, there are several sustainability practices and stakeholders that mentioned and discussed in previous studies. Each of the practices has been investigated based on the sustainability reports, plus publicly available information from the firm's website. In order to facilitate the cross case analysis, these practices were labeled and counted across the firms. A table is used to display the summarized data of the LSPs under study.

## 4. Coding and Discussion of Results

## 4.1 Coding

Data collected from the various sources is enormous as there are on average hundred pages of reports available for each LSP per year. Coding was then done to categorize and display data in a more meaningful way. To capture environmental initiatives as well as information about stakeholders' involvement and economic effect, we have demarcated segments within data based on types of identified best practices from previous literature.

Seven segments are developed and labeled with short phrases under environmental initiatives according to Lam and Dai (2013). They are Efficient and carbon neutral transportation (TPT), Inventory and warehouse management (IWM), Green value added service (VAS), Lean process (LP), Electronic information and communication (EIC), Clean technologies (CT), and Alternative energy (AE). Three groups of stakeholders, government, employees and community, are identified under the social portfolio to help investigate involvement with environmental practices. Economic aspect is also examined to show the effect from financial outcomes.

Unlike financial performance of firms, sustainability performance is mainly presented in a descriptive manner instead of numeral figures. Due to limited availability of quantitative sources, the research adopts a qualitative analysis method. A note of Y, N or L is used to indicate the LSP's engagement of certain practices. Y represents that a firm has well engaged in significant amounts in the corresponding attribute, and N and L indicate no engagement and limited engagement respectively. As shown in table 1, the numbers of Y are counted both horizontally and vertically to show the overall sustainability in all three portfolios in both the corporate and industry level.

## 4.2 Results of Cross Case Analysis

After a proper coding process, data is categorized and displayed in a better way for analysis. Table 1 shows the engagement of each LSP in various environmental practices, and its involvement from social and economic dimensions. The column of number of practice engaged implies the sustainability performance for each of the exemplars. It provides the base to uncover the differential and mutual traits across LSPs. The last

row in Table 1 indicates the engagement of the practices across all the LSP cases examined in this research, which implies common practices and emphases in the logistics industry.

## 4.3 Corporate Level

Current LSPs have already realized the importance of sustainability and made significant efforts on environmental practices as well as involvement of stakeholders. From the third column of Table 1, among the 11 attributes in determining overall sustainability performance, 16 out of all 20 exemplars have well engaged with more than half of the attributes. The awareness of sustainability and practical action of LSPs reveal that sustainability issue has gained remarkable attention in recent years. Some of the sustainability reports and annual reports have mentioned that under current economic situation, with growing concerns about global warming and resource deletion, in order to maintain competitive advantages in a long run, it is necessary and important to be responsible in sustainability issues. The cases correspond with researches that suggest it is becoming urgent to develop and adopt sustainability initiatives in logistics industry (Dey et al., 2011; Jeffers, 2010; Nicole & Thorsten, 2012).

There are significant differences among the 20 LSPs even though every company shows certain attention on the sustainability issues. The number of practices engaged for each company varies from 3 to 11, revealing the varying levels of emphases on sustainability performance. The top ones develop and provide separate sustainability reports, showing their specific intention and marketing efforts on sustainability aspect. In the top 10 LSPs, 7 companies have separate sustainability reports while there is only 1 in the latter 10. Whether the firm develops a separate sustainability shows the attitude and intention regarding to sustainability issue, and it also implies the motivation behind sustainability efforts. Sustainability report is issued mainly for current or potential customers and investors for enhancing good relationship, building up company image and promoting competitive advantages. It is coherent with the result from previous studies, which have shown that customers' demand on sustainability is one of the major motivations of sustainability practices adoption (González-Benito & González-Benito, 2006; Kim & Han, 2012).

Economic involvement in environmental initiatives is also different when comparing the performance of the top 10 and the latter 10. The ones shown limited engagement in economic dimension are all in latter 10. It may be probably because they have less awareness of sustainability issue comparing to the top 10, and limited amount of environmental initiatives have been adopted by these companies to show economic investment as well as benefits on environmental sustainability.

## 4.4 Industry Level

After analysing the corporate level, to understand sustainability of the logistics industry as a whole, it is necessary to consolidate the data from all exemplars at the industry level for analysis. As table 1 shows, the last row arranges the count of Y for each of the attributes which shows the industry is engaged in the identified practices in varying degrees.

## 4.4.1 Engagement in environmental Practices

To enhance the analysis, table 2 was developed in the sequence of number of companies well engaged in certain environmental practices to reveal engagement of a certain environmental practice in the logistics industry. As shown in Table 2, TPT and CT have attracted most attention and are well applied across the major players in the logistic industry. Especially for TPT, among the 20 exemplars, all of them are well engaged in this practice in a significant amount, exhibiting the focus of sustainability efforts on transportation. With respect to environmental concerns, transportation is the most visible aspect in logistics service industry. Transportation  $CO_2$  emissions amount to some 14% of total global emissions level (Stern, 2007).

Most of the exemplars have started to indicate the carbon footprint, which is defined as the total amount of carbon dioxide emitted for production and transport (Wright, Kemp, & Williams, 2011), throughout the logistics service especially transportation, and 5 of them have imported detailed and audited carbon dioxide emission figures. The rationale behind can be explained by Figure 1.

		ECON	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Г	Υ	L	Υ	L	Υ	L	16		alue
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	SOCIAL	Employ ee	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Γ	Γ	Υ	Γ	Υ	Υ	Υ	Υ	L	Υ	Υ	L	15	ctivity	ement), VA ative energy
		Govern ment	Υ	Υ	L	Ν	Υ	Υ	Ν	Υ	Ν	Υ	Ν	Г	Υ	Ν	Γ	Υ	Υ	Υ	Ν	Ν	10	gement in a	use manag AE (Alterna
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20 LSPs		CT	γ	Υ	Υ	Υ	γ	γ	Υ	γ	γ	Υ	Υ	Υ	γ	Υ	Υ	Ν	Υ	Υ	Г	L	17	ctivity; L=li	(Inventory (Clean tech
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	IRONMEN	LP	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Ν	L	Ν	Ν	Ν	Υ	15	N= no enga	al transporta nd communi
Sustainabi	ENV	VAS	Υ	Υ	Υ	λ	Γ	N	λ	N	Υ	N	Υ	Ν	N	Ν	Ν	Ν	Ν	Ν	Ν	Ν	7	it amounts;	arbon neutra
Table 1.		IWM	Υ	Γ	Υ	Υ	Υ	Υ	Γ	Υ	Γ	Γ	Z	N	Γ	N	Г	Υ	Ν	Γ	Ν	Ν	L	n significan	cient and ca ectronic inf
		TPT	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	20	he activity i	x: TPT (Eff ss), EIC (E
	Number	of practice engaged	11	10	10	6	6	6	8	8	7	7	7	7	9	9	9	9	2	5	4	3		mgaged in t	tices Matrix (Lean proce
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Environmental Metrics	Description	
TPT Efficient and carbon neutral transportation	Control carbon footprint during transportation process. E.g. improvement of vehicle performance, intermodal transportation	20
CT Clean technologies	Advanced technologies applied in order to generate less or no pollution. E.g. recycling, using environmental friendly materials, infrastructure and tools when logistics service is performed	
LP Lean process	Pre-planning processes that reduce lead-time, inventory and waste. E.g. Just-in-time logistics	15
AE Alternative energy	Application of recycling, renewable and low sulfur energy resources other than fossil fuel to reduce environmental pollution	12
EIC Electronic information and communication	Usage of seamless information flow and communication will lead to effective and efficient logistics operations, which enhance supply chain visibility and responsiveness thus lower waste and redundant work flow	9
IWM Inventory and warehouse management	Sustainable efforts include activities, e.g. terminal and warehouse location and design, enhancing inventory control system, proper storing and disposing of hazardous materials, and energy efficient storage and movement.	7
VAS Green value added service	Logistics services that provide environmental solution for customers. E.g. reverse logistics, eco-friendly packaging	7

Table 2. Engagement in Environmental Practices of Top 20 LSPs

## Figure 1. Model of LSPs' responsiveness of GHG Control



A major rationale to explain the scenario is the current legitimate regulation, non-government organizations and international conventions on environmental requirements tend to have more detailed restriction on carbon dioxide emission. For example, the ISO 14001 is an authoritative certificate issued by International Standard Organization (ISO), which has certain criteria on annual emission. Such criteria motivate those who want to build up better company image to take actions to adopt CT, TPT and AE for the sake of reducing emission. Additionally, consumers, non-governmental organizations and other interest groups focus increasingly on the sustainability performance of the logistic sectors as it contributes significantly to the whole supply chain sustainability. If a LSP manages to obtain media coverage, which serves publicity purpose, for being a best practice example of a successful, responsible and sustainable company, this can dramatically enhance brand value, customer satisfaction and sales figures (Kumar et al., 2012).

The another reason behind, as suggested by Rommert, Jacqueline, and Ioannis (2012), is that customers can base their production selection on this carbon footprint in logistics. Customers of logistics industry are manufactures and retailers who are also subject to all the pressure from external as mentioned above. As for

the significant impact that logistics has on the environment, it can produce up to 75 percent of a company's carbon footprint in supply chain (CSCMP, 2008), which makes logistics a key factor in determining overall carbon footprint across customers' supply chains. Carbon neutral transportation is the most measurable practice in environmental attributes, which provides precise numeral data for customers to view and compare. That is the possible reason why it has been widely adopted in logistics industry.

IWM and VAS have gotten significantly less concern comparing to other environmental initiatives. Only 7 out of 20 companies have well engaged in both environmental practices, showing that less attention on environmental innovation from managerial and service perspectives. As mentioned multiple times in sustainability or annual reports across all exemplars, the common knowledge is that single and isolated environmental practices could not help to make a big difference on sustainability performance, and integrated and comprehensive management is urgently needed to achieve holistic and true sustainability. As one of the companies stated in their report, the firm has one of the most diverse and long-standing alternative energy fleets in industry to cut greenhouse emission, but it only makes a small difference in the environment. The real challenge is to improve and optimize the management and provide better service to integrate various components in the network.

#### 4.4.2 Involvement of Stakeholders from Social Dimension

From the data under the major portfolio of the social aspect, the involvement of stakeholders groups in environmental initiatives was investigated. As Table 3 shows, the overall performance on involvement of stakeholders is quite significant. The range is from 10 to 17 companies, showing that stakeholders are well involved in major LSPs' environmental initiatives.

Tuble 5. Involvement of Mujor Sumenorders in Environmental Trachees				
Stakeholders	Description	Count		
Government	Regulations, policies and laws enforced by government.	10		
Employees	Encourage employees participate into environmental projects. Improve the safety and health policy for employees.	15		
Communities	Communicate with local communities to listen to environmental request and keep good relationships.			

 Table 3. Involvement of Major Stakeholders in Environmental Practices

However, we notice that government involvement ranked the lowest among the three social groups. Only half of the LSPs stated the engagement with government in environmental practice, which fits the recent research on relationship of stakeholders' pressure and sustainability motivation. The research has found out that government influence on implementation of sustainability practice has declined (González-Benito & González-Benito, 2006; Kim & Han, 2012), which is opposite to previous studies that showed legitimate concerns are the leading factors on motivating company sustainability efforts (Bansal & Roth, 2000; Christmann, 2004). The result does not mean that government has lower importance in sustainability. Since LSPs started to realize that good sustainability performance could enhance firms' competitiveness and also reduce overall operating cost, thus the initiatives are no longer driven mainly by government regulations and law. Environmental practice has been brought to a higher standard of meeting the requirement of customers. On the contrary, LSPs have made adequate efforts to involve their employees and communities into their environmental initiatives. More than 3/4 of exemplars have well engaged employees and communities in sustainability.

## 4.4.3 Economic Performance in Sustainability

As the count in the last column of Table 1 suggests, it seems that most of LSPs have gotten positive influence on economic dimension from environmental practices based on the fact that 16 exemplars out of 20 have shown good economic involvement. Some previous research proposed various conceptual models to evaluate the relationship with environmental practices and financial performance, and it showed positive relationship between the two that is the same as the outcome in this study (Ameer & Othman, 2012; Rao & Holt, 2005). However, the short-term financial returns are not prominent from the present exemplars. Most of them expect positive influence on economic performance in a long run through building up better company image instead of material financial impact in the current year. The positive economic influence relating to sustainability effort are stated as "increase firm's reputation", "show the responsibility on environment" and "meet customers' requirement" but rarely on direct short-term financial impact. The situation is similar to the survey conducted by Adams, Thornton, and Sepehri (2012), in which 55 percent of the surveyed CEOs agree that sustainability investment helps to build reputation, and 36 percent see building reputation as a top reason for addressing sustainability issues. The outcome also supports the analysis that the direct motivation of adopting environmental practices is from stakeholders, especially customers.

## 5. Conclusion and Recommendation

From the analysis and discussion above, it shows that most top LSPs have already paid significant attention to sustainability issues and various practices have been adopted in order to achieve holistic sustainability in the overall logistics service procedures.

The focus on environmental practices is on carbon neutral transportation and reduction of greenhouse emission. The analysis suggests that the most commonly adopted environmental practices across these cases are Efficient and carbon neutral transportation and Clean technologies, and less common in Inventory and warehouse management and Green value added service. Current LSPs are more focused on the issue of carbon footprint, which can be taken as an industry trend since government, environmental organization, and international conventions all emphasize on the GHG emission problem. It has been noticed that some environmental organizations have more influence than expected. Improvement on management and eco-service is an opportunity to logistics industry since it helps optimize the efficiency of the whole service chain with relative low capital investment and significantly reduce overall cost in the long run.

From social dimension, evidence from this research shows that legitimation concern is no longer the leading driving force of sustainability efforts as stated in previous studies (Bansal & Roth, 2000). By tacitly implied information in companies' sustainability report and statement, the direct motivation behind of adopting environmental practices in current LSPs is mainly the pressure from customers. The driving force for companies to pursue environmental sustainability has shifted from legitimation motivation to a higher standard of meeting customers' green requirement to build better company image and keep good investor relationship, which leads to overall higher criteria of sustainability in the whole logistics industry.

Direct influence from economic portfolio is haply positive from cases. In most cases the firms' motivation and behavior cannot be interpreted solely from a short-term economic perspective. However, indirect effect could be seen on long-term bases by improving brand image, building up better investor relationship and reduce operation cost. Better low-cost and efficient sustainability model design is needed to encourage more LSPs adopt more environmental practices and achieve better sustainability performance.

This paper provides a comprehensive review of the sustainability literature, analyzes the sustainability strategies adopted by the current top LSPs and how sustainability can contribute to the competitive advantage to LSPs. It examines the sustainability performance of 20 companies within the field of logistics service providers and uncovers the interrelationship of three major aspects of sustainability in a holistic view. Based on the 20 exemplars, the study helps understanding future trend of sustainability in logistics services and provides practical suggestions for better development of sustainability initiatives.

While the study has provided a comprehensive portfolio analysis as the issues discussed above, some limitations must be acknowledged, leading to anchors for future research. First, like all the case studies research, to ensure higher reliability and validity, larger samples are needed to find out generic result for the entire logistics service industry in worldwide. Second, to further eliminate researcher bias and reduce information asymmetry, interview should be conducted with industry professionals. Finally, despite the efforts of data selected from enormous information available, there is still lack of precise financial figures in regards to economic performance. Further research should analyze financial performance on a better base with sufficient numeral figures and better model to see if more precise interrelationship could be concluded.

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# **Traceability System Using RFID in Fishery Logistics**

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#### Abstract

Nowadays, fishery products are traded in a variety of forms including live, fresh, frozen and processed and we can purchase fishery products almost anywhere such as markets, grocery stores and fishmongers. This phenomenon is partly thanks to temperature management during transportation from the point of production to the point of consumption. On the other hand, the workers in the field of fishery products need to find ways to add high value in order to meet the high demands of consumers. One way to achieve this is traceability system that all of the enterprises can share information about fishery product. Traceability system will improve the ability to respond quickly when problems occur and ensure reliability of food label. In this paper, for the purpose of improving transportation quality in fishery logistics, we describe traceability system using active RFID. Besides, we conducted indoor positioning experiments using active RFID. The result of the experiments show that the water does not have much effects on transaction distance of active RFID which themselves emit radio waves.

Keywords: fishery logistics, traceability system, active RFID, indoor location detection

## 1. Introduction

Developments of low-temperature transportation technology have made the long-term storage and broader distribution of food products possible. Nowadays, fishery products are traded in a variety of forms including live, fresh, frozen and proceed and we can purchase fishery products almost anywhere such as market, grocery stores and fishmongers. On the other hand, fishery logistics is becoming more complicated than ever, the workers in the field of fishery products need to construct systems to visualize fishery logistics.

In order to visualize fishery logistics, it needs to gather location information of cargoes. During transportation, location information is collected by vehicle equipped with GPS system. During storage, it is collected by reading AIDC (Automatic Identification and Data Capture), such as barcode, 2D-barcode and RFID in distribution center. During storage, information is typically only recorded at logistics activities such as shipping, and inspection. Therefore, information on the status and location of cargoes inside facilities is currently not obtainable.



#### Figure 1: Collection of location information in logistics

In this research, we summarize the current state of fishery logistics, and show examples of the adoption of returnable containers and RFID as a way to construct traceability in fishery logistics. In addition, we conduct experiments using active RFID to verify the influence of water on active RFID transmission.

#### 2. Measures to Construct Traceability System in Fishery Logistics

In this section, we summarize the feature of fishery logistics, and introduce the action in Denmark as examples of way to construct traceability.

## 2.1 Feature of fishery logistics

Because developments of low-temperature transportation technology have made long-term storage and broader distribution of fishery products possible and brought a new variety of fishery products, distribution channel of fishery logistics has become more complex, as shown Fig2.



#### **Figure 2: Fishery logistics structure**

The distribution process that takes fish from catch to the consumer differs based on the condition of the fish (live fish, fresh fish, frozen fish), as do the containers used for transportation. In the case of live-fish transportation, it must be transported keeping fish alive from catch to consumer region. Therefore, water tanks equipped with pumps, aeration systems and the like are used as transport containers for transporting live-fish. In the case of fresh fish, wooden boxes and plastic containers are used in fishing boats and fishing ports as interim storage boxes. After the selection of fish at fishing ports, fresh-fish is generally packed in Styrofoam box in conjunction with ice and water, then, is delivered to each destinations. In the case of frozen-fish transportation, metallic containers which are superior in cool keeping property are used as transportation containers used in fishery logistics vary according to size, condition or temperature zone of fish.

boxes/containers	various types of fish	Durability	Characteristics of boxes/containers
Water tanks	Live-fish	Returnable	<ul> <li>Keeping fish alive from catch to consumer region, it is equipped with pumps.</li> </ul>
Mater tariks			aeration systems and the like.
		Returnable	•Durable.
Wooden boxes	Fresh-fish		<ul> <li>Mold is caused by water-stained.</li> </ul>
			<ul> <li>It should be avoided to reuse from the aspect of hygiene.</li> </ul>
Plastics containers	Freeh-fieh	Returnable	•Durable.
	FreshTish		<ul> <li>It is strong to water-stained and superior in hygiene aspect.</li> </ul>
Styrofoam boxes	Fresh-fish	Non-returnable	•Weight is light.
			•It is superior in cold-retentive property, buffer nature, heat-insulation
			property, and water resistance.
Metallic containers	Frozen-fish	Returnable	•Durable.
			•It has high heat-conductivity and superior in cold-retentive property.
			•Rust is caused by water-stained.
			<ul> <li>It should be avoided to reuse from the aspect of hygiene.</li> </ul>

 Table 1: Boxes/containers used in fishery logistics

## 2.2 *Case Study; Use of returnable container and RFID in fishery logistics*

On the past few years, several experiments using RFID for food traceability have been conducted. But many of those are not in use because the workers have to collect RF tags from each distribution centers.

Pack and Sea – a consortium made up of companies from 10 Danish fishing harbours - has been partnership with Lyngsoe Systems – an ex expert in developing intelligent logistics solutions – to develop an asset management solution to handle the administration of more than 200,000 fish crates with RFID tags. The solution makes it possible to track the fish crates all the way through the logistics chain. Each crate has unique ID enabling employers to see where all the crates are located.

At present, it is used for the crate management, but can be used for fish traceability by writing information regarding the product on RF tag at each logistics activities.

#### 3. Verification Experiments for Using Active RFID under Fishery Logistics Environment

For the purpose of construction of food traceability, it is promoted to use RFID in food logistics. In this section, we conduct experiments to inspect reading properties of active RFID under the environment that assumed fishery logistics.

## 3.1 Feature and classification of RFID

RFID is an automatic identification technology based on wireless communication technology. RFID has features that are not available in barcode, such as non-contact, simultaneous reading of multiple tags and data writing and recording capability. However, it has drawbacks, such as reduced read distance and accuracy owing to the presence of metal and moisture.

There are two methods of power supply: active and passive. A passive RFID tag does not have its own power supply and responds to an electromagnetic wave transmitted by the reader/writer. An active RFID tag has a built-in power supply and receives and transmits a radio wave from the power supply for data exchange. Semi-passive tags have been developed that do not use a power supply for signal reception and transmission but have a power supply for the sensor circuit.

	hara a da	2D haraada	RFID	
	barcode	2D barcode	passive type	active type
			ormon	
communication distance	a few centimeters ~ ten centimeters	tens of centimeters	a few centimeters ~ a few meters	a few centimeters $\sim$ tens of meters
scanning when datacarrier is dirty	difficult	difficult	pos	sible
reading and writing of information	impossible	impossible	possible	
duplication	easy	easy	very difficult	
mass reading of multiple items	impossible	impossible	possible	
recordable amount of information	tens of bytes	a few kilobytes	tens of kilobytes	tens of kilobytes ∼ a few megabytes

 Table 2: Feature of AIDC

## 3.2 Location detection using AIDC

The maximum communication range of barcode and 2D barcode is till 10 centimeters, and that of passive

RFID is from a few centimeters to a few meters. On the other hand, active RFID which has battery themselves can do long-range communication, and detect objects inside a building.

Methods of indoor location detection using AIDC can be classified in three methods shown in table 4. Each methods of indoor location detection can be realizable by using suitable recording medium.



 Table 3: Classification of indoor location detection using AIDC

## 3.3 Verification experiments for using active RFID under fishery logistics environment

RFID communicates using electromagnetic wave or radio wave. RFID sometimes can't communicate in environment surrounded by obstacles. Therefore, when introducing RFID into logistics fields, it is necessary to conduct verification experiments in a form that approximates actual operations.

We conducted experiments using active RFID attached to plastic containers, comparing a container containing water to an empty box in order to evaluate whether there is a difference in the transmission distance or RSSI (received signal strength indicator) values.

RFID system is comprised of tags with peculiar ID and reader/writer which read from or write to tags. Below, we show the flow of the communication of active RFID that we use in experiments.

1. Tags send a signal with peculiar ID by radio wave.

2. Reader receives signals from tag.

3. PC displays information about signals that reader received from tags such as tag ID, RSSI values, arrival time of signals.

Data communication between tags and reader/writer is carried out by repeating the procedure mentioned above.

We conducted experiments under the environment without obstacles between readers and plastic containers, but there were walls, metal shelves and desks around readers and plastic containers. In order to verify the influence of water on active RFID transmission, we put a vinyl bag containing water into a plastic container.

Table 4. Specification of KF1D				
Operating frequency	312MHZ			
Modulation method	OOK modulation			
Signal transmission period	9 sec			
receivable SSI	-112dBm∼-55dBm			

## **Table 4: Specification of RFID**





(C) Packing of water

#### (A) **RFID** system

(B) Attach tags to plastic containers Figure 3: Experiment condition

## 3.3.1 Measurement of transmission distances

We tested readable distance of RFID, using a plastic container which attached a RF tag. We lengthened distance between a reader and a plastic container every 1m until it could no longer be read.





Fig.6 shows the results of the case that a tag was attached to an empty box and the case that a tag was attached to a container containing water. In both case, communication were stable until 7m. But the reading rate dropped considerably at around 8m -9m, neither can receive radio waves at more than 11m.



#### 3.3.2 Measurement of RSSI values

Active RFID can estimate the position of objects by triangulation using multiple readers. Either the strength of radio waves or the arrival time of radio waves is used for location estimation, but there are measurement errors by multipath propagation.

This experiment tested differences of RSSI values between when a tag is attached to an empty box and when a tag is attached a box that contains water. We attached RF tags to plastic containers, and arranged 10 plastic containers in a straight line. On the each end, we placed a reader. The equipment and measurement environment are the same as the conditions in the previous experiment.

#### Figure 6: Arrangement of two readers and plastic containers with RF tag



Each RSSI values are shown in figure 8 and figure 9. RSSI values tend to become weaker as the distance between a tag and a reader increases.



Figure 7: Measurement result of RSSI values

(A) RSSI of reader 1

These experiments shows that water does not have much effects on transaction distance of active RFID which themselves emit radio waves.

#### 4. Conclusions

In this paper, we summarize the use of returnable containers and RFID in fishery logistics. In addition, we conducted experiments to look at the effect of water on active RFID communication. The experiments showed that water does not have much effects on communication of active RFID which themselves emit radio waves unlike passive RFID.

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# Large Scale Disruption Risk Management: A Comparison of the Humanitarian and Commercial Supply Chain Responses

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#### Abstract

Humanitarian organizations need to respond to large scale disasters with a very short lead time and operate effectively in very disruptive environments. At the same time, these large scale disruptions are emerging as one of the most pressing issues for commercial supply chains. This development has been well publicised after significant events such as the 2011 tsunami in Japan. Consequently, supply chain managers and researchers have strived to develop risk conscious management practices to build better resilience into the supply chain. This paper therefore seeks to compare the characteristics of a humanitarian supply chain with those of commercial organisations, thus preparing for effective large scale disruption risk management. We survey the extant literature on humanitarian supply chains to draw out the similarities and differences between the disaster-response supply chains of humanitarian organisations and selected commercial supply chains. Next, we apply system dynamics to simulate and understand the causal loops and yield some performance benchmarks in terms of the disruption impact and costs. We posit that the supply chains for the disaster response operations and commercial purposes differ in terms of the management strategies, adaptive capacity, and supplier relations. By adopting some of the humanitarian supply chain's features, such as Supplier Framework Agreements and Rapid Assessment Processes, we demonstrate an enhancement of the disruption handling capabilities of commercial supply chains. The cross-sectional study of the supply chain of humanitarian organisations can help commercial supply chain managers to improve their disruption risk management practices. This is the first study to analyse the potential for improving the disruption risk management of the commercial supply chain community through learning from humanitarian organizations.

Keywords: Supply Chain Risk Management, Humanitarian Logistics, System Dynamics, Disruption Risk

#### 1. Introduction

Large scale disruptions are one of the major threats to commercial supply chains (CSC) (Smyrlis 2006). They are frequently caused by disasters, such as the 2011 tsunami in Japan. This event had an immediate effect on the economy, leaving many manufacturing facilities in the region either destroyed or severely damaged. In particular the lean managed, just-in-time supply chains of Japan's IT and automobile industries were impacted. This disruption propagated quickly through the supply chain and soon after, the shortage of supply parts forced Toyota to close all its North American factories and General Motors to shut down its Louisianan plant (Park et al. 2013). Notwithstanding this, other events apart from natural disasters can also disrupt supply chains severely. For instance, the union strike of less than 100 dock workers on a neuralgic point of the US west coast caused significant disruption to the entire flow of Pacific shipments into the US and onwards to Europe. It took nearly six months to finally clear and deliver all goods and for schedules to be returned to normal (Cavinato 2004). These large scale disruption can have a devastating impact on affected enterprises, from severe losses in share price value to immediate default (Hendricks & Singhal 2005). As a result, supply chain disruptions are arguably the most pressing issue to firms today and the main focus of management and academia (Craighead et al. 2007).

Research on supply chain risk management has seen a number of contributions (e.g. Tang 2006; Kleindorfer & van Wassenhove 2004), with increasing attention to the field of disruption risk management (e.g. Sheffi

2009; Gurnani et al. 2012). However, good insights are still scarce, especially when it concerns large scale disruptions (Kovács & Tatham 2009). Nonetheless, prevailing insights suggest that effective disruption risk management requires some compromise on lean management principles (Christopher & Towill 2000). Increased redundancies, strategic inventory pre-positioning, and business continuity planning are some examples of the current of strategies suggested (Sheffi 2009).

This paper seeks to analyze the problem from a different angle. While commercial supply chain managers tend to see the disruption as an unlikely event (Hale & Moberg 2005), for some humanitarian organizations, these disruptive environments with high levels of uncertainty are daily occurrences. These organizations specialize in immediate response humanitarian catastrophes, such as natural disasters and they deploy their supply chains strategically to deliver large quantities of relief goods, namely, food, medicine or shelter to the affected population. After decades of professionalizing their approach, these Humanitarian Response Supply Chains (HRSC) have already earned the reputation of being among the most responsive and agile supply chain in the world (Hoffman 2005).

Supply chain managers of both commercial and humanitarian organizations face a similar challenge: They are confronted with a surge in demand. In the commercial supply chain, the scheduled supply of goods may not arrive due to a large scale disruption and this creates an unexpected demand for substitutes in order to keep the factories running. In the HRSC, the local market fails to supply basic relief goods and the disaster-struck population creates a demand for relief goods. Both supply chains have to adapt to the situation and satisfy this demand as fast as possible in order to minimize suffering and loss. Further, both chains are confronted with the disruption often without prior notice and are initially unaware of the full scale of the impact and its consequences.

In this paper, we consider the HRSC as an example of a supply chain with possibly superior disruption management capabilities. Therefore, our research question is:

Which features of the HRSC can improve the disruption management capabilities in CSCs?

Consequently, we first compare the HRSC with a commercial counterpart to carve out the differences in terms of structure, logic and functions, through a literature search. Next, we simulate the two types of supply chains. Then, we generate an objective comparison in terms of the disruption impact and cost. From the results, we identify the superior features to enable better large scale disruption risk management. We conclude with some suggestions for future research.

## 2. Theoretical Background

In order to provide some background on the humanitarian organization's theatre of operations and the setting for the HRSC, we briefly introduce the Disaster Management Cycle. Next, we give an overview on the differences between a Commercial Supply Chain (CSC) and the HRSC. Finally we describe three distinctive features of the HRSC, which we suspect are main drivers of the agility and hence most interesting in terms of Disruption Risk Management

## 2.1 Disaster Management Cycle

The humanitarian organization's supply chain during a disaster operation is very flexible and can adapt to constantly changing requirements in order to aid the disaster victims, also called beneficiaries in the humanitarian theatre of operations. This process is described in four phases using the Disaster Management Cycle (DCM).

Disaster management is perceived as a cyclical process, consisting of four distinct phases: (i) an initial Preparation phase, and following a disaster, the (ii) Response, (iii) Recovery, and (iv) Mitigation phases respectively (see for e.g. the National Governors' Association 1979 and Howden 2009). The Preparation phase focuses on strengthening disaster management capabilities on a continuing basis and with a long term horizon. It may include the development of organizational capabilities as well as the prepositioning of relief goods in designated locations. As soon as a disaster strikes, the Response phase is initiated. With its focus on
agility as in rapid response, the HRSC can be activated within hours (Kovács & Spens 2009). This phase has a short duration, often lasting for several weeks (Howden 2009). The type and volume of the supplies required can be erratic and high, albeit the goods are often standardized, to meet the needs of a homogeneous demand. Based on a crude initial assessment of the number of beneficiaries and their needs, the relief goods are "pushed" into the disaster zone (Long & Wood 1995). The subsequent Recovery phase is considerably longer in duration and sometimes effort. Requirements of the beneficiary population change and the supply chain transforms to a lean and efficient one (Oloruntoba & Gray 2006). Uncertainty in the operation decreases and the supply chain becomes more stable (Maon et al. 2009) and supplies increasingly get "pulled" based on demand (Long & Wood 1995). The initial focus from a fast, life-saving, response now turns into a more multi-dimensional management (Farahani et al. 2009). Further, the supplies are progressively sourced locally in order to support the local economy. They are less standardized so as to cater to the specific needs of the beneficiaries (Kovács & Spens 2009). The final phase, Mitigation, is aimed at reducing both the risk and the impact of a subsequent disaster and feeds back into the initial Preparation phase (Howden 2009). This effectively closes the loop and provides an operating mechanism for learning.

The high level of agility during the Response phase is worth a closer look. Learning the ability to react to sudden changes and adapt the supply chain accordingly is what commercial supply chains are currently struggling with. Thus, the focus of our work is on the supply chain in the Response phase (HRSC) and its Preparation phase. The supply chain in the Recovery as well as the Mitigation phases has a different focus and is excluded from the present analysis.

# 2.2 Differences between HRSC and CSC

While the HRSC faces a similar challenge as a disrupted CSC, some differences exist. The most obvious one is the diverging strategic goal. While the CSC aims to increase profitability, the HRSC primarily minimizes the loss of life after a disaster strikes (Ilhan 2011). Another difference is the source of uncertainty: The CSC has the means to forecast and influence demand even in the case of a disruption. Therefore, the disruption creates uncertainty mainly on the supply side (Sheffi 2001). This is in contrast to the HRSC. Its uncertainty is mainly on the demand; the supply side in the HRSC is reasonably reliable and stable. Further differences exist in the choice of equipment and IT systems, which are often basic but multifunctional in the HRSC (Gonçalves 2008) compared to the very specialized solutions in the CSC (van Wassenhove 2006). Finally, the complexity of the stakeholder network differs. While the CSC has clear interfaces throughout the supply chain with its suppliers and customers, the HRSC is embedded in a more complex situation. The beneficiaries are the final recipients, who do not create demand in form of an order nor transfer funds in return for the delivery of goods. The demand is assessed by the humanitarian organization requests donations from public and private donors. In turn, these donors expect fast and effective relief to the beneficiaries.

# 2.3 Features of the HRSC

We analyzed relevant case studies to identify the features of the HRSC. These features are the Rapid Assessment Process, the VMI and Emergency Stock as well as the Supplier Framework Contracts. We now describe these features, followed by the implications on the simulation model.

#### 2.4 Rapid Assessment Process

As soon as the humanitarian organization knows about a disaster in its scope, the Rapid Assessment Process is initiated to assess the situation and identify the demand for relief goods (Thomas 2003). An assessment team is assembled to collect information on the impact of the disaster and the affected population. The sources of information are primary data from "on the ground" as well as data from databases. The response operation is then scaled, based on an assessment of the results, common demand patterns as well as funding limitations, and goods are pushed through the supply chain.

Model implication: A considerably shorter assessment time allows subsequent steps in the disaster response to take place earlier.

# 2.5 Vendor Managed Inventory and Emergency Stock

Another feature of the HRSC is the strategy to build up inventory in the warehouses at central locations or in the proximity of disaster prone regions (World Vision International 2009). This allows immediate access to goods and fast shipment to almost any point of need. Further, these goods are often standardized for universal application, e.g. kits for families with universal foodstuff and basic kitchen items (van Wassenhove & Pedraza Martinez 2012). Additionally, the supplier often guarantees the immediate availability of a certain quantity of goods at any time. This is akin to a Vendor Managed Inventory (VMI) concept practiced commercially (Kovács & Tatham 2009).

Model implication: Prepositioned goods in the VMI or the organization's Emergency Stock are immediately available. Since fixed costs such as warehousing and depreciation accumulate, suppliers will increase the price for VMI goods and internal transfer prices on Emergency Stocks will be higher than the regular purchase costs.

#### 2.6 Supplier Framework Contracts

A further distinguishing feature of the HRSC is the Supplier Framework Contract. Other than the elements which are common in a commercial context, e.g. upfront agreed upon prices and quality requirements, the contracts often contain the supplier's commitment to hold spare fulfilment capacity for emergency orders and the guarantee of a maximum lead time up front (Kovács & Tatham 2009).

Model implication: In case of a disruption, emergency orders can be placed under upfront negotiated and guaranteed conditions. For keeping this spare capacity, the supplier is likely to demand higher purchase prices for the goods and an initial setup-fee for establishing such requests.

#### 3. Method

We use VenSim 6.0a for the systems dynamics simulation. Figure 1 shows a simplified version of the simulation model, displaying the structural elements of the supply chain including the warehouses and goods flows. Figure 2 provides the detailed model.



#### Figure 1: Structural Elements of Simulation Model

The model's structure is divided into four parts, in order to represent the limits of control. These are the focal organization controlling the supply chain, either the humanitarian or the commercial organization, two of its suppliers, and a customer. Depending on the situation, the customer could be the victims of a natural disaster that the humanitarian organization is serving, or an internal or external customer of the commercial

organization. The model is described in a logical sequence. The main modeling parameters are mentioned in brackets. Table 1 shows the parameter values for the disruption impact.

Modelling F	arameters	Event	[unit]	
Disruption Impact		2,000	Units/Day	
	Duration	28	Days	
	Loss	10	\$/Units/Day	

#### **Table 1: Modelling Parameters for Disruption Impact**

Initially, the HRSC experiences a disruption, which is expressed through the sudden increase in customer demand for a certain quantity of goods per time step (Disruption Impact) over a given time period (Disruption Response Duration). The product of both attributes is the total unsatisfied demand for the supply chain. For every unit of deficit in the customer's inventory, the organization has to pay a penalty at each time step (Disruption Loss). This mimics the loss from an idle production facility in the CSC. In the case of the humanitarian organization, the loss serves as a quantitative proxy for the suffering of the beneficiaries while being under-supplied. Next, the parameters for the configuration of the HRSC and CSC are shown in Table 2. The influence of the HRSC's features is highlighted in different colors.

Key		HRSC		CSC				
Rapid Assessment Process         VMI and Emergency Stock         Supplier Framework Contract         Time Step = Day         Modelling Parameters		Supplier1	Supplier2	Organization	Supplier1	Supplier2	Organization	[unit]
Delay	Assessment			1			4	Days
	Transshipment			3			3	Days
	Production	10	7		15	10		Days
	Delivery (Production&VMI)	6	5		7	6		Days
	Distribution			2			2	Days
Capacity	Production	3,000	4,000		2,000	3,000		Units/Day
	Delivery	3,000	4,000		2,000	3,000		Units/Day
	Transshipment			4,000			4,000	Units/Day
Costs	Production Purchasing	20	25		18	20		\$/Unit
	Initial (Set-Up Costs)	20,000	30,000		10,000	15,000		\$
	VMI Purchasing	30	38		30	38		\$/Unit
	Internal Purchasing			50			20	\$/Unit
	Delivery/Transshipment	10,000	15,000	15,000	10,000	15,000	15,000	\$/Capacity Limit
Initial Inventory	VMI/Warehouse	4,000	4,000	10,000	0	0	5,000	Units

**Table 2: Model Assumptions and Feature Impact** 

Immediately after a disruption, the organization assesses the situation as well as the customer's demand. Consequently, response strategies are reviewed and selected. This activity delays the next set of activities (Organization Assessment Delay). The response is initiated by placing orders in the same quantity of the total assessed demand to the following recipients in the stated order: Emergency Stock from the organization's own warehouse, the VMIs and ultimately the production of goods at either of the two suppliers. The organization's own warehouse is equipped with Emergency Stock (Organization Warehouse Initial Inventory). This stock is available for transport with a delay (Organization Transshipment Delay) and can be transported by considering a capacity limit per time step (Organization Transshipment Capacity). Transportation costs (Organization Transshipment Costs) for a maximum capacity transport apply, but are calculated proportionally for partial capacity transport. Internal purchasing costs for these goods are considered as well (Organization Internal Purchasing Costs).

The organization can further purchase goods directly from its VMIs in a limited quantity (Supplier1/2 VMI Initial Inventory) at certain costs (Supplier1/2 VMI Purchase Cost). If the demand exceeds all those stocks, the organization places orders with its suppliers. These goods are available within a certain lead time (Supplier1/2 Production Delay) and the organization incurs new purchase costs (Supplier1/2 Production Purchase Costs) together with the initial setup costs for exercising the emergency order right (Supplier1/2 Production Initial Costs). Further, every supplier has a limited production capacity per time step (Supplier1/2 Production Capacity). The Delivery Costs, Capacity and Delay for the suppliers are labelled and calculated similar to a transshipment-like behavior for the good flow (need to explain this more).

All shipments arrive at the organization's local warehouse, from where they face another delay until the shipment ultimately reaches the customer (Organization Distribution Delay). This delay includes the Customs procedures and distribution.

On the logic of the model, two elements of the model are worth noting: the customer demand pattern, and the distribution of the production orders between both suppliers. We choose a monotone increasing demand pattern to depict the daily food consumption of a disaster victim (or the consumption of a specific part in a factory). The duration of the demand is limited to cater to the structure of the HRSC. In a humanitarian response operation, the HRSC transforms into a recovery supply chain. In a CSC, the cause of a disruption may be resolved internally. The supplies from the suppliers are distributed immediately, to minimize the sum of the purchasing and transportation costs, as well as the expected losses associated with the production and delivery delays. Practically, the large losses for the inventory deficits lead to most production orders being assigned to the supplier who can provide smaller delays and higher capacity, while the small losses would favor a cost-efficient supplier.

#### 4. **Results and Discussion**

Chart 1 shows the simulation results of the HRSC.





The diagonal of Chart 1 defines a declining customer inventory level, without considering any changes in the supply chain, in response to the disruption. Deficits accumulate until the disruption is over. The dotted line shows the actual inventory level of the customer with initial deficits and positive inventory levels towards the end of the disruption period. Three different measures of the HRSC provide relief for the customer's situation: First, the impact of the Emergency Stocks sets in and provides significant relief for the customer's inventory for a short period of time. Second, goods from the VMI arrive at the customer's site. Both of these measures have fast, but finite impact. They merely bridge the gap until the third measure, goods produced from the supplier, intervenes and finally resolves the deficit.

In Chart 2, we show the impact of a number of different supply chain configurations: three CSCs, one enhanced with one feature of the HRSC, one CSC without any features as well as one with all three features.



**Chart 2: Disruption Management Performance of Different Supply Chain Configurations** 

The HRSC's profile of the customer's inventory is identical to Figure 2. It is the best response to the disruption, with smallest deficits throughout the disruption period. In comparison, the CSC fares worse. It takes more time to react initially and then only mobilizes a small amount of goods from internal sources, buffer stock or in transit goods, lacking a proper Emergency Stock strategy. Given a standard commercial supplier contract with no emergency order clauses, the supply lead time is longer and capacity is less.

Additionally, three hybrid SCs are simulated. First, the CSC with a Rapid Assessment Process. By adding this feature, the initial response time is shortened and all consecutive actions are compressed. The result increases deficits slightly in comparison to the CSC. Second, the introduction of VMI and Emergency stocks provide a positive short term effect on the customer's inventory, shown by the characteristic hump. The disruption influence on the customer is reduced with the introduction of this feature. Third, the Supplier Framework Contract with shorter lead times and higher production capacity leads to significantly reduced deficits towards the later stage of the disruption period. Every feature combined with the CSC has a positive impact on the customer's inventory in the simulated disruption case.

Chart 3 shows the organization losses as well as supply chain costs.



Chart 3: Costs and Disruption Loss Comparison of Different Supply Chain Configurations

The losses result from deficits in the customer's inventory. The supply chain costs are the costs for countermeasures taken to resolve the disruption.

The worst case in the disruption scenario, the lean managed CSC, experiences the lowest costs but highest financial loss in the disruption case mentioned earlier. Both costs and losses serve as benchmarks. In contrast,

the HRSC has 80% lower losses but 38% higher costs for the disruption response. The cost difference is from the higher purchase prices of goods from the VMI and Emergency Stock.

In between those two cases are the hybrid SCs. The Rapid Assessment feature can reduce the disruption losses of the CSC by 9%. This is especially noteworthy, since this feature is not associated with additional costs in the disruption case. The VMI and Emergency Stock feature reduces the CSC's disruption losses by about 44%, but incurs 30% additional costs. The Supplier Framework Contract, with 47% loss reduction, has the strongest individual loss reduction effect of all three features. The additional costs compared to the CSC are only 11%. The answer to our research question is therefore positive. All three features of the HRSC seem to be valid measures in improving the disruption management capability of the CSC. The Rapid Assessment Process has a comparably minor impact on the disruption losses, albeit at no additional cost. The VMI and Emergency Stock as well as the Supplier Framework Contract have a stronger impact, with a cost advantage to the latter.

#### 5. Conclusion

Our study has limitations. The chosen simulation parameters are extracted from published case studies. We currently aim to increase the reliability of the simulation results by collecting first hand data for a humanitarian as well as a commercial case. We also face a challenge in accounting for one-off costs (e.g. implementation costs) as well as accruing the fixed costs (e.g. warehousing and good's depreciation) in our variable cost model. Although we acknowledge these costs with a surcharge (50-100%) on the goods from VMI and Emergency Stock, the surcharge depends heavily on the turnover of these goods, given by the disruption frequency which is very different in both cases.

This paper show the superior ability of the HRSC in handling large scale disruptions. Further, our simulation shows positive impact on the disruption loss originating from the HRSC's individual features. Additional costs for these enhancing features vary, with the Rapid Assessment Process and the Supplier Framework Contracts being the most beneficial. The HRSC and its individual features can therefore serve as a model for developing new strategies for disruption risk management in CSCs.

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Figure 2: Structural and Functional Elements of the System Dynamics Model

# An Ant-Based Algorithm for the Cross Docking Scheduling Problem for Distribution Centers

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#### Abstract

With an aim to reduce inventory level, raise handling efficiency, and to improve customer service, more and more logistics operators choose to adopt the cross-docking strategy. As no storage is involved at a distribution center (DC), transportation coordination becomes critical for a successful implementation of cross docking. The Cross-Docking Scheduling Problem (CDSP) determines the schedules of the inbound (supplier) and outbound (customer) trucks for a DC with the objective of minimizing the total work time span. Owing to the nature of the sequencing decision problem associated with the CDSP, this study designs the solution algorithm based on Ant Colony Optimization (ACO), which has some inherited advantages over other meta-heuristics due to its sequential framework for the searching process and the solution building procedure. An ant-based algorithm is developed to generate the outbound sequence under the condition of one single truck. Given this ant-generated initial sequence, a heuristic of several steps is used to make the scheduling decisions for both the inbound and outbound vehicles under the multiple-truck situation. In the numerical experiment, the developed algorithm is compared with a solution algorithm based on the classic Johnson's Rule in the literature. It is found that the developed ant-based algorithm is promising for providing a new approach to solve the CDSP.

Keywords: Cross Docking, Distribution Center, Ant Colony Optimization, Heuristic

#### 1. Introduction

In order to improve customer service and reduce operation cost, more and more logistics operators choose to adopt the cross-docking strategy, for which only sorting and consolidating is involved at a distribution center (DC), and storage and order-picking activities are minimized. The cost associated with inventory carrying and material handling is significantly reduced. Meanwhile, customers can be served in a much more timely fashion, and customer satisfaction is thus raised. The other important advantage of cross-docking operation is the saving in transportation cost. As the inbound shipments from the suppliers and the outbound shipments to the customers are both consolidated at a cross-docking DC, shipping volume is increased and the unit transportation cost is reduced. The cross-docking operation at an DC is illustrated in Figure 1.

The benefit of cross-docking can never be realized if the shipping decisions of the inbound and outbound shipments are not made in a integrated way. As the example in Figure 1, if the truck from Supplier A has not arrived at the DC, none of the customer trucks is ready to leave. A poor scheduling plan for the cross-docking operation can cause the congestion at the docks and the temporary storage and sorting/consolidating areas to further affect the efficiency of the DC.

#### Figure 1: Illustration of Cross-Docking Operation at Distribution Centers



For this study, the Cross-Docking Scheduling Problem (CDSP) determines the schedules of the inbound (supplier) and outbound (customer) trucks for a DC with the objective of minimizing the total work time span. Usually, an approximate solution algorithm is needed for the CDSP with a practical size, as the problem complexity is increased in a factorial way. In particular, multiple trucks are considered in this study. Owing to the nature of the sequencing problem associated with the CDSP, this study chooses the Ant Colony Optimization (ACO), which has some inherited advantages over other meta-heuristics due to its sequential framework for the searching process and the solution building procedure. An ant-based procedure is used to generate an initial customer service sequence, by which the feasible solution is derived based on some simple steps without too much computation effort.

The remainder of this paper is organized as follows. The second section provides the literature review. The mathematical model of the CDSP and the solution algorithm are presented in the third and fourth section respectively. The numerical experiment is described in the fifth section. Finally, conclusions are drawn in the last section.

#### 2. Literature Review

According to Agustina, et al.(2010), the mathematical models for cross docking can be classified as three major levels: strategic, tactical, and operational. The focus of this study is the operational decision regarding the scheduling of the trucks, and other operational issues such as dock door assignment and vehicle routing are not considered. For a more general and complete introduction to CDSP, the recent survey papers of Boysenand and Fliedner (2010) and Agustina *et al.* (2010) serves as excellent sources for more related information.

This study focuses on the truck scheduling for cross-docking operation, unlike some integrated models such as Shakeri *et al.* (2008) combining the truck scheduling problem with the dock door assignment. The type of the CDSP in this study is similar to the problem of Chen and Lee (2009). The objective is to minimize the total work time span, but their work is under the context of single-truck for both suppliers and customers. A branch-and-bound algorithm is developed to derive the optimal solution. Lin and Lin (2010) deals with a model similar to that in Chen and Lee (2009), but with the context under the manufacturing application with two flow shop machines. The products of the second stage machine requires some product-specific semifinished products made by the first stage machine. A branch-and-bound exact algorithm is developed to find the optimal solution for the problem with the size of 10 and 40 semi-finished and final products. In addition, an iterative approximate heuristic is designed to deal with larger problem instances.

Song and Chen (2007) first extend the single-truck problem to the version with multiple inbound/supplier trucks. Chen and Song (2009) later extend to the case of multiple trucks for both suppliers and customers. They develop an integer programming (IP) model, which is solvable for the problem with very small size. For larger problems, they develop a approximate heuristic based on the classic John's Rule. For this study, the same problem with some formulation modification is solved by a new solution algorithm, which provides a better solution quality as described in the following sections.

#### **3.** Mathematical Model

The following IP formulation of (1) to (13) basically follows the one in Chen and Song (2009), though some minor modifications have been made. Based on the numerical experiment of Chen and Song (2009), only small instances of this IP formulation can be solved by current IP solvers, and heuristic algorithms are thus required. The study develops an ant-based algorithm to tackle this problem, and the details of the algorithm design are presented in the next section.

$$Min. \quad C_{\rm max} \tag{1}$$

$$\sum_{u\in U}^{S.I.} x_{iu} = 1 \quad \forall i \in I$$
<sup>(2)</sup>

$$\sum_{v \in V} y_{jv} = 1 \quad \forall j \in J \tag{3}$$

$$C_{i}^{a} \ge p_{i} \quad \forall i \in I \tag{4}$$

$$C_{j}^{a} \ge C_{i}^{a} + q_{j} \quad \forall j \in J, \forall i \in S^{j}$$

$$C_{i}^{a} + Q(3 - x_{i} - x_{i} - w_{i}) \ge C_{i}^{a} + p_{i} \quad \forall i \in I, h \in I - \{i\}, \forall u \in U$$
(6)

$$C_{h}^{b} + Q(3 - v_{i} - z_{i}) \ge C_{i}^{b} + a_{i} \quad \forall i \in J, k \in J - \{i\}, \forall v \in V$$

$$(7)$$

$$C > C^{a} \quad \forall i \in I$$

$$(8)$$

$$C_{\max} \ge C_j^b \quad \forall j \in J$$
(9)

$$x_{iu}: binary \quad \forall i \in I, \forall u \in U \tag{10}$$

$$y_{jv}: binary \quad \forall j \in J, \forall v \in V \tag{11}$$

$$w_{ih}: binary \quad \forall i, h \in I$$

$$z_{ik}: binary \quad \forall j, k \in J$$
(12)
(13)

#### Notations

- 4

*i*, *j*: indices of suppliers and customers respectively (*I* and *J* are the corresponding sets.)

*u*, *v*: indices of supplier and customer trucks respectively (*U* and *V* are the corresponding sets.)

 $p_i, q_j$ : processing (service/transportation) time for *i* and *j* respectively

Q: a big number less than the maximum possible completion time

 $C_{max}$ : total work time span

 $C_i^a, C_j^b$ : completion time of *i* and *j* respectively

 $s_{ij}$ : binary parameter for precedence requirement, if = 1 indicating goods from supplier *i* is needed by customer *j*.

S: matrix of  $s_{ij}$  ( $S_i$  and  $S^j$  are the *i*th row vector and the *j*th column vector of S respectively.)

 $x_{iu}$ : binary variable, if = 1 indicating supplier *i* is served by truck *u*.

 $y_{jv}$ : binary variable, if = 1 indicating customer *j* is served by truck *v*.

 $w_{ih}$ : binary variable, if = 1 supplier *i* is served before supplier *h*.

 $z_{ik}$ : binary variable, if = 1 customer *j* is served before customer *k*.

The objective (1) is to minimize the total work span, considering serving all suppliers and customers Constraint (2) and (3) ensure suppliers and customers are served by one of their associated trucks respectively. The completion time of each individual supplier is related to Constraint (4). The individual completion of each customer is related to Constraint (5), which further considers its precedence requirement. Constraint (6) regulates the relationship of the completion times between two suppliers that are assigned to the same truck. Under such a case ( $x_{iu} = x_{hu} = 1$ ), if supplier *i* is scheduled to be served before supplier *h* ( $w_{ih} = 1$ ), the completion time of *h* would be that of *i* plus the processing time of *h*. Constraint (7), similar to (6), specifies the completion time relationship among any pair of customers. Based on Constraint (8) and (9),  $C_{max}$  is the maximum of the completion times of all suppliers and customers and leads to the definition of the total work time span. Finally, Constraint (10) - (13) define the binary variables.

#### 4. **Solution Algorithm**

The whole solution algorithm designed in this study consists of two major parts, which are presented in the following two sub-sections. The initial service sequences of customers under the condition of one single truck are first generated by a group of ants, and the initial sequence generated by each ant is used to derive a feasible solution, which includes the assignment and schedule of trucks for both suppliers and customers under the condition of multiple trucks. Once the feasible solutions and their associated objective function values for the ant-generated sequences in one iteration are derived, the pheromone is updated and used in the next iteration.

#### 4.1 Ant Sequence Generation Procedure

The first ACO algorithm was the ant system algorithm (ASA), which was proposed in the Ph.D. thesis of Dorigo (1992) and formally published in Dorigo et al.(1996). The ASA together with several ACO variants have been found to be effective for many combinatory optimization problems, including several sequencing problems. For example, there were several successful applications to the traveling salesman problem (TSP), such as Dorigo and Gambardella (1997) and Stutzle and Hoos (1997). For the introduction to the ACO and its associated algorithms and applications, Dorigo and Stutzle (2004), Dorigo et al. (2006) and Mullen et al. (2009) serve as excellent references.

For this study, the search space of ants is illustrated as the two-dimensional space consisting of the customers and the stages. The latter in fact has the number equal to the number of customers as shown in Figure 2. For each stage, the *n* nodes correspond to the choice of the *n* customers. The links are created only between the nodes between two adjacent stages. Beginning with a dummy origin as the stage of zero, the ant chooses the link based on (14), a typical choice probability defined in many ant-based algorithms. The probability is based on the pheromone deposited by the ants in the previous iterations. In addition to pheromone, some problem specific information, the heuristic value, is also incorporated. Once the ant reaches the dummy final destination at the stage of (n+1), the initial assignment sequence is derived. As shown in Figure 2, the illustrative sequence is 1-2-5-3-4-10-8-9-6-7, which is treated as the sequence of customers to be served, if there is only one truck.



(14)

index of iteration t:

pheromone on link (i, j) for iteration t  $\tau_{ii}(t)$ : parameter to control the influence of pheromone α:  $\eta_{gij}^{k}(t)$ : heuristic value of link (i, j) at stage g for ant k in iteration t parameter to control the influence of the heuristic value β:

 $B_{g}^{k}(t)$ : set of nodes already visited by ant k at stage g in iteration t

 $p_{gij}^{k}(t)$ : probability of choosing link (i, j) at stage g for ant k in iteration t

One of the most important tasks for designing an ant-based algorithm is the setting of the heuristic value. For the classic TSP, the heuristic value is usually set as the inverse of the link distance, which attracts the ants to move to the neighboring nodes. Based on the characteristics of the CDSP, this study sets the heuristic value by (15), in which a new set is defined to consider the number of suppliers required by the customer currently under consideration, but not required by the customers already visited by the ant. A customer with fewer such kind of suppliers is more likely to be selected and thus to be served earlier. This idea is similar to the concept of LSFS (Less-Supplier First-Served) highlighted in Chen and Lee (2009).

$$\eta_{gij}^{k}(t) = \frac{1}{\left(\left|U_{gj}^{k}(t)\right| + 1\right)}, \text{ where } U_{gj}^{k}(t) = \left\{u \mid u \in S^{j}, u \notin B_{g}^{k}(t)\right\}$$
(15)

 $U_{gj}^{k}(t)$ : set of suppliers that is needed by customer *j*, but not needed by the customers already visited by ant *k* at stage *g* in iteration *t* 

Given the iterative structure of the ASA, the pheromone is updated from iteration to iteration based on (16), in which the first part is about the evaporation, and the second part is the enhancement for the links used by ants. In particular, the increase of pheromone for the used links is affected by the quality of the associated solution as shown in (17).

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \sum_{k=1}^{N} \Delta \tau_{ij}^{k}(t)$$

$$\Delta \tau_{ij}^{k}(t) = \begin{cases} \frac{M}{f^{k}(t)} & \text{if } (i,j) \text{ is used by ant } k \text{ for iteration } t \\ 0 & \text{otherwise} \end{cases}$$
(16)
(17)

 $\rho$ : parameter to control the evaporation of pheromone

- *N*: Number of ants for each iteration
- $f^{k}(t)$ : objective function value achieved by ant k in iteration t

*M*: parameter to control the impact of solution quality on pheromone increase

Based on (14), the larger the pheromone and the heuristic value are, the more likely the link is chosen. However, the relative importance of the pheromone versus the heuristic value is controlled by the two parameters  $\alpha$  and  $\beta$ . These two parameters together with the other two parameters  $\rho$  and M build up a mechanism, which makes the ants to follow the promising trials found earlier and, at the same time, search the less-explored space so as to avoid being trapped at the local optimal solutions.

#### 4.2 Feasible Solution Generation Procedure

The sequence generated by an ant as discussed in the previous sub-section is treated as the initial service sequence of customers (i.e., the outbound shipments of a DC) under the condition of one truck. Based on this sequence, the following 3-step procedure further transforms it into the assignment and scheduling of multiple trucks for both suppliers and customers.

- Step 1: Under the assumption of one supplier truck, determine the sequence of suppliers to be served based on the ant-generated service sequence of customers. That is, if a customer is served earlier, its corresponding suppliers are also served earlier. (Of course, if the service of a supplier is already scheduled under the consideration of an earlier customer, it is not served for the second time.) For the multiple suppliers of the same customer, the tie can be broken arbitrarily.
- Step 2: Based on the supplier service sequence in Step 1, schedule the beginning of the service for the supplier as soon as a truck is available.
- Step 3: Given the service schedule of the multiple supplier trucks in Step 2, whenever a customer truck is

available, dispatch it to serve the customer that is ready to be served (i.e., the processes of all required suppliers have already been finished) and has the largest processing time.

The design of Step 1 is motivated by Lin and Lin (2010), in which, under the condition of single truck for both suppliers and customers, it is proved that the optimal supplier sequence can be derived according to the way in Step 1 if the customer service sequence is fixed. Once the schedule of the supplier and customer trucks are determined, the objective function (i.e., the total work time span) is computed, and the pheromone on the links is updated for the next iteration.

#### 5. Numerical Experiment

The design of the test problems basically follows that of Chen and Song (2009), but with some modifications, as shown in Table 1. Regarding the problem scale, the number of suppliers  $(n_1)$  is set at four levels (40 to 70), and the number of customer are randomly generated based on a uniform distribution with the range of 0.8 to 1.2 times of the number of suppliers. The processing time for both suppliers and customers are assumed to be uniformly distributed between 10 and 100.

Table 1: Design of Test Problems					
Factors	Values				
Number of suppliers $(/I/)$	40, 50, 60, 70				
Number of customers $(/J/)$	Unif [0.8/ <i>I</i> /, 1.2/ <i>I</i> /]				
Processing time $(p_i \text{ and } q_j)$	Unif[10, 100]				
Number of trucks $( U  =  V )$	4, 10				
Precedence requirement	Unif[0, 1]				

In addition to the issue of problem scale, four groups of test problems are designed to examine the performance of the developed ant-based algorithm for the CDSP. The same number of trucks are used for both suppliers and customers, and it is set as 4 or 10 to represent two levels of resource availability. Regarding the precedence requirement, the entries of the |I|-by-|J| matrix *S* are generated by a uniform distribution between 0 and 1. If the value is higher than 0.75, the corresponding parameter  $s_{ij}$  is set as 1, indicating customer *j* needs the product from supplier *i*. Otherwise, it is set as 0. Unlike Chen and Song (2009), this study makes a setting of  $s_{ij}$  that does not lead to a dense precedence requirement matrix. It is believed that a dense precedence matrix would make the scheduling decision less challenging. The reason is that the scheduling of customer trucks is less relevant to the scheduling of supplier trucks, as not many customer trucks can be dispatched before all suppliers are served. Under such a situation, the shipping decisions of the two stages (i.e., inbound and outbound) at a cross-docking DC is almost de-coupled. Another threshold of 0.85 is used to further reduce the density of the precedence requirement matrix. Thus, given the two levels of resource availability (4 and 10 trucks) and the two levels of precedence requirement (low and high, represented by the threshold of 0.85 and 0.75 respectively), there are four scenarios as shown in Table 2.

Sco	enario	Scale					
Trucks	Precedence Requirement	40	50	60	70		
4	Low	8.7%	8.2%	7.6%	5.2%		
4	High	7.3%	5.8%	6.3%	4.3%		
10	Low	8.5%	8.9%	8.0%	8.5%		
10	High	9.7%	10.4%	8.9%	6.4%		

For each scenario and each problem scale, 10 test problems are generated. The solution of the ant-based algorithm is compared with the heuristic of Chen and Song (2009), an approximate method based on the classic Johnson's Rule. The improvement in terms of the average of the 10 test problems is shown in Table 2. For all problem scales and scenarios, the solution quality of the ant-based algorithm is consistently better than that of the heuristic in Chen and Song (2009). In particular, it seems that the ant-based algorithm shows more advantage when more trucks are available. However, its improvement is degraded, to some extent, when problem scale is increased.

Regarding the environment of the numerical experiment, the operating system is Windows XP SP3, and the hardware is a personal computer with Intel Core 2 Duo E8400 3.00GHz CPU and 2G RAM. Both algorithms are coded by MATLAB. For the heuristic of Chen and Song (2009), the computation time is very short, only about a couple of seconds. For the ant-based algorithm of this study, it takes 30 - 180 seconds for the various scales of test problems in Table 2. Although the solution quality of the ant-based algorithm is significantly better than that of the simple heuristic algorithm based on the classic John's Rule, the extra computation time is not nominal for today's personal computers. Therefore, there is an incentive to improve its computational efficiency. Nonetheless, the developed ant-based algorithm should be able to handle most of the practical cross-docking operations nowadays based on its current capability.

#### 6. Conclusions

This study focuses on the Cross-Docking Scheduling Problem (CDSP), which determines the schedules of the inbound (supplier) and outbound (customer) trucks for a DC with the objective of minimizing the total work time span. This study designs an ant-based algorithm to take advantage of its sequential framework for the searching process and the solution building procedure. Based on the results of the numerical experiment, the solution quality of the developed algorithm is promising for providing a new approach to solve the CDSP.

For future research directions, the immediate one is to boost the computational efficiency of the ant-based algorithm, even though its current capability in general can meet the practical needs. A reduction of the computation time is expected, if more effort is paid to the coding languages and skills. In addition, since the ant system algorithm is a very basic version of the ant-based algorithm family, search efficiency, computational performance, and solution quality can be improved by employing some advanced ant-based algorithms to generate superior initial sequence.

Meanwhile, the current solution algorithm can be improved if a more sophisticated procedure is developed to replace the 3-step procedure in Sub-section 4.2 to derive the feasible solution based on the ant-generated initial sequence. For example, Step 1 can generate the best supplier truck sequence based on the ant-generated customers sequence under the assumption of one single truck. If the multiple supplier trucks are considered at the same time, there is a chance to derive a better schedule.

Finally, more practical considerations of the cross-docking operation at distribution centers can be included in the model. For example, the customer service time window can be a critical issue for some industries or types of business. However, the challenge is that a much more complicated procedure is needed, without too much computation effort, to derive a good feasible solution based on the ant-generated initial sequence.

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# Service Network Design for an Intermodal Container Network with Flexible Due Dates/Times and the Possibility of Using Subcontracted Transport

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#### Abstract

An intermodal container transportation network is being developed between Rotterdam and several inland terminals in North West Europe: the EUROPEAN GATEWAY SERVICES (EGS) network. This network is developed and operated by the seaports of EUROPE CONTAINER TERMINALS (ECT). To use this network costefficiently, a centralized planning of the container transportation is required, to be operated by the seaport. In this paper, a new mathematical model is proposed for the service network design. The model uses a combination of a path-based formulation and a minimum flow network formulation. It introduces two new features to the intermodal network-planning problem. Firstly, overdue deliveries are penalized instead of prohibited. Secondly, the model combines self-operated and subcontracted services. The service network design considers the network-planning problem at a tactical level: the optimal service schedule between the given network terminals is determined. The model considers self-operated or subcontracted barge and rail services as well as transport by truck. The model is used for the service network design of the EGS network. For this case, the benefit of using container transportation with multiple legs and intermediate transfers is studied. Also, a preliminary test of the influence of the new aspects of the model is done. The preliminary results indicate that the proposed model is suitable for the service network design in modern intermodal container transport networks. Also, the results suggest that a combined business model for the network transport and terminals is worth investigating further, as the transit costs can be reduced with lower transfer costs.

Keywords: Intermodal planning, synchromodal planning, network optimization, container transportation

#### 1. Introduction

#### 1.1 Development of container networks

A tendency of more integrated supply chains has sparked initiative in North-West Europe to create transportation networks for containers (Groothedde et al., 2005, Lucassen and Dogger, 2012, Rodrigue and Notteboom, 2012, Port of Rotterdam, 2012). These container transportation networks are generally a cooperation between multiple barge service operators, rail service operators and terminals. Roso et al. (2009) defined the concept of a *dry port*: "a hinterland terminal in close connection to the sea port, where customers can leave or pick up their standardized units as if directly at a seaport." Based on this concept, Veenstra et al. (2012) introduced the concept of an *extended gate*: a dry port for which the seaport can choose to control the flow of containers to and from that inland terminal. This control by the seaport distinguishes the extended gate from a dry port as defined by Roso et al. (2009) and introduces a central management for the intermodal container network. This concept has been implemented in the EUROPEAN GATEWAY SERVICES (EGS) since 2007, a subsidiary of EUROPE CONTAINER TERMINALS (ECT) with three seaports in Rotterdam. The network consists of these three seaports and an increasing number of terminals in North-West Europe (see Figure 1).



#### Figure 1: Overview of connections in the EGS network [EGS, 2012]

#### 1.2 Definitions: intermodal and synchromodal

The network of Figure 1 shows hinterland connections between Rotterdam (where the three seaport terminals are located) and the inland terminals (status 2012). This study focuses on the transportation from the seaport terminal to a hinterland terminal (import) or vice versa (export), organised by the sea port terminal and final drayage to a customer is excluded. This is called *hinterland transportation*. In the network, transport is carried out by three different modes: barge, rail and truck. Hence, as different modes can be selected, the transportation in the network is considered *multimodal transportation*. At terminals, containers can be exchanged from one mode to another. In scientific literature, the term transhipment is used for all types of exchange. However, to prevent confusion with the common practice in the Rotterdam port, the following definitions are used throughout this paper. An exchange at a terminal is called *transhipment* if the container is exchanged from one ship to another and *transfer* if other modes are involved. Figure 2 shows a schematic view on three terminals. The figure shows five mode-specific *corridors* by which the terminals are directly connected. As multiple modes connect two terminals, multiple corridors exist. Terminal A and C are indirectly connected via terminal B, and transport is possible using the corridors to B and then to C. Each of the transport steps from one terminal to another is called a *leg*. The two consecutive legs are referred to as a connection between A and C. The service on a corridor between terminals is the movement of a vehicle from one terminal to another, following a specific *route*. The number of services per time period on a certain route is called the *service frequency*. EGS uses frequency to denote the number of services per week on a corridor. The specific path of a container, including the terminals and services used, is called an *itinerary* (Crainic and Kim, 2007) or a *path*.



The transport between the hinterland location, e.g. a warehouse, and the inland network terminal is carried out by truck in most cases. Hence, most containers are transported using multiple consecutive services. This is referred to as intermodal transportation. Intermodal transportation is defined as *Multimodal transport of* goods, in one and the same intermodal transport unit by successive modes of transport without handling of the goods themselves when changing modes (UNECE et al., 2009). The central management of the network allows for central intermodal network planning. With *intermodal network planning*, the routing of containers with multiple consecutive services is possible, using *intermediate transfers* of the containers at network terminals. In this study the term *intermodal transfer* is used for a transfer between different modes. A container that has an itinerary with two services uses such an intermodal transfer. Throughout this report, a transfer within the network is considered an *intermediate transfer*.

On top of that, a network with centrally planned transportation can use *real-time switching* (Lucassen and Dogger, 2012). Real-time switching refers to changing the container routing over the network in real-time to cope with transportation disturbances, such as service delays or cancellations. The combination of intermodal planning with real-time switching is often referred to as *synchromodal planning*, a new term on the agenda of the Dutch Topsector Logistiek (2011). However, no unambiguous definition for synchromodality exists yet. In this study, the following definition for synchromodality is used: *intermodal planning with the possibility of real-time switching between the modes* or online intermodal planning. This study focuses on the first part of synchromodal planning: the use of intermediate transfers in the intermodal planning. For that reason, the service network design is assessed, considering additional corridors between inland terminals and container transportation over paths with multiple consecutive legs and intermediate transfers.

# 1.3 New aspects of the proposed model

In this paper we propose a new mathematical model for the tactical service network design of intermodal container networks. It is important to investigate the cost-impact of using intermediate transfers on the service network design, because the seaport controls both transportation and terminal activities in the currently developing networks. Existing intermodal planning models do not suffice for this purpose for two reasons:

- 1. Current models use time restrictions for delivery. However, the daily practice in the container transportation (at EGS) is that planners and customers agree in mutual consultation on delivery times. Depending on the circumstances (transportation volume, disturbances) they are flexible in their negotiations. This cannot accurately be modelled by strict due time restrictions.
- 2. Moreover, existing service network design models focus on the selection of self-operated services in the network. But container transportation networks use a combination of self-operated services and subcontracted services.

In the case of self-operated services, the network operator pays for the entire barge or train and incurs no additional transportation costs per TEU (twenty feet equivalent unit, a standardized container size measure). In the case of subcontracted transportation, transportation is paid for per TEU. Nonetheless, the loading and unloading of containers (handling costs) does have a cost per TEU for both cases.

The service network design model proposed in this study introduces two new aspects to the service network design problem:

- 1. Overdue delivery is not restricted, but penalized by a penalty per TEU per day of overdue delivery.
- 2. The model allows for a combined use of self-operated and subcontracted services.

#### *1.4 Structure of the paper*

This paper is organised as follows. Section 2 briefly reviews literature on service network design models. Section 3 introduces the proposed intermodal container network model. The case of EGS is used as an example for the intermodal container network model of this study in Section 4. The results of the experiments are discussed in Section 5. Section 6 concludes the paper and proposes further research.

#### 2. Literature Review

In academic literature, three levels of network planning are distinguished (Crainic and Laporte, 1997, Macharis and Bontekoning, 2004): strategic, tactical and operational planning. The exact boundary between these levels often depends on the point of view of the planning. In general, strategic planning focuses on long-term network design, such as locations of terminals or transport hubs (e.g. Ishfaq and Sox, 2010). Kagan

(2012) provides an overview of the *hub-location problem*. Operational planning focuses on the day-to-day planning of network transportation (e.g. Jansen et al., 2004, Ziliaskopoulos and Wardell, 2000). An overview is provided by Crainic and Kim (2007). This paper focuses on a tactical level planning, the service network design. Service network design consists of the following aspects as described by Crainic (2000): the selection and scheduling of the services to operate, the specification of the terminal operations and the routing of freight. Network design models are often mixed-integer problem-based formulations of a network structure where nodes represent terminals and arcs represent services (Crainic, 2000). When multiple modes can travel between the same network terminals, multiple arcs are used to represent these corridors. Both the assignment of cargo to routes and the number of services on each corridor are considered simultaneously. In the existing literature about intermodal container transportation networks, several service network design models have been proposed. Two types of models can be distinguished:

- Minimum cost network flow models (MCNF)
- Path-based network design models (PBND)

Both types of models are able to consider capacitated flow and multiple commodities (see Table 1). In this sense a commodity, or equivalently cargo class, is used to denote a set of containers that have equal properties, such as mass, origin, destination and delivery time.

	MCNF	PBND
Single commodity	Ziliaskopoulos (2000)	
	Holmberg and Hellstrand (1998)	
Multi-commodity	Crainic & Rousseau (1986)	Crainic & Rousseau (1986)
	Crainic (2000)	Crainic & Laporte (1997)
	Ishfaq & Sox (2010, 2012)	Crainic (2000)

Table 1: Examples of existing service network design models

MCNF models have the possibility of flexible routing of cargo over various links in the network. Also, explicit constraints on the link capacity can be set. However, the main disadvantage is the number of decision variables for multi-commodity, multi-mode formulations. A variable is required for each cargo class on each arc. For applications with many origin-destination pairs, mass categories and delivery times, the number of decision variables becomes too high for practical computation times. For PBND type of models, the possible paths for each cargo class are predetermined. A path is the exact route of a container using subsequent services and terminals. This reduces the number of decision variables significantly, provided that the number of possible paths is kept at a low enough number. However, with the traditional PBND formulations, the capacity of services travelling on each arc cannot be restricted directly, as multiple paths for the same or different cargo classes coincide on single services. The model proposed in the next section uses a formulation that combines the arc capacity restrictions with the routing of containers over predetermined paths, as suggested by Crainic (2000).

Some of the existing tactical service network formulations use strict constraints on delivery time (Ziliaskopoulos and Wardell, 2000) or no due time restrictions (e.g. Crainic, 2000). Strict constraints do not accurately model the flexibility that transportation planners have in consultation with customers. No time restrictions at all neglect the existing time pressure in the container transportation. The proposed model uses an alternative formulation that better suits the flexible delivery time restrictions.

Several models use formulations that model the economies of scale that occur when cargo is consolidated on an arc (e.g. Ishfaq and Sox, 2012). These abstract formulations of economies of scale cannot directly represent the current situation. The current practice in intermodal container networks is that multiple service and terminal operators cooperate and in this perspective, economies of scale are exploited by selecting services operated by the network operator (self-operated services) or use subcontracted transport. The difference in cost structure between these two cannot be modelled in the existing formulations for the economies of scale. Hence, the proposed model allows for a combined use of self-operated and subcontracted services.

#### 3. Proposed Model

To solve the service network design problem, the optimal number of services on all corridors in the network must be determined, referred to as the service schedule in the remainder of this paper. Note that a service schedule would also require determining the departure times during the week, but that is out of scope of the model. Determining the optimal service frequencies is done by the central network operator and is evaluated every couple of months. The objective is to create a single weekly service schedule that minimizes the weekly transportation costs for a set of expected demand patterns. So, the service schedule is determined while considering a set of demand patterns Q. A *cargo class* is a group of containers with equal origin and destination, the same weight class and with the same period for delivery (due time). Each pattern  $q \in Q$ consists of an expected transportation volume for each cargo class  $c \in C$ . The expected transportation volume of cargo class c in demand pattern q is denoted by  $d_{c,q}$  (in TEU). For each cargo class c the parameters  $w_c$ and  $t_c$  denote the weight and due time of that cargo class, respectively.

The model is formulated as a mixed-integer linear programing problem with a linear objective and linear constraints. It combines aspects of the MCNF and PBND formulations described in the previous section (e.g. by Crainic, 2000). Moreover, two aspects are added: the possibility for overdue delivery, at the cost of a penalty, and the possibility of using self-operated and subcontracted transportation. The objective minimizes the weekly transportation costs consisting of four cost terms:

- The cost of operating the self-operated services
- The cost of subcontracted transportation
- Transfer costs (loading and unloading containers)
- Penalties for overdue delivery

The possible paths in the network for each cargo class must be predetermined. This can be done in various ways, such as using the expert knowledge in existing networks, or by an automated path generation method as is used in the case study of the next section. The set of all possible paths is denoted by P. The subset of feasible paths for each cargo class c is denoted by  $P_c$ . In this study a path is considered feasible for cargo class c if the origin and final destination coincide. The weight of containers in a cargo class could be added as an additional criterion for a path's feasibility.

The model uses four sets of decision variables. The (integer) service frequencies  $y_{ijm}$  denote the number of self-operated services between terminal *i* and *j* with mode *m*, defined as *corridor* (*i*, *j*, *m*). The set of available corridors is denoted by *A*. The service frequencies are determined while considering multiple demand patterns  $q \in Q$ . The amount of TEU of cargo class *c* on self-operated or subcontracted services on corridor (*i*, *j*, *m*) in pattern *q* is denoted by the flow variables  $z_{ijm}^{c,q}$  and  $\zeta_{ijm}^{c,q}$ , respectively. Finally, the path selection variable  $x_p^{c,q}$  denotes the number of TEU of cargo class *c* transported on path *p* in pattern *q*. The objective of the model is to minimize the following objective function *J*:

$$J = \sum_{(i,j,m)\in A} f_{ijm} y_{ijm} + \sum_{(i,j,m)\in A} \sum_{(c,q)\in C\times Q} c_{ijm} \zeta_{ijm}^{c,q} + c_F \sum_{p\in P} F_p \sum_{(c,q)\in C\times Q} x_p^{c,q} + c_\tau \sum_{(c,p)\in C\times P} \tau_p^c,$$
(1)

where

- $f_{ijm}$  and  $c_{ijm}$  denote the costs of operating a service or subcontracting one TEU on corridor (i, j, m), respectively,
- $c_F$  is the cost per transfer,
- $F_p$  is the number of transfers on path p;
- $c_{\tau}$  denotes the cost per TEU for each day late delivery.

Hence, the first term of the objective represents the cost for the selected services to operate self; the second term sums all costs for subcontracted transports in all patterns q; the third term denotes the costs for transfers and the fourth term is the penalty cost for overdue delivery.

The minimization of objective function *J* is subject to constraints: all transportation demand must be fulfilled, while meeting the capacity restrictions of the selected services. The TEU-capacity and maximum weight of a service on corridor (i, j, m) is denoted by  $u_{ijm}$  and  $m_{ijm}$ , respectively. Besides, the allocation of containers to paths,  $x_{p,m}^{c,q}$ , must be translated to the allocation of containers to services, denoted by the flow variables  $z_{ijm}^{c,q}$  and  $\zeta_{ijm}^{c,q}$ . This mapping of selected paths to the flow variables is done with  $\delta_{ijm}^{p}$ , which is 1 if the corridor (i,j,m) is on path *p* and zero else. The constraints of the model are formulated as follows:

$$\sum_{p \in P_c} x_p^{c,q} = d_{c,q} \qquad \qquad \forall (c,q) \in C \times Q \tag{2}$$

$$\sum_{c \in C} z_{ijm}^{c,q} \le u_{ijm} y_{ijm} \qquad \qquad \forall (i,j,m) \in A; \ \forall q \in Q \qquad (4)$$

$$\sum_{c \in C} w_c z_{ijm}^{c,q} \le m_{ijm} y_{ijm} \qquad \qquad \forall (i,j,m) \in A; \ \forall q \in Q \qquad (5)$$

$$\sum_{q \in Q} x_p^{c,q} (T_p - t_c) \le \tau_p^c \qquad \forall (c,p) \in C \times P \qquad (6)$$
  

$$y_{ijm} = y_{jim} \qquad \forall (i,j,m) \in A \qquad (7)$$
  

$$x_p^{c,q} \ge 0 \qquad \forall (c,q) \in (C \times Q); \forall p \in P \qquad (8)$$
  

$$\forall (c,p) \in C \times P \qquad (9)$$
  

$$\forall (c,p) \in C \times P \qquad (9)$$

$$y_{ijm} \in \mathbb{N}$$

1

Here, constraint (2) ensures that all transportation demand is met in all patterns. The allocation of the demand to the paths is mapped to the flow variables by Constraint (3). This mapping depends on the used services (self-operated or contracted) in the predefined paths. Constraints (4) and (5) are the capacity constraints on each corridor, dependent on the selected number of services. Note that the capacity on subcontracted services is considered unlimited in this formulation. Constraint (6) ensures that the auxiliary variable  $\tau_p^c$  equals the total number of overdue days for all TEU of cargo class *c* on path *p*, by measuring the difference in the available delivery period  $t_c$  and the predetermined path duration  $T_p$ . If cargo class *c* is on time using path *p*, Constraint (9) ensures that  $\tau_p^c$  is equal to zero. Constraint (7) is the balance equation for the used equipment for self-operated services: it ensures the same number of self-operated services back and forth on a corridor, to keep the equipment balanced over the network. Finally, Constraints (8)-(10) ensure the nonnegativity of the other variables and Constraint (11) restricts  $y_{iim}$  to the integer set of natural numbers.

 $\forall (i, j, m) \in A$ 

(11)

#### 4. Case study of EGS

#### 4.1 Network and paths

The model is applied to the real-world case of the network transportation in the EUROPEAN GATEWAY SERVICES network. The EGS network has been continuously growing with terminals and connections (EGS, 2012). This study's focus is on the network situation of June 2012: it consists of three ECT seaports in Rotterdam (Delta, Euromax and Home) and seven inland terminals in the Netherlands, Belgium and Germany, i.e. Moerdijk, Venlo, Willebroek, Duisburg, Dortmund, Neuss and Nuremberg. All terminals can accommodate barge, rail and truck services, with a few exceptions: Willebroek and Moerdijk cannot accommodate train services; Dortmund and Nuremberg do not have a barge terminal.

Before the model can be applied to the service network design for this network, suitable paths must be predetermined. The number of possible paths could grow exponentially with the number of terminals in the

network. However, in order to solve the model in a reasonable amount of time, some smart path selection was applied to restrict the number of possible paths. Suitable paths between all locations are predetermined using the *k-shortest path* method by Yen (1971). This method is able to select shortest paths without loops in a network, based on Dijkstra's algorithm. In this study, the number of selected paths was restricted using the following three rules, all based on practical experience at the EGS planning department:

- Paths are selected based on the geographical length of the network arcs, up to a length of three times the length of the shortest path. Longer paths are considered unrealistic for use in practice. The geographical length of a network arc is measured as the length of the truck route on that arc.
- Subsequently, omitting all paths that consist of more than three transportation legs reduces the number of paths further. More than two intermediate transfers are not considered in this study.
- Then, paths that have a detour of more than 10% in any of the transportation legs are omitted. This detour is measured as the difference in distance to the destination from both ends of a leg. Let  $T_{kD}$  denote the trucking distance from node k to the destination. Then, a path is considered to make a detour if  $T_{iD} \ge 1.1T_{jD}$  in any of its legs (i, j). This rule is added to prevent paths with unrealistic detours, a little detour is allowed, though.

All of the remaining paths describe a geographic route with one to three transportation legs in the network. The final step of the path generation is to generate all intermodal possibilities of such a route, based on the possibility of barge and train corridors between the network locations. Truck is only considered for the last (first) leg before (after) the hinterland destination (origin), as it does not make sense to do truck transfers. E.g. a route Rotterdam Delta  $\rightarrow$  Venlo  $\rightarrow$  Nuremberg results in four paths (see Figure 3):

Delta	$\xrightarrow{barge}$	Venlo	$\xrightarrow{rail}$	Nuremberg,
Delta	$\xrightarrow{rail}$	Venlo	$\xrightarrow{rail}$	Nuremberg,
Delta	$\xrightarrow{rail}$	Venlo	$\xrightarrow{truck}$	Nuremberg,
Delta	barge →	Venlo	$\xrightarrow{truck}$	Nuremberg,

where both Delta and Venlo have a rail and barge terminal, but Nuremberg does not have a barge terminal. Note that the truck mode is only considered for the last leg. With each path p is associated a travel time  $T_p$  and a number of transfers  $F_p$ .





4.2 Costs and transportation demand

The cost parameters in the study are based on the actual costs in the current operation of the EGS network. To protect the confidentiality of the data, all costs in this paper are masked by a confidentiality factor. The corridor costs per service  $(f_{ijm})$  and per TEU  $(c_{ijm})$  are modeled with a linear approximation of the actual

network costs and the corridor length  $d_{ijm}$ , i.e.  $c_{ijm} = \alpha d_{ijm} + \beta$ . For each transfer a cost of  $c_F = 23.89$  is used. The cost of overdue delivery per TEU per day is  $c_{\tau} = 50$ .

For this case study, the expected demand is determined based on the historic transportation volumes. An analysis of the transportation on the EGS network in the period of January 2009 - June 2012 did not show significant periodic behaviour, so periodic demand fluctuations can be neglected. The weekly transportation volumes are tested for normality. As the transported volume grew fast in 2010, the weekly demands were

further analysed based on the period January 2011 - June 2012. Using Pearson's  $\chi^2$  Goodness-of-fit test (Cochran, 1952), the hypothesis of normality of the distribution of the weekly volume was accepted with a *p*-value of 0.93.

Hence, the expected demand patterns for all cargo classes are based on the estimated normal distribution of transportation volumes in the period January 2011-June 2012. The parameters of the normal distribution of the weekly volume are determined for each cargo class. With this, ten 10-percentile subsets of the normal distribution are generated for each cargo class. These demands are used as ten patterns q in the proposed model. The model will determine the optimal service frequencies simultaneously, optimized for all ten 10-percentile sets.

# 5. Experiments

#### 5.1 Scenarios

The model is solved for the EGS-case with AIMMS 3.12, using CPLEX 12.4, on a MacBook Pro with a dual core 2.66GHz processor and 8GB of RAM memory. Four different experiments are carried out. The service network design of the current EGS situation is considered the *basic scenario*. The other three experiments are hypothetical situations to assess the importance of the different aspects of the current model:

- It is interesting to investigate the relation between transfer costs and the use of intermediate transfers. Therefore, a scenario where the transfer costs are lowered by 50% is studied to find the effect of transfer costs on the service schedule
- The proposed model introduces the use of flexible due times. So, a scenario is considered where due times are ignored, or equivalently, the overdue costs are set to zero. This shows the impact of due times on the results.
- The proposed model also introduced the combination of self-operated services and subcontracted transport. To show the importance of this, a scenario without the possibility of selecting subcontracts is assessed. This shows the impact of using subcontracts along with the network services.

#### 5.2 Results

The results of the EGS case and the three hypothetical scenarios are shown in Table 2. The table shows the resulting costs in total and separately for the four objective terms. Also, the computation times to carry out the experiments are shown.

The table shows that a large part of the weekly network transportation costs are for the handling of containers (transfer costs). These do not vary much between the various experiments; apart from the scenario were the transfer costs are reduced by 50%, obviously. In that case, the number of transfers increases by 4.1%. It can also be seen that the *transit costs*, the costs for self-operated or subcontracted transportation, does vary between the four experiments. That means that the service network design is sensitive to the tested parameters in the experiments.

		1 abel 2.	Results case study			
Cost terms	Total	Self-operated	Subcontracted	Transfers	Overdue	Comp. time [s]
EGS case	1142	223	163	632	122	119
50% transfer costs	818	201	166	329	122	111
No due times	946	206	103	638	0	106
No subcontracts	1424	636	0	634	153	4067

#### Tabel 2: Results case study EGS

#### 5.3 Discussion

The scenario with 50% transfer costs obviously has lower costs for transfers. However, also the transit costs (i.e. the costs for self-operated services and subcontracted transports) are reduced by 7.3%. The number of

containers for which an intermediate transfer takes place increases from 1.2% to 5.4%. These results suggest that the network operator must look into the combined business model of services and terminals. Terminals with low utilization of the available capacity can easily handle intermediate transfers, and in that way possibly reduce transportation costs.

The scenario in which due times are omitted also shows a reduction of transit costs, with 22%. Hence, in the studied base case 22% of the transportation costs are made in order to deliver on time. On top of that, in the basic case the model 'accepts' a fictional penalty of 10.6% for late delivery. This shows the importance of the overdue delivery flexibility introduced in the model.

The scenario in which subcontracted transports are not considered shows the importance of the combination of self-operated and subcontracted transports. Without subcontracted transports, the total transportation takes place with self-operated services. Operating all these services increases the transit costs with 61% compared to the basic case solution. Even then, the number of late containers increases with 25%.

The proposed intermodal container network model was able to solve the various experiments fast in most scenarios. Computation times were below 2 minutes, except for the case in which no subcontracts were allowed. Solving that hypothetical case took more than an hour. The regular solution time of minutes makes the model suitable for the service network design of the current problem instance. An acceptable solution time is not guaranteed for larger problem instances, but it is expected that the solution method behaves well for regular cases. The size of regular problems is expected to be relatively small: most container networks will focus on the industrial zones supplied from a certain seaport. Such a network will often comprise a limited set of terminals, such as in the shown case of EGS. With increasing problem sizes, the number of arc-related variables  $(y_{ijm}, z_{ijm}, \zeta_{ijm})$  increases quadratic with the number of terminals. The number of paths (and path-related variables  $x_p^{c,q}$  and  $\tau_p^c$ ) could increase exponentially, but smart path generation based on experience or other insights can be applied to restrict the number of paths. This will depend on the specific case, though. If, however, a studied network is very large, it will often be possible to split the network in independent sub problems with no loss of generality. This option will depend on the specific geographical situation though.

Hence, it is expected that the model will perform well for regular problem sizes; and using smart path generation, the method is also expected to work well enough for larger problem instances. Regardless, the model is relevant from a theoretical point of view, e.g. it illustrates the importance of transfer costs in the case study.

#### 6. Conclusions & Future research

In this paper we have proposed a new model for the service network design of intermodal container networks. The model combined aspects of MNCF and PBND formulations and introduced two new aspects to the service network design: flexibility for overdue delivery and the use of subcontracted transport alongside self-operated services. With this model we assessed the benefit of intermediate transfers in the container transportation paths. The following general conclusions are drawn for intermodal container networks, based on the results of this study:

- A reduction of transfer costs will also result in a reduction of transit costs, by the use of intermediate transfers. This suggests that a combined business model for network terminals and transportation provides opportunities for reducing transportation costs.
- The proposed model is suitable for the service network design in a modern intermodal container transport network.

Future research is planned to extent the results based on the proposed model. The research will focus on a further sensitivity analysis of the service network design for the transfer costs and the overdue delivery penalty. Also, the scalability of the model to larger problem sizes will be tested. The new aspects of the model may also be beneficial for planning at an operational level. Future research into using an adapted model to operational container network planning is intended as well.

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# The Impact Factor Analysis in Shanghai Marine Transport Industry based on Gray Correlation Method

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#### Abstract

In recent years, Shanghai has been speeding up the construction of the International Shipping Center and the status of shanghai is becoming more and more important in the world shipping industry. Marine transport is the most significant sector of the shipping industry (which includes marine transport and inland water transportation), it is essential to analyze and evaluate the impact factors of marine transport. The results also have a reference value to other harbor cities worldwide.

This paper is supported by the project on "theoretical and technical comparison research on marine economy's auxiliary decision support system", which is approved by Shanghai Municipal Oceanic Bureau. First, the article qualitatively analyzes and selects totally 17 factors in 6 aspects including the economic environment, the shipping infrastructure, vessel's operating cost, foreign trade, international tourism and people's living standards in hinterlands. Then, according to the internal statistics of 2006-2011 provided by Shanghai Municipal Oceanic Bureau, the paper uses the added value of Shanghai marine transport industry as generating sequence and the impact factors as sub-sequences. Grey correlation analysis method is applied to quantitatively study the correlation degree between the various impact factors and marine transport and evaluate the importance degree of each factor. The study may help promote the development of the marine transport in Shanghai and provide decision support for related departments.

Keywords: Marine transport Industry; Impact Factor; Grey Correlation Analysis; Shanghai

#### 1. Introduction

Marine transport industry refers to activities which involve marine transportation with ships as main tools and provide service for marine transport, including marine passenger transportation, marine transport of goods, auxiliary activities of water transport, pipeline transportation, loading and unloading, and other transportation service activities. Shanghai is located in the central coast of Chinese mainland, the interchange of the Yangtze River's estuary and the East China Sea. The superior geographical position and hinterland conditions of Shanghai provide favorable conditions for the development of marine transport industry, which is one of the traditional marine industries in Shanghai. In recent years, with the proposal of constructing international economic, financial, trade and shipping center in Shanghai and the construction of Yangshan deep-water port and port-surrounding industry cluster, the development of Shanghai marine transport industry has been greatly promoted. At present, both cargo throughput and container throughput of Shanghai Port remain No.1 in the world. Moreover, on Jan.10th 2012, China's State Oceanic Administration issued a document about the implement of the marine economy's system of monitoring and assessment. The impact factor analysis is one of the important part of the system and obtain strong support of government departments. In conclusion, it is

necessary and practical to determine the impact factors influencing Shanghai marine transport industry and study their extent of influence.

Currently, grey correlation analysis method created by Professor Deng Julong in 1982 has been used in many fields including economic management, social system, ecosystem, ocean economy and so on. Grey System Theory has been early applied to agricultural relevant research (Jiyi Liang et al, 1984). In recent years, some researchers have used the grey correlation analysis to study the correlation between marine economy and its each ocean industry (Jing Fu, 2009; Dan Zhang, 2011). Research on impact factors of tourism industry has been done with grey correlation method (Xumei Lang et al, 2012). However, little research using grey correlation analysis has been done in the field of ocean transportation. This method does not require a large number of sample data and can work out the problem of insufficient and incomplete information easily. In consideration of the complexity and uncertainty of ocean transportation, it is appropriate and of practical significance to apply grey correlation method for the correlation analysis of Shanghai marine transport industry.

Marine transport system is complicated and fluctuant, whose impact factors also involve many different aspects. This paper adapts literature research, field survey, expert interviews and other ways to determine 16 major factors influencing Shanghai marine transport from 6 aspects. By means of the data from 2006 to 2011 mainly from the "Statistical compilation of marine transport economy in Shanghai" provided by Shanghai Municipal Oceanic Bureau and the "Statistical yearbook of Shanghai", the paper uses grey correlation analysis method to quantitatively study the correlation degree between the various impact factors and the added value of marine transport and get the importance degree of each factor. The research findings may help relevant government departments adjust the policy of the marine transport and strengthen the construction of related aspects, thus promoting the further development of Shanghai marine transport industry.

#### 2. Selection and Analysis of Impact Factors

Marine transport is a complicated and volatile system and the main factors influencing Shanghai marine transport involve many different aspects. The research is based on a practical project and the selection of factors is mainly in accordance with the achievements of the project. According to the principle of science, comprehensiveness and maneuverability, and by using the methods of literature research, field survey, expert interviews, this article selects the impact factors of Shanghai marine transport industry from 6 aspects namely the shipping economic environment, the shipping infrastructure, the vessel's operating cost, foreign trade, international tourism and people's living standards in hinterlands.

#### 2.1 Economic environment

The global economic growth rate: International ocean transportation, as a derivative demand of international trade, is closely related to the development of global economy. The impact of the world's economy on the international marine transport industry is mainly shown in two aspects. On the one hand, this impact derives from the periodic fluctuations of the world's economy. Researches show that the cycle of the global economy is generally 4 to 5 years and this cyclical fluctuation can lead to periodic changes in the demands of international shipping. On the other hand, the impact of global economy derives from the changes of the international division of labor caused by regional development. China has gradually become the global manufacturing center in the last decade, which contributes to the rapid development of Shanghai ocean transportation.

GDP in Shanghai: It refers to the final achievement of all the products and services at market prices produced by the resident units in the whole city during a certain period of time (usually one year). The GDP in Shanghai, as one of the most important indicators reflecting the conditions of economic operation, can indicate the total scale of Shanghai's regional economy and can be used to measure the region's economic strength and wealth. The development of Shanghai marine transport industry is influenced by the economic environment since powerful economic strength can increase production and international trade, so as to promote the development of marine transport industry.

#### 2.2 Shipping infrastructure

The amount of ships completed: It refers to the number or weight of the newly-build ships completed in a certain period of time (usually one year). The amount of ships completed reflects the newly increased amount of the vessel supply, since vessels are the direct supply of ocean transportation.

Coastal quay length: Coastal quay is a location by the sea where passengers and cargoes are loaded or unloaded, the length of which has an effect on the waiting time of ships in port and the efficiency of cargo handling, etc. The longer the length is, the more ships can be in operation at the same time. On the contrary, a lot of vessels will need to wait for a long time if the quay length is too short, which may affect the efficiency of port operation.

Coastal berth number: Coastal berth is a location with relevant equipment and facilities used for calling and mooring of vessels, and loading and unloading of cargoes and passengers. Similar to the coastal quay length, the coastal berth number, as another important parameter to verify a port's traffic capacity, has an impact not only on the throughput capacity, but also on the waiting time and terminal charges of a ship in port.

#### 2.3 Vessel operating cost

International price index of crude oil: It refers to the average price index calculated from the prices of different types of crude oil with a certain method. The fuel cost, the charges of fuel oil consumed by a ship during its operation, accounts for more than 50%, the largest proportion of the total vessel operating costs. Therefore, fluctuations in oil prices directly influence the cost of shipping companies.

Crew's average wage: Crew's wages include all kinds of sailing wages, allowances, bonuses, subsidies, navigation allowances and so on. The marine transport industry is a labor-intensive industry, so the crew's wage is another major component of the total operating costs. In recent years, with the increase of the crew's wages, its influence on vessel operation costs is more and more significant.

# 2.4 Foreign trade

The value of import and export: International trade in goods is a buyer of the marine transport services so that foreign trade determines the demand of the marine transport industry. China has gradually become the global manufacturing center in the last decade. Raw materials are imported to China and the final products are exported to all over the world. This has brought great trade volumes to Shanghai so as to drive the development of the marine transport industry.

The Customs' value of import and export: It refers to the total value of goods carried in or out through the Shanghai Customs and can reflect the marine transport demands more directly. There exists no sea in many inland areas so that many goods there, which cannot be transported directly by sea, need to be carried by means of the land or inland water transportation to a port city like Shanghai before the international transport is started.

Cargo throughput of the coastal port: As one of the significant indicators of a port's production capacity, it refers to the total amount of goods which have been carried in or out of a port and simultaneously loaded or unloaded in the port. The factor has a direct effect on the business scale of a port, thus influencing the size of the marine transport industry.

Container throughput of the coastal port: Similar to the previous index, this factor, which is also one of the important indicators of a port's production capacity, refers to the number of containers which have been carried in or out of a port and loaded or unloaded in the port.

#### 2.5 International tourism

International inbound tourist arrivals: It refers to the number of inbound tourists coming to Shanghai from abroad. At present, foreigners visiting Shanghai mostly travel by air or by sea. As a result, this factor, to a certain extent, influences the scale of passenger transport and the business income of Shanghai marine transport industry.

Number of outbound tourists: Contrary to the international inbound tourist arrivals, this factor means the number of domestic visitors travelling to abroad from Shanghai and it can also reflect the scale of the marine transport of passengers.

# 2.6 *People's living standards in hinterlands*

Urban per capita disposable income: It is an index indicating the part which can be used to arrange daily family life of all the cash income of urban households. Personal disposable income is considered to be one of the most important determinant factors of consumption expenditure therefore it is often used to measure living standards. The higher people's living standards are, the stronger the power of consumption is so as to promote the marine transport of the goods.

Rural per capita disposable income: It refers to the part which can be used for rural residents to arrange daily family life of all the cash income of rural households.

Total retail sales of social consumer goods: This factor can reflect the improvement of people's material and cultural living standards, social purchasing power of commodity and the size of the retail market. Large total retail sales of social consumer goods indicate that people have a large demand for goods and strong ability to pay, making the marine transport of goods more frequently.

From the above, the totally 16 impact factors of Shanghai marine transport industry are summarized in Table 1.

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Impact factors of	Economic environment	The global economic growth rate				
	Economic environment	GDP in Shanghai				
		The amount of ships completed				
	Shipping infrastructure	Coastal quay length				
		Coastal berth number				
	vessel operating cost	International price index of crude oil				
	vesser operating cost	Crew's average wage				
		The value of import and export				
transport industry	Foreign trade	The Customs' value of import and export				
transport muustry		Cargo throughput of the coastal port				
		Container throughput of the coastal port				
	International tourism	International inbound tourist arrivals				
	International tourism	Number of outbound tourists				
		Urban per capita disposable income				
	hinterlands	Rural per capita disposable income				
	minerialius	Total retail sales of social consumer goods				

# Table 1: Impact factors of Shanghai marine transport industry

# 3. Methodology and data collection

#### 3.1 *Methodology: grey correlation analysis*

# 3.1.1 The principle of the grey correlation analysis method

Grey System Theory was created by Professor Deng Julong in 1982, which has been continuously developed and extensively applied to many fields of both social and natural science. Grey correlation analysis is an important part of the Grey System Theory and it can quantitatively explain the uncertain relative situation of system factors and main action which changes with time. By calculation of characteristic serial curves and the degree of geometrical similarity of these curves, this method can determine whether or not variables are correlated and the degree of their correlation so that key factors and minor factors can be determined.

Compared with general methods of mathematical statistics (such as regression analysis, variance analysis, etc.), the advantages of the grey correlation analysis method are that it does not require a large number of sample data and that it is equally applicable whether the sample sequences are regular or not. Besides, there is a relatively smaller amount of calculation and it generally won't appear that quantitative results are inconsistent with qualitative analysis.

#### 3.1.2 The steps of the grey correlation analysis method

First, in order to not influence the characters of equal weight, equal measurement and equal polarity among impact factors, these factors must be standardized in grey correlation analysis. The methods used for equal weight include initial value processing, equalization, maximum/ minimum method, original value method, etc, and this paper adopts the method of initial value processing. Set the dependent variable and its impact factors as the original data series, which are respectively presented by X0 (t) and Xi (t), t=1,2, ..., m(presenting the year) and i=1, 2, ..., n(presenting the number of impact factors). The meaning of initial value processing is that all the numbers must be divided by the first number and then we obtain a new data series (Shown in formula (1)).

$$X_0'(t) = X_0(t)/X_0(1), X_i'(t) = X_i(t)/X_i(1)$$
(1)

Then, the correlation coefficient of factor i in the year t, which is denoted by  $\xi_i(t)$ , can be calculated as follows(Shown in formula (2)).

$$\xi_{i}(t) = \frac{\min_{i} \min_{t} |X_{0}(t) - X_{i}(t)| + \rho \max_{i} \max_{t} |X_{0}(t) - X_{i}(t)|}{|X_{0}(t) - X_{i}(t)| + \rho \max_{i} \max_{t} |X_{0}(t) - X_{i}(t)|}$$
(2)

in which,  $\rho$  is differentiation coefficient and the value of  $\rho \in (0,1)$  is usually assigned 0.5.

In the end, the grey correlation degree between the dependent variable and each impact factor can be described in formula (3):

$$r_{i} = \frac{1}{m} \sum_{t=1}^{m} \xi_{i}(t)$$
(3)

By sorting the correlation degree, the importance of the impact factors can be determined.

#### 3.2 Data collection

After the selection and analysis of the 16 impact factors of Shanghai marine transport industry, this paper sets about the collection of relevant data. The added value of Shanghai marine transport industry, which can best indicate the condition of marine transport economy, is regarded as generating sequence and the impact factors as sub-sequences. The main data source is the "Statistical yearbook of Shanghai", the 2012 edition of which has not yet been released therefore the data is only from 2006 to 2011. Besides, several data are obtained in other ways. The data of added value of Shanghai marine transport industry and the amount of ships completed derive from the internal data "Statistical compilation of marine transport economy in Shanghai" while the global economic growth rate and the international price index of crude oil come respectively from International Monetary Fund and Oil.in-en.com. Original data collected are shown in Table 2.

Table 2: Original data of factors of Shanghai marme transport industry from 2000 to 2011										
Impact factor	2006	2007	2008	2009	2010	2011				
Added value of Shanghai marine transport industry (0.1bn yuan )	246.81	339.73	320.37	115.52	347.50	185.92				
The global economic growth rate (%)	4.9	4.7	1.0	0.5	4.75	3.9				
GDP in Shanghai (0.1bn yuan)	10572.24	12494.01	14069.87	15046.45	17165.98	19195.69				
The amount of ships completed (10KT)	516.42	529.55	716.21	932.08	1212.6	1331				
Coastal quay length (10KM)	9.16	10.15	11.49	11.68	11.92	11.97				
Coastal berth number	1140	1155	1203	1145	1218	1226				
International price index of crude oil	18.67	17.39	20.26	20.24	18.92	20.11				
Crew's average wage (yuan)	32525.9	38177.7	43452.2	47067.9	51433.16	57164.67				
The value of import and export (0.1bn USD)	2274.89	2829.73	3221.38	2777.31	3688.69	4374.36				
The Customs' value of import and export (0.1bn USD)	4287.54	5209.09	6065.57	5154.89	6846.45	8123.14				
Cargo throughput of the coastal port (10KT)	53748	56144	58170	59205	65339	72758				
Container throughput of the coastal port (10K TEU)	2171.9	2615.2	2800.6	2500.2	2906.9	3173.9				
International inbound tourist arrivals (10K person-time)	605.67	665.59	640.37	628.92	851.12	817.57				
Number of outbound tourists (10K person-time)	58.54	68.91	73.83	86.04	116.86	132.44				
Urban per capita disposable income (yuan)	20668	23623	26675	28838	31838	36230				
Rural per capita disposable income (yuan)	9213	10222	11385	12324	13746	15644				
Total retail sales of social consumer goods (0.1bn yuan)	3375.2	3873.3	4577.23	5173.24	6070.5	6814.8				

# Table 2: Original data of factors of Shanghai marine transport industry from 2006 to 2011

# 4. Empirical Results

# 4.1 Calculation of results

First, based on formula (1), the original data can be dimensionless by means of initial value processing (shown in Table 3). Then, the correlation coefficient can be calculated according to formula (2) (shown in Table 4).

Table	3: I	nitia	l value	processing	results of	<b>Original</b>	data fro	m 2006 to	) 2011
				r		- 8			

·	0					
Impact factor	2006	2007	2008	2009	2010	2011
Added value of Shanghai marine transport industry	1.000	1.376	1.298	0.468	1.408	0.753
The global economic growth rate	1.000	0.959	0.204	0.102	0.969	0.796
GDP in Shanghai	1.000	1.182	1.331	1.423	1.624	1.816
The amount of ships completed	1.000	1.025	1.387	1.805	2.348	2.577
Coastal quay length	1.000	1.108	1.254	1.275	1.301	1.307
Coastal berth number	1.000	1.013	1.055	1.004	1.068	1.075
International price index of crude oil	1.000	0.931	1.085	1.084	1.013	1.077
Crew's average wage	1.000	1.174	1.336	1.447	1.581	1.758
The value of import and export	1.000	1.244	1.416	1.221	1.621	1.923
The Customs' value of import and export	1.000	1.215	1.415	1.202	1.597	1.895
Cargo throughput of the coastal port	1.000	1.045	1.082	1.102	1.216	1.354
Container throughput of the coastal port	1.000	1.204	1.289	1.151	1.338	1.461
International inbound tourist arrivals	1.000	1.099	1.057	1.038	1.405	1.350
Number of outbound tourists	1.000	1.177	1.261	1.470	1.996	2.262

Urban per capita disposable income	1.000	1.143	1.291	1.395	1.540	1.753
Rural per capita disposable income	1.000	1.110	1.236	1.338	1.492	1.698
Total retail sales of social consumer goods	1.000	1.148	1.356	1.533	1.799	2.019

#### Table 4: Correlation coefficient between factors and added value of marine transport industry from 2006 to 2011

Impact factor	2006	2007	2008	2009	2010	2011
The global economic growth rate	1.000	0.686	0.455	0.714	0.675	0.955
GDP in Shanghai	1.000	0.824	0.965	0.488	0.809	0.462
The amount of ships completed	1.000	0.722	0.911	0.406	0.492	0.333
Coastal quay length	1.000	0.773	0.954	0.531	0.895	0.622
Coastal berth number	1.000	0.715	0.790	0.630	0.729	0.739
International price index of crude oil	1.000	0.672	0.811	0.597	0.698	0.738
Crew's average wage	1.000	0.818	0.960	0.482	0.840	0.476
The value of import and export	1.000	0.873	0.885	0.548	0.810	0.438
The Customs' value of import and export	1.000	0.850	0.887	0.554	0.828	0.444
Cargo throughput of the coastal port	1.000	0.733	0.809	0.590	0.826	0.603
Container throughput of the coastal port	1.000	0.841	0.991	0.572	0.929	0.563
International inbound tourist arrivals	1.000	0.767	0.791	0.615	0.997	0.605
Number of outbound tourists	1.000	0.821	0.961	0.477	0.608	0.377
Urban per capita disposable income	1.000	0.796	0.992	0.496	0.873	0.477
Rural per capita disposable income	1.000	0.774	0.936	0.512	0.916	0.491
Total retail sales of social consumer goods	1.000	0.799	0.940	0.461	0.700	0.419

At last, we can obtain the correlation degree between Shanghai marine transport industry and each impact factor based on formula (3). Furthermore, for the 6 overall aspects, we can calculate the average correlation degree of each aspect to study the whole influence of every aspect. The results are shown in Table 5.

Table 5. Correlation degree between each factor and added value of marme transport industry						
Aspect	T (C)	Correlation	Average correlation			
	Impact factor	degree	degree of each aspect			
altinging approximite	The shell see we will be seen to be the					
sinpping economic	snipping economic I ne global economic growth rate		0 7525			
environment	GDP in Shanghai	0.758	0.7525			
shipping infrastructure	The amount of ships completed	0.644	0.7357			
	Coastal quay length	0.796				
	Coastal berth number	0.767				
vessel operating cost	International price index of crude oil	0.753	0.7590			
	Crew's average wage	0.763	0.7580			
foreign trade	The value of import and export	0.759				
	The Customs' value of import and export	0.760	0 7729			
	Cargo throughput of the coastal port	0.760	0.7758			
	Container throughput of the coastal port	0.816				
international tourism	International inbound tourist arrivals	0.796	0.7515			
	Number of outbound tourists	0.707				
people's living standards in hinterlands	Urban per capita disposable income	0.772				
	Rural per capita disposable income		0.7543			
	Total retail sales of social consumer goods	0.720				

Table 5. Correlation degree between each factor and added value of marine transport industry

According to the results from Table 5, we order the correlation degree of each impact factor and the average correlation degree of each aspect respectively (Shown in Figure 1 and Figure 2) so as to determine which factors are important and which are less important.



Figure 1: Ordering of the correlation degree of the 16 impact factors



Figure 2: Ordering of the average correlation degree of the 6 aspects

# 4.2 Discussion of results

From Figure 1, the most important impact factor of Shanghai marine transport industry is container throughput of the coastal port, followed by coastal quay length and international inbound tourist arrivals. Other factors are orderly urban per capita disposable income, rural per capita disposable income, coastal berth number, crew's average wage, the Customs' value of import and export, cargo throughput of the coastal port, the value of import and export, GDP in Shanghai, International price index of crude oil, the global economic growth rate, total retail sales of social consumer goods, number of outbound tourists and the amount of ships completed is the least significant impact factor.

Container throughput of the coastal port is the most significant impact factor of Shanghai marine transport industry. At present, except the large bulk cargo and liquid cargo, most general cargo will be carried by container transport and the container throughput of Shanghai Port has remained the first in the world in recent years. Moreover, international inbound tourist arrivals also have a great effect on Shanghai marine transport industry. China, with vast territory and abundant resources, is rich in tourism resources. Nowadays, more and more foreigners would like to travel to China, and with the increasing perfection of the cruise's facilities and services, many international tourists choose to travel by ship. The coastal quay length is also an important factor influencing the marine transport industry in Shanghai. It is one of the most significant indicators of shipping infrastructure which has an effect on the efficiency of ships' handling. Shanghai is gradually becoming an international shipping center, more and more goods go through the ports in Shanghai. The least significant impact factor is the amount of ships completed. Although newly built ships can strength the supply

capacity of ocean transportation, the shipping market in Shanghai has been in a situation of excess supply in recent years due to the continuous impact of the global financial crisis. Some ships are in idle so that newly built ships make little sense to Shanghai ocean transportation. Besides, ships built in Shanghai may not be applied to Shanghai marine transport, maybe they are used in foreign areas.

From Figure 2, based on the average correlation degree of the 6 aspects, we obtain that foreign trade is the most significant aspect influencing Shanghai marine transport industry, followed in order by vessel operating cost, people's living standards in hinterlands, shipping economic environment, international tourism and shipping infrastructure.

The most important aspect impacting the marine transport industry in Shanghai is foreign trade. The marine transport can be classified as cargo transport and passenger transport in accordance with the objects of transportation and the ocean cargo transport accounts for the most of the ocean transportation. Foreign trade is a direct demand of ocean cargo transportation, and excess supply exists in Shanghai marine transport industry at present so that foreign trade plays a very important part. Secondly, as a cost factor, vessel operating costs, mainly referring to the fuel cost and crew's wages, have a direct impact on the revenue of marine transport industry. After that, people's living standards, especially the per capita disposable income, also play a significant role in Shanghai marine transport. The improvement of residents' living standards can stimulate the consumption of goods, thus promoting the carriage of goods. Shipping infrastructure has a minimal impact of all the 6 aspects mainly due to the influence of the amount of ships completed, but according to the analysis of individual influence factor, it is found that the level of a port's infrastructure including quay length and berth number is still significant.

# 5 Conclusions and recommendations

# 5.1 Conclusions

The research on impact factors of Shanghai marine transport industry can help promote the development of marine transport and accelerate the construction of the international shipping center in Shanghai. Based on a practical project and by using the methods of literature research, field survey and expert interviews, this article qualitatively selects the impact factors of Shanghai marine transport industry from 6 aspects, which are the shipping economic environment (including the global economic growth rate and GDP in Shanghai), shipping infrastructure (including the amount of ships completed, coastal quay length and coastal berth number), the vessel's operating cost (including International price index of crude oil and the crew's average wage), foreign trade (including the value of import and export, the Customs' value of import and export, cargo throughput of the coastal port and container throughput of the coastal port), international tourism (including international inbound tourist arrivals and the number of outbound tourists) and people's living standards in hinterlands (including urban per capita disposable income, rural per capita disposable income, total retail sales of social consumer goods).

By using the grey correlation analysis method, the article quantitatively study the correlation degree between the various impact factors and Shanghai marine transport so as to determine the important and less important factors. Results show that the most important impact factor is container throughput of the coastal port, followed by coastal quay length and international inbound tourist arrivals while the amount of ships completed is the least significant factor. From the perspective of the overall aspect, foreign trade is the most significant of all the 6 aspects, followed in order by vessel operating cost, people's living standards in hinterlands, shipping economic environment, international tourism and shipping infrastructure.

# 5.2 Recommendations

According to the achievements of this paper, the government should take some measures to promote the development of marine transport industry in Shanghai. It is necessary to strengthen international communication and cooperation and to further deepen the development of the manufacturing industry so as to promote foreign trade. At the same time, shipping companies should pay attention to control vessel operating costs. Fuel costs can be reduced by means of technical improvement and energy conservation methods while

by improving the efficiency and professional quality of the crew, the crew can be reduced and thus labor costs saved. In addition, accelerating the economic development and constantly improving people's living standards can enhance people's consumption capacity, thus promoting the development of marine transport industry. The last but not least, with excess supply in global shipping market, it is better for shipping companies to appropriately reduce the orders of new ships.

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# **Determinants of Container Terminal Operation from Green Port Perspective**

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### Abstract

This study made use of both the analytic hierarchy process (AHP) and gray relational analysis (GRA), where AHP was first used to determine the out the degree of importance of green container terminal assessment criteria, and GRA was employed to identify the ranking order of six main commercial ports in the Far East area based on the degree to which they satisfy the aforementioned green container terminal assessment criteria.

Main findings of the paper stated as: (1) Shipping companies and port management companies have different perceptions of green container terminal assessment criteria. Shipping companies focused chiefly on assessment criteria concerning operating aspects, while port management companies paid more attention to overall management aspects. (2) The ranking order of six international ports in the Far East area in terms of degree of satisfaction in accordance with the assessment criteria toward was Singapore > Hong Kong >Tokyo >Shanghai >Busan > Kaohsiung, which suggests that Kaohsiung port should emulate the green container terminal planning and operation strategies from the port of Singapore. (3) As a member of the world community, Kaohsiung port should share responsibility for coping with the threat of climate change by improving energy conservation and CO2 reduction through the realization of a green container terminal.

Keywords: Container terminal, green port, analytic hierarchy process, gray relational analysis

### 1. Introduction

Shipping is the main means of carrying marine cargo, and is often considered a mode of transportation characterized by sustainability, energy efficiency, and relative friendliness to the environment. Shipping is nevertheless a significant source of greenhouse gas emissions, and its share of total emissions increased from 1.8% in 1986 to 7% in 2000. Assuming that over 90% of global cargo is carried by ocean transportation, better engines, reduced speeds, and more efficient ship hull designs can lower the  $CO_2$  carbon emissions volume of the shipping industry by 50% (IMO, 2000).

According to Levelton Consultants (2006), ships are the chief source of waste gas emissions in the container terminal supply chain, and account for 62% of the fine particulate matter (PM2.5), 60% of nitrogen oxides (NOx) and 92% of sulfur oxides (SOX) in this supply chain. Container terminals account for 50% of the  $CO_2$  emissions in the supply chain, and cargo-handling equipment will become the largest source of emissions in the future, accounting for 31% of particulate emissions, 22% of nitrogen oxide emissions, and 36% of  $CO_2$  emissions. In addition, in-port vessels and locomotives produce approximately 3% of particulate matter emissions, and trailers account for around 1%.

A survey of academic papers concerning container terminals reveals only a few studies of green container terminals. Sisson (2006) and Pedrick (2006) provide definitions of green container terminals and draw attention to their features, while Lazic (2006) and Clarke (2006) suggest that automated equipment and semi-automated cargo handling equipment can be considered elements of a green container terminal. These papers lack any quantitative analysis, however. Lun (2011) investigated various aspects of green management practices and their association with corporate performance in container terminal operation. A number of papers address topics concerning a general description of green ports, without providing any empirical

analysis (Guo and Li, 2006; Xu, 2007; Wu, 2009), estimate greenhouse gas emissions from ports employing economic models (Zheng and Zhang, 2003; Kim et al. 2009 and 2010), determine green port assessment indicators (Lu, 2009), and present case studies of energy saving and carbon reduction at foreign green ports (Lee, 2009; Park, 2010)

While past studies have addressed many research topics concerning the environmental aspects of green ports and ecological ports, fewer past studies have focused on green container terminal issues. The use of interviews and questionnaire surveys with experts at shipping companies and port management companies may serve as another appropriate channel of collecting data concerning green port issues.

Gray relational analysis (GRA) was proposed by Julong Deng in 1982 as an extension of gray theory, which had already been shown to be a simple and accurate method for solving decision-making problems with multiple attributes (Tang and Chen, 2012). Gray system theory offers the advantages of minimal data requirements, simplicity of use, and reasonable expected results (Lin and Wu, 2011), while GRA involves first translating the performance of all alternatives into a comparability sequence. AHP and GRA have been increasingly applied to academic research in recent years, and the literature describes applications to financial and banking issues. For example, Pophali et al. (2011) suggested that AHP and GRA are powerful tools which can be used in determination of appropriate alternatives in multiple objective decisions. Lin and Hsu (2003) used AHP to determine the relative weights of evaluative criteria, while employing GRA to rank and select the best alternatives.

The paper seeks to investigate the green container terminal concept and the impact of climate change on container terminal operations by first establishing green container terminal assessment variables via a review of recent literature concerning green ports and interviews with academic researchers and workers in the industry. The paper further conducted a questionnaire survey of personnel at shipping companies and port management companies.

This study used the AHP method to calculate the relative weights of green container terminal assessment criteria, and then used gray relational analysis with AHP weights to evaluate the relative ranking order of assessment criteria for six mega-hub ports in East Asia, namely the ports of Singapore, Hong Kong, Busan, Tokyo, and Kaohsiung. Consequently, our findings are proposed some suggestions for shipping company and port management operating green container terminal and formulating green port strategies.

The following is a summary of the main purposes of this paper:

- To explain the development status of container terminals and the physical concept of a green container port.
- To determine assessment criteria for green container terminals, and to identify the ranking order of six mega-hub ports in East Asia based on aforementioned green container terminal assessment criteria.
- To propose several suggestions concerning the operation of green container terminals and green port strategies for shipping companies and port managers.

## 2. Literature Review

### 2.1 Assessment criteria of green container terminal

The assessment factors were collected from recent literature proposing with green container terminal assessment factors based on container terminal layout. These assessment factors were accepted when they appeared more than twice in the literature, and were confirmed by five experts at shipping companies (including three business executives from APL, Evergreen and Yang Ming line, and two executives from Taiwan International Ports Corporation and the Kaohsiung Harbor Branch Company). The green container terminal assessment criteria were subsequently classified under the four dimensions of berth area, container yard area, gate area, and whole area categories. The green container terminal assessment criteria comprised 21 factors under the four dimensions (see Table 1).

Dimensions	Assessment criteria	Sources
Berth Area	Deployment of on-shore power equipment	Pedrick (2006), Sisson (2006), Wang (2010), Lin Z. L. (2012), Zhong (2011)
	Layout of automatic mooring system	Sisson (2006), Lazic (2006)
	Gantry cranes with twin-lift or tandem-lift operating	Pedrick (2006), Sisson (2006),
	capabilities	Levelton Consultants (2006),
		Obata et al. (2010)
	Shortened moving distance of trailers or handling equipment in CT	Sisson (2006), Lazic (2006)
	Optimal CT layout for energy conservation and carbon reduction	Lau and Zhao (2008), Geerlings and Duin (2010)
	Reduction in speed of ships near the port	Lin Z. L. (2012), Lirn and Yen (2010)
Container	Use of automated handling equipment	Clarke (2006), Pedrick (2006),
Yard		Sisson (2006), Lazic (2006),
Area		Wang (2010), Obata et al. (2010)
	Conversion of diesel equipment to electric power	Levelton Consultants (2006),
	systems	Geerlings and Duin (2010), Obata
		et al. (2010), Wang (2010), Choi et
		al. (2011)
	Replacement of old equipment or acquisition of	Obata et al. (2010), Lirn and Yen
	electric-powered equipment	(2010), Choi et al. (2011)
	installation of wireless remote control system of laser	Comparation (2005) KMCT (2011)
	Adoption of the measures for reducing toilor anging	Levelton Concultants (2006) Chai
	Adoption of the measures for reducing tanor engine	Level on Consultants (2000), Choi $et al. (2011)$
Gate	Establishment of character recognition software (OCR)	
Area	and radio frequency identification (RFID) systems to	Wang (2010), Choi et al. (2011),
	speed up the passage of trailers through the gate area	KMTC (2011)
	Installation of a gate assignment system to reduce external trucks' queuing time and gate passage time	Pedrick (2006), Sisson (2006)
	Control of harbor and stevedore operations via electric data transmissions	Wang (2010), Choi et al. (2011)
	Requiring that external vehicles turn off their engines while idling and queuing to enter the gate	Sisson (2006), Lazic (2006)
	Use of IC tags or smart cards to facilitate passage	Tobishima Container Berth
	through control points	Corporation (2005), KMTC (2011)
Integrated	Use of hybrid and environmentally-friendly vehicles	Levelton Consultants (2006),
Area	and the use of ultra-low-sulfur fuel oil to reduce air pollution emissions	(2010), Geerlings and Duin
	Restriction on entry into the port area by older vehicles,	Levelton Consultants
	while encouraging replacement by	(2006),Wang2010), Zhong
	environmentally-triendly vehicles	(2011)
	Implementation of energy conservation and carbon	wang (2010), Zhong (2011)
	reduction measures in offices	
	rocus on port rand, air and water quality, ecological	Clarke (2006), Lin (2012)
	Establishment of elevated roadways out of the port area	Zhong (2011) L in (2012)
	Establishment of clevated roadways out of the polt area	2011, $2011$ , $2012$

 Table 1: Green Container Terminal Assessment Dimensions and Criteria

#### 2.3 Structural diagram of green container terminal model

After receiving the returned questionnaires in July 2012, this study performed data processing employing a hybrid approach involving the AHP and GRA methods, and obtained the ranking order of green container terminals at the six mega-hub ports in East Asia. A structural diagram of the green container terminal assessment criteria is shown in Figure 1.





#### 3. Methodology and Empirical Analysis

#### 3.1 Methodology

This study employs a hybrid analytical appropriate combining AHP and GRA methods to rank six mega-hub ports in East Asia based on green container terminal assessment criteria. The proposed model comprises two aspects. The first part relies on a review of the literature and interviews with experts at shipping companies and port management companies to identify appropriate evaluation criteria for green container terminals, and then applies the AHP method to determine the relative weights of these assessment criteria. The second part employs gray relational analysis (GRA) to rank the six East Asian mega-hub ports, which include the port of Singapore, port of Hong Kong, port of Tokyo, port of Shanghai, port of Busan, and the port of Kaohsiung. This hybrid analytical approach is faster and simpler than traditional AHP in terms of the questionnaire design and calculation process.

With regard to GRA, the processed data are including alternatives  $(x_i)$ , evaluation criteria  $(c_j)$ , relative weights  $(w_j)$ , and alternative performance under each criterion  $(x_{ij}(j))$ , must be normalized in advance, and the data matrix is therefore normalized.

After the collection of relevant data, the aspired  $(x^*)$  and worst  $(x^-)$  value can be identified using the performance matrix, where  $x^*(j) = \max \max(x_{ij}(j))$  and  $x^-(j) = \min \min(x_{ij}(j))$ .

After the data is collected and processed, GRA is performed in accordance with the steps below:

1. Gray relational coefficients for aspired values:

$$\gamma (\mathbf{x}^{*}(j), \mathbf{x}_{i}(j)) = \min_{i} |\mathbf{x}^{*}(j) - \mathbf{x}_{i}(j)| + \delta \max_{i} \max_{j} |\mathbf{x}^{*}(j) - \mathbf{x}_{i}(j)|$$
$$|\mathbf{x}^{*}(j) - \mathbf{x}_{i}(j)| + \delta \max_{i} \max_{j} |\mathbf{x}^{*}((j) - \mathbf{x}_{i}(j)|$$

Grade (degree) of gray relation (larger is better)

$$\gamma(x^*, x_i) = \sum_{j=1}^n w_j \gamma(x^*(j), x_i(j))$$

Where the weight  $w_i$  can be obtained by AHP, and the  $\delta$  value is assumed to be 0.5.

2. Gray relational coefficients for worst values:

$$\gamma (\mathbf{x}^{-}(j), \mathbf{x}_{i}(j)) = \min_{i} \min_{j} |\mathbf{x}^{-}(j) - \mathbf{x}_{i}(j)| + \delta \max_{i} \max_{j} |\mathbf{x}^{-}(j) - \mathbf{x}_{i}(j)|$$

$$\frac{|\mathbf{x}^{-}(j) - \mathbf{x}_{i}(j)| + \delta \max_{i} \max_{j} |\mathbf{x}^{-}(j) - \mathbf{x}_{i}(j)|}{|\mathbf{x}^{-}(j) - \mathbf{x}_{i}(j)|}$$

Grade (degree) of gray relation (larger is worse, smaller is better)

$$\gamma(\mathbf{x}, \mathbf{x}_{i}) = \sum_{j=1}^{n} w_{j} \gamma(x^{-}(j), x_{i}(j))$$

#### 3. Relative gray relational grade:

Combine the foregoing (1) and (2) to obtain a ranking based on the relative gray relations of the aspired and worst values.

$$R_i = \frac{\gamma(x^*, x_i)}{\gamma(x^-, x_i)}$$

#### 3.2 Descriptive Analysis of respondents' profile

As shown in Table 2, a total of 40 questionnaires were distributed to 20 experts at shipping companies and 20 experts at port management companies by mail during June and July of 2012, and 25 questionnaires were returned, for a response rate of 62.50%. Among the respondents, in terms of type of work, 52% were affiliated with shipping firms and 48% with port management companies. With regard to job title, 40% held the position of general manager, and 24% constituted a manager or vice manager. In terms of working experience, 24% had 26 years or more, 20% had 21-25 years, and 16% had 11-15 years. The respondents' professional affiliations, job titles, and working experience suggested that their opinions were competent and representative.

### 3.2 AHP analysis

Based on the Respondents' opinions concerning the relative importance of the various assessment dimensions and assessment criteria, this study used the AHP method to calculate the weights of the four assessment dimensions and 21 assessment criteria. The weight of each dimension was then multiplied by the weights of the individual evaluation factors under that dimension to obtain the overall weight for that dimension.

The example shown in Table 2 contains the overall weights of assessment criteria from the viewpoint of shipping companies, and regarding to the weight ranks of the assessment dimensions and variables from the viewpoint of the shipping companies, the former had a ranking order of *berth area* (0.418), *container yard area* (0.233), *integrated area* (0.181), *and gate area* (0.168). The ranking order of the top five assessment variables was gantry cranes with twin-lift or tandem-lift operating capabilities (0.125), *deployment of on-shore power equipment* (0.077), *reduction in speed of ships near the port* (0.074), *use of automated handling equipment* (0.072), and *shortened moving distance of trailers or handling equipment in CT* (0.065).

Dimension	Assessment criteria	Weight (B)	Overall weight (C=AxB)	Rank
Berth area	Deployment of on-shore power equipment	0.185	0.077	2
weight (A)	Layout of automatic mooring system	0.074	0.031	17
(0.418)	Gantry cranes with twin-lift or tandem-lift operating capabilities	0.298	0.125	1
	Shortened moving distance of trailers or handling equipment in CT	0.156	0.065	5
	Optimal CT layout for energy conservation and carbon reduction	0.111	0.046	9
	Reduction in speed of ships near the port	0.176	0.074	3
Container	Use of automated handling equipment	0.308	0.072	4
yard area	Conversion of diesel equipment to electric power systems	0.206	0.048	7
weight (A) (0.233)	Replacement of old equipment or acquisition of electric-powered equipment	0.154	0.036	13
	Installation of wireless remote control system or laser sensor technology in the operating system	0.196	0.046	10
	Adoption of measures to reduce trailer engine idling	0.136	0.032	15
Gate Area weight (A) (0.168)	Establishment of character recognition software (OCR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area	0.288	0.048	8
	Installation of a gate assignment system to reduce external trucks' queuing time and gate passage time	0.189	0.032	16
	Harbor and stevedore operations via electric data transmission	0.159	0.027	19
	Turning off external vehicles' engines while idling and queuing to enter the gate	0.111	0.019	21
	Use of IC tags or smart cards to facilitate passage through control points	0.253	0.043	11
Integrated Area	Use of hybrid and environmentally-friendly vehicles and the use of ultra-low-sulfur fuel oil to reduce air pollution emissions	0.270	0.049	6
weight (A) (0.181)	Restriction on entry into the port area by older vehicles, while encouraging replacement by environmentally-friendly vehicles	0.156	0.028	18
	Implementation of energy conservation and carbon reduction measures in offices	0.147	0.027	20
	Focus on port land, air and water quality, ecological protection, and pollution prevention	0.193	0.035	14
	Establishment of elevated roadways out of the port area	0.235	0.043	12

Table 2. Owwall Weights of Assessment Cuitoria from a Chinning Commony Dorge of	
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Table 2. Over an averging of Assessment Criteria from a Simpping Company relisped	UVC

As for the weight ranks of the assessment dimensions and variables from the viewpoint of the port management companies, the former had a ranking order of *container yard area* (0.378), *integrated area* (0.233), *berth area* (0.221), and *gate area* (0.178). The ranking order of the top five assessment variables was replacement of old equipment or acquisition of electric-powered equipment (0.106), *use of automated handling equipment* (0.085), *Conversion of diesel equipment to electric power systems* (0.082), *focus on port land, air and water quality, ecological protection, and pollution prevention* (0.065), and *establishment of character recognition software* (0CR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area (0.063).

Finally, after determining the weight ranks of the assessment dimensions and variables from the viewpoint of all respondents, the former had a ranking order of *container yard area* (0.303), *berth area* (0.288), *integrated area* (0.211) and *gate area* (0.198). The ranking order of the top five assessment variables was use of automated handling equipment (0.076), *deployment of on-shore power equipment* (0.071), *establishment of character recognition software* (OCR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area (0.066), Conversion of diesel equipment to electric power systems (0.064), and replacement of old equipment or acquisition of electric-powered equipment (0.059).

Table 3 reveals that shipping companies and port management companies have different perceptions of the top five green container terminal assessment criteria. The former pay more attention to berth area and container yard area assessment criteria, which can achieve effective carbon emission reduction from a practical operations perspective, while the latter place more emphasis on all green container terminal assessment criteria, including assessment variables ranging from the berth area to the whole area.

	Shipping Company		Port Management Com	ipany	All respondents	
No.	Assessment Criteria	Weight	Assessment Criteria	Weight	Assessment Criteria	Weight
1	Gantry cranes with twin-lift or tandem-lift operating capabilities	0.125	Replacement of old equipment or acquisition of electric-powered equipment	0.106	Use of automated handling equipment	0.076
2	Deployment of on-shore power equipment	0.077	Use of automated handling equipment	0.085	Deployment of on-shore power equipment	0.071
3	Reduction in speed of ships near the port	0.074	Conversion of diesel equipment to electric power systems	0.082	Establishment of character recognition software (OCR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area	0.066
4	Use of automated handling equipment	0.072	Focus on port land, air and water quality, ecological protection, and pollution prevention	0.065	Conversion of diesel equipment to electric power systems	0.064
5	Shortened moving distance of trailers or handling equipment in CT	0.065	Establishment of character recognition software (OCR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area	0.063	Replacement of old equipment or acquisition of electric-powered equipment	0.059

Table 3: Ran	king Order o	of Overall	Weights o	f Assessment	Criteria
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## 3.3 GRA analysis

In implementing gray relational analysis, this study first used the data to calculate mean values of all respondents' degree of satisfaction toward each assessment criteria, normalized the degree of satisfaction of each criterion, and then used the normalized values to perform difference series calculations. The GRA formula was finally employed to obtain GRA coefficients and GRA grades were calculated from the GRA coefficients multiplied by the AHP weights, allowing the ranking order of the six mega-hub ports in East Asia to be found based on their GRA grades (refer to table 4).

Table 5 shows the ranking order of the green container terminals at six international hub ports in East Asia based on the results of a satisfaction survey. All respondents expressed that the ranking order is port of Singapore > port of Hong Kong > port of Tokyo > port of Shanghai > port of Busan > port of Kaohsiung. The shipping company personnel expressed a very similar ranking order for the international hub ports; except for switching the positions of Tokyo and Hong Kong, they ranked the other three international ports in the same order.

Assessment Criteria	Kaohsiung	Busan	Tokyo	Shanghai	Hong Kong	Singapore	Weight
Deployment of on-shore power equipment	0.44	0.65	1.00	0.90	0.82	1.00	0077
Layout of automatic mooring system	0.33	0.54	1.00	0.76	0.83	1.00	0.031
Gantry cranes with twin-lift or tandem-lift operating capabilities	0.91	0.62	0.62	1.00	0.66	0.91	0.125
Shortened moving distance of trailers or handling equipment in CT	0.73	0.56	0.92	0.60	0.79	1.00	0.065
Optimal CT layout for energy conservation and carbon reduction	0.62	0.58	1.00	0.58	0.62	0.76	0.046
Reduction in speed of ships near the port	0.67	0.73	1.00	0.85	0.59	1.00	0.074
Use of automated handling equipment	0.52	0.66	0.77	0.83	0.71	1.00	0.072
Conversion of diesel equipment to electric power systems	0.60	0.75	1.00	1.00	0.82	1.00	0.048
Replacement of old equipment or acquisition of electric-powered equipment	0.58	0.66	1.00	0.83	0.91	0.91	0.036
Installation of wireless remote control system or laser sensor technology in the operating system	0.52	0.66	0.91	0.91	1.00	0.91	0.046
Adoption of measures to reduce trailer engine idling	0.48	0.65	1.00	0.65	0.80	0.80	0.032
Establishment of character recognition software (OCR) and radio frequency identification (RFID) systems to speed up the passage of trailers through the gate area	0.40	0.62	0.83	0.83	1.00	1.00	0.048
Installation of a gate assignment system to reduce external trucks' queuing time and gate passage time	0.67	0.67	1.00	0.67	0.72	0.92	0.032
Harbor and stevedore operations via electric data transmission	0.58	0.76	0.91	0.71	0.83	1.00	0.027
Turning off external vehicles' engines while idling and queuing to enter the gate	0.39	0.55	0.91	0.45	0.047	1.00	0.019
Use of IC tags or smart cards to facilitate passage through control points	0.42	0.53	0.72	0.56	0.72	1.00	0.043
Use of hybrid and environmentally-friendly vehicles and the use of ultra-low-sulfur fuel oil to reduce air pollution emissions	0.45	0.60	1.00	0.53	0.90	1.00	0.049
Restriction on entry into the port	0.38	0.49	0.83	0.47	0.71	1.00	0.028

 Table 4: GRA Grade of Satisfaction toward Six Hub Ports from the Viewpoint of Shipping Companies

area by older vehicles, while							
encouraging replacement by							
environmentally-friendly vehicles							
Implementation of energy							
conservation and carbon	0.52	0.58	0.91	0.49	0.83	1.00	0.027
reduction measures in offices							
Focus on port land, air and water							
quality, ecological protection, and	0.42	0.53	1.00	0.41	0.59	0.72	0.035
pollution prevention							
Establishment of elevated	0.56	0.52	0.62	0.62	0.67	1.00	0.042
roadways out of the port area	0.30	0.55	0.05	0.05	0.07	1.00	0.045
MAX value	0.39	0.20	0.12	0.28	0.22	0.08	
MIN value	0.02	0.06	0.00	0.00	0.00	0.00	
GRA grade	0.534	0.625	0.904	0.730	0.782	0.951	
Ranking order	6	5	2	4	3	1	

#### 4. Conclusions

This study establishes a new model for selecting green container terminal assessment criteria based on the green port perspective. The proposed model employs two methods. The first method consists of relies on interviews with maritime experts and a review of the literature to identify suitable assessment criteria for green container terminals, after which the AHP method is applied to determine the relative weights of the criteria, and to distinguish the differing perceptions of green container terminals among shipping companies and port management companies. The second method involves the use of gray relational analysis (GRA) to rank the six green container hub ports in East Asia and determine the differing perceptions of the ports' ranking order among the two groups of respondents.

Table 5: Ranking Order of Satisfaction	toward International Hub Po	orts in East Asia
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	Shipping company				management co	ompany	All respondents		
	N.	Port name	GRA	No.	Port name	GRA	No.	Port name	GRA
	1	Singapore	0.951	1	Singapore	1	1	Singapore	0.998
	2	Tokyo	0.904	2	Hong Kong	0.701	2	Hong Kong	0.716
Shipping	3	Hong Kong	0.782	3	Tokyo	0.528	3	Tokyo	0.690
company	4	Shanghai	0.730	4	Shanghai	0.527	4	Shanghai	0.613
	5	Busan	0.625	5	Kaohsiung	0.5	5	Busan	0.537
	6	Kaohsiung	0.534	6	Busan	0.486	6	Kaohsiung	0.531
	1	Singapore	0.941	1	Singapore	1	1	Singapore	0.997
	2	Tokyo	0.904	2	Hong Kong	0.691	2	Hong Kong	0.728
Port	3	Hong Kong	0.782	3	Tokyo	0.553	3	Tokyo	0.701
company	4	Shanghai	0.730	4	Kaohsiung	0.514	4	Shanghai	0.593
company	5	Busan	0.625	5	Shanghai	0.512	5	Busan	0.537
	6	Kaohsiung	0.534	6	Busan	0.483	6	Kaohsiung	0.520
	1	Singapore	0.946	1	Singapore	1	1	Singapore	0.997
	2	Tokyo	0.895	2	Hong Kong	0.693	2	Hong Kong	0.721
All	3	Hong Kong	0.773	3	Tokyo	0.534	3	Tokyo	0.698
respondents	4	Shanghai	0.731	4	Shanghai	0.513	4	Shanghai	0.593
	5	Busan	0.624	5	Kaohsiung	0.507	5	Busan	0.533
	6	Kaohsiung	0.542	6	Busan	0.480	6	Kaohsiung	0.519

This study obtained the following empirical findings:

First, shipping companies and port management companies have different perceptions of green container terminal assessment criteria; the former emphasized assessment criteria involving the berth area and container yard area, where actions can be taken to reduce carbon emission; the latter paid balanced attention to all green container terminal assessment criteria, including those involving the berth area and those involving the whole area of the terminal.

Second, the satisfaction survey revealed that all respondents agreed with a ranking order of green container hub ports in East Asia of Singapore > Hong Kong > Tokyo > the Shanghai > Busan > Kaohsiung. The viewpoints of shipping company respondents were the same as those of all respondents, with the port of Kaohsiung occupying the final position. However, port management company personnel considered the port of Kaohsiung to have a higher rank than that of port of Shanghai and the port of Busan, which suggests that significantly different perceptions of green container terminal development at the port of Kaohsiung exist between shipping companies and port management companies. In comparison with the East Asian benchmark model of the port of Singapore, Port management companies should maintain a balance between economic development and environmental protection in order to maintain sustainable development, and should move away from an exclusive focus on port competitiveness and container handling volume.

Third, in response to climate change and the need to conserve energy and reduce carbon emissions, the port of Kaohsiung should fulfill its responsibility as a world citizen by eliminating its rigid focus on container terminal operating efficiency, and adopting the green port concept in the terminal planning and operations so as to achieve the goals of carbon reduction and sustainable development. To achieve the beneficial effects of a green container terminal as quickly as possible, we recommend that the port of Kaohsiung adopt measures including the use of automated handling equipment, deployment of on-shore power equipment for ships, Installation of character recognition software (OCR) and radio frequency identification systems (RFID) to speed passage of external trailer trucks through the gate control area, conversion of diesel equipment converted to electric power, and replacement of old handling equipment or acquisition of electric RTGs.

Fourth, diesel-RTGs produce large amounts of engine noise and exhaust emissions during operation, and have long constituted a serious source of pollution in the port area, not to mention severely impacting the physical and mental health of container terminal workers. This paper suggests that container terminal operators and shipping companies should review all handling equipment and then assess the feasibility of either a conversion project or acquisition of new handling equipment (such as RMGCs, automatic RMGCs, and automatic stacking cranes) in compliance with environmental protection requirements.

Fifth, electric gantry cranes and other cargo handling equipment offer the advantages of not producing greenhouse gas emissions, causing less noise pollution than diesel engines, needing less light and fewer light poles, and improving air quality in the container terminal. This study concludes that the government should require terminal operators, especially in the case of new container terminals, to install electric gantry cranes and cargo handling equipment in order to achieve the goals of energy conservation and carbon reduction.

Finally, this study considers the aim of the green container terminal concept to achieve state-of-the-art port construction in line with the characteristics of environmental health, ecological protection, rational use of resources, low energy consumption, and low pollution. Another goal of this concept is ensure the sustainable development of a port while maintaining harmony between container terminal operation and healthy living.

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# Seaport Competition and Strategic Investment in Accessibility

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### Abstract

This study investigates the strategic investment decisions of local governments on inland transportation infrastructure in the context of seaport competition. In particular, we consider two seaports with their respective captive catchment areas and a common hinterland for which the seaports compete. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own inland transportation system. We find that (i) increasing investment in the hinterland lowers charges at both ports; and (ii) increasing investment in a port's captive catchment area will cause severer reduction in charge at its port than at the rival port. We also examine the non-cooperative optimal investment decisions made by local governments, as well as the equilibrium investment levels under various coalitions of local governments.

Keywords: Seaport Competition; Inland Accessibility; Strategic Investment; Coordination

## 1. Introduction

As a node in the global supply "chain" (Heaver, 2002), a port connects its hinterland – both the local and interior (inland) regions – to the rest of the world by an *intermodal transport* network. Talley and Ng (2013) deduce that determinants of port choice are also determinants of maritime transport chain choice. Among these determinants, hinterland accessibility is of major concern. It is argued that hinterland accessibility in particular has been one of the most influential factors of seaport competition (e.g. Notteboom, 1997; Kreukels and Wever, 1998; Fleming and Baird, 1999; Heaver, 2006). Empirical studies on major container ports in China and the Asia-Pacific region have found port-hinterland connection as a key factor in determining port competitiveness and productivity (Yuen et al., 2012). Wan et al. (2012, 2013) have found negative correlation between local road congestion and throughput and productivity of sampled container ports in the U.S.

As it is the intermodal chains rather than individual ports that compete (Suykens and Van De Voorde, 1998), seaport competition has been largely affected by the transportation infrastructure around the port as well as the transportation system in the inland. Consequently, plans on local transport infrastructure improvements, such as investment in road capacity, rail system and dedicated cargo corridors, are critical for local governments of major seaport cities as well as inland regions where shippers and consignees locate. Jula and Leachman (2011) study the allocation of import volume between San Pedro Bay Ports (i.e. Los Angelus and Long Beach ports) and other major ports in the U.S. and find that adequate port and landside infrastructure plays a significant role for San Pedro Bay Ports to maintain competitiveness.

Theoretical works discussing the interplay between ports and their landside accessibility are emerging (see De Borger and Proost, 2012, for a comprehensive literature review). One stream of the literature studies a single intermodal chain. Yuen et al. (2008) models a gateway port and a local road connecting the port to the hinterland and investigates the effects of congestion pricing implemented at the port on the hinterland's optimal road pricing, road congestion and social welfare. De Borger and De Bruyne (2011) examine the impact of *vertical integration* between terminal operators and trucking firms on optimal road toll and port

charge, allowing trucking firms to possess market power. The other stream focuses on transport facility investment in the context of seaport or airport competition. De Borger et al. (2008), Zhang (2008), and Wan and Zhang (2013) study the impact of urban road or cargo corridor expansion on the performance of competing seaports. De Borger and Van Dender (2006) and Basso and Zhang (2007) study the investment decisions of two congestible but competing port facilities. The major difference between these two papers is that the former assumes ports face demand from final users (e.g. shippers and passengers) directly, while the later incorporates the vertical structure between the upstream ports and downstream carriers which in turn face demands from final users. One issue which has been overlooked by those papers is that transport infrastructure investment decisions made by individual local governments can affect the well-being of other port regions as well as the inland region through the mechanism of port competition. In the literature of seaport competition, to our knowledge, there is little work investigating the strategic behaviors of and interactions among seaport regions and inland region when making infrastructure investment decisions.

Thus, the focus of the present paper is the strategic investment decisions of local governments on local as well as inland transportation infrastructure in the context of seaport competition. In particular, we consider two seaports with their respective captive catchment areas and a common hinterland for which the seaports compete in prices. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own regional transportation system. Based on this model, we answer the following questions: (1) how do infrastructure investment decisions affect port competitiveness? (2) How does transport infrastructure improvement affect each region's welfare? (3) How do optimal investment decisions look like under various forms of coordination (coalitions) among local governments? Although some the aforementioned analytical papers also consider duopoly ports competing for a common hinterland, they focus on the competition and welfare effects of road or corridor expansions on the port regions while abstracting away the infrastructure decision of the common hinterland. Our setting is closest to Takahashi (2004) and Czerny and Hoffler (2013), but there are a few major differences: (1) Takahashi does not care about investment decision of the inland region and assume local governments make both price and investment decisions; (2) Czerny and Hoffler focus on port privatization games and ignore facility investment decisions; and (3) the present paper is the first one to examine the infrastructure investment rules under various forms of coordination among local governments of the seaport regions and the inland region.

Our main findings are as follows. Increasing investment in the common hinterland lowers charges of both competing ports. Increasing investment in the captive catchment area of a certain port will cause severer reduction in its port charge than that of the rival port. As a result, an increase in investment in the port region will reduce the welfare of the rival port region but improve the welfare of the common inland region. However, an increase in investment in the inland region will harm the port region with poorer accessibility. We also examine the non-cooperative optimal investment decisions made by local governments as well as the equilibrium investment rules under various coalitions of local governments. In general, for port regions, the incentive of infrastructure investment is the lowest when two port regions collude. They will invest more once at least one of them colludes with the inland region. The inland region, on the other hand, always has higher incentive to invest at lower level of coordination.

The rest of the paper is organized as below. We present the basic model in Section 2. In Section 3, we derive the pricing decision of public seaports and the non-cooperative investment decisions of local governments are derived in Section 4. Section 5 compares the infrastructure decision in non-cooperative scenario with three forms of coalitions among local governments.

### 2. Basic Model

We consider a linear continent, with three countries, B, I and N. Countries B and N have ports, but country I does not (Figure 1). The ports are non-congested regarding ship traffic and cargo handling and they deliver the cargoes right in the frontier between their countries and country I. We put the origin of coordinates at the boundary between port B and country I, and country I has a length of d.



For simplicity, we assume that countries B and N start from the boundary points of country I and extent infinitely on the line. In all three countries, shippers, i.e. people or firms that want something shipped in from abroad, are distributed uniformly with a density of one shipper per unit of length. We assume that all shippers desire the same product and each has a demand to ship one unit of containerized cargoes.

Liners and forwarders bring the containers from abroad into the two ports for a fee, but the shippers are the ones that have to decide through which port the containers enter the continent and pay the port fee. Shippers are sensitive to the congestion time costs in the connection section, and have to pay then for an inland transportation service to bring the container to their address. We assume that the inland transportation costs are  $t_B$ ,  $t_b$  and  $t_N$ , per unit of distance in each country's non-congestible transportation network respectively.

Assume that liners and forwarders behave competitively, and hence bringing the containers into one or the other port costs the same. Thus, we will collapse their action to charge a given fee per container, which is set to zero without further loss of generality. The relevant players in this game then are: the two public ports, governments B, N and I and the shippers.

As for objective functions, private ports will maximize profit; while governments or public ports will maximize regional welfare which should include infrastructure expenditure, port profits and national shipper surplus. Shippers are considered because they contribute to a port's traffic and therefore to their profits. Liners and forwarders will not be considered.

The timing of the game is as follows. In the first stage, governments decide investment in accessibility, that is t's. In the second stage, ports decide on prices to maximize a weighted average of profits and consumer surplus. Finally, shippers decide whether they will demand the product or not, and which port to use. This defines the catchment areas of each port (and the market size for the forwarders). The game is solved by backward induction and we start with shippers' decisions.

### 2.1 Shippers Demand model

Shippers have unit demands (per unit of time) and derive a gross-benefit of V if they get a container; otherwise their benefit is zero. Shippers care for the full price. Consider a shipper located in country I (i.e. at 0 < z < d). If the shipper decides to use port B to bring in the container, she derives a full price of  $\rho_B = p_B + t_1 z$ , and net utility of  $U_B = V - \rho_B = V - p_B - t_1 z$ . Similarly, if she uses port N, she derives a net-utility:  $U_N = V - \rho_N = V - p_N - t_1(d - z)$ . Note that  $\rho_h$  is the full price,  $p_h$  is the port fee (per container), and  $t_I$  is the inland transportation cost that shippers from country I have to pay.

We assume that every shipper in country *I* gets a container and that both ports bring in containers for country *I*, then the shipper who's indifferent between using either port is given by  $\rho_B = \rho_N$ , that is  $\tilde{z} = d/2 + (p_N - p_B)/2t_I$ . This condition also implies that part of country *B* shippers will demand containers as well and those containers will be brought in through the national port. The same goes for *N*. We define  $z^I$  as the last shipper on the left side of port *B* who gets a container. Similarly, we define  $z^r$  as the last shipper on the right side of port *N* who gets a container. Hence, taking into account the distribution of shippers along the line, the direct demands that each port faces is given by

$$Q_B = \tilde{z} + |z^l| = \tilde{z} + \frac{V - p_B}{t_B}$$
 and  $Q_N = (d - \tilde{z}) + (z^r - d) = (d - \tilde{z}) + \frac{V - p_N}{t_N}$ .

Replacing  $\widetilde{z}$  , we obtain the following demands

$$Q_{B} = \frac{dt_{B} + 2V}{2t_{B}} + \frac{p_{N}}{2t_{I}} - \left(\frac{2t_{I} + t_{B}}{2t_{I}t_{B}}\right)p_{B} \text{ and } Q_{N} = \frac{dt_{N} + 2V}{2t_{N}} + \frac{p_{B}}{2t_{I}} - \left(\frac{2t_{I} + t_{N}}{2t_{I}t_{N}}\right)p_{N}$$
(1)

Let  $k_B = 1/t_B$ ,  $k_N = 1/t_N$  and  $k_I = 1/2t_I$ , and then the demand functions in (1) reduce to:  $Q_B = (d/2) + k_B V - (k_B + k_I) p_B + k_I p_N$  and  $Q_N = (d/2) + k_N V + k_I p_B - (k_N + k_I) p_N$  (1.1)

This is a linear demand system with the standard dominance of own-effects over cross-effects, i.e.,  $|-(k_h + k_I)| > |k_I|$  for h = B, N, since  $k_B, k_N, k_I > 0$ . Furthermore, (1.1) shows that two ports produce substitutes. The substitutability arises due to the presence of country *I*'s shippers who may use either port for their shipment. To see this, recall that a port obtains its business from two markets: the captured national shippers and the overlapping shippers in country *I*. For port h (h = B, N) the quantity of the captured market may be denoted as  $Q_{hh}$ , and that of the overlapping market  $Q_{hI}$ . These quantities can be calculated as,

$$Q_{BB} = k_B (V - p_B), \qquad Q_{BI} = (d/2) + k_I (p_N - p_B) Q_{NN} = k_N (V - p_N), \qquad Q_{NI} = (d/2) + k_I (p_B - p_N)$$
(2)

Clearly, we have  $Q_{hh} + Q_{hI} = Q_h$ . As can be seen from (2), the port demand of a captured market depends only on the price of its own. On the other hand, the port demand of the overlapping market depends on the prices of both ports: here, the two ports offer substitutable services. In particular, with  $Q_{BI} + Q_{NI} = d - a$ fixed number – the gain in demand by one port is the loss in demand of the other port, and vice verse. We shall further assume all the four quantities in (2) are positive, implying that  $p_B < V$ ,  $p_N < V$ , and  $p_B$  and  $p_N$  are not too different from each other, i.e.  $|p_B - p_N| < d/2k_I$ .<sup>1</sup>

#### **3.** Decisions of Public Ports

Consider first that each port decides on its price to maximize regional welfare. This is the case in which the port is publicly operated: the port authority chooses the region's social surplus as its objective. More specifically, region *B*'s welfare is the sum of region *B*'s consumer surplus and the port's profit, minus the infrastructure cost  $c_B(k_B)$ .

$$W^{B}(p_{B}, p_{N}; k_{B}, k_{I}) = CS^{B} + \pi^{B} - c_{B}(k_{B}) = (k_{B}/2)(V - p_{B})^{2} + p_{B}Q_{B} - c_{B}(k_{B})$$
(3)

In (3) region B's consumer surplus is calculated as  $CS^B = \int_0^{k_B(V-p_B)} [V - p_B - (z/k_B)] dz$ , and the port has zero operating cost and so its profit is just equal to revenue  $p_B Q_B$ . Also note that  $k_I$  enters the  $W^B(\cdot)$  function via  $Q_B(\cdot)$ . Similarly, region N's welfare can be expressed as,  $W^N(r_B, r_B, r_B, r_B) = CS^N + r_B^N - r_B(r_B, r_B) - (k_B - (2))^2 + r_B - Q_B - r_B(r_B) - (k_B - (2))^2 + r_B - Q_B - r_B - (k_B - (2))^2 + r_B - (k_B - (2))^2$ 

$$W^{N}(p_{B}, p_{N}; k_{N}, k_{I}) = CS^{N} + \pi^{N} - c_{N}(k_{N}) = (k_{N}/2)(V - p_{N})^{2} + p_{N}Q_{N} - c_{N}(k_{N})$$
(4)

The equilibrium port prices are determined by the following first-order conditions:

<sup>1</sup>  $Q_{BI}$  and  $Q_{NI}$  are both positive if  $|p^B - p^N| = (d/2)(|k_N - k_B|/\Delta_W) < (d/2)(1/k_I)$  and we can prove that for any  $k_I$ ,  $k_B$  and  $k_N > 0$  this inequality condition will hold.

$$W_B^B \equiv \partial W^B / \partial p_B = 0, \qquad W_N^N \equiv \partial W^N / \partial p_N = 0 \tag{5}$$

The ports' second-order conditions are satisfied:  $W_{BB}^{B} = -k_{B} - 2k_{I} < 0$  and  $W_{NN}^{N} = -k_{N} - 2k_{I} < 0$ (subscripts again denoting partial derivatives). Further, the equilibrium is unique and stable, as  $\Delta_{W} \equiv W_{BB}^{B}W_{NN}^{N} - W_{BN}^{B}W_{NB}^{N} = k_{B}k_{N} + 2k_{B}k_{I} + 2k_{N}k_{I} + 3k_{I}^{2} > 0$ .

Using  $p^{B}(k_{B},k_{N},k_{I})$  and  $p^{N}(k_{B},k_{N},k_{I})$  to denote the equilibrium port charges, we obtain, by (5), the identities  $W_{B}^{B}(p^{B},p^{N};k_{B},k_{I}) \equiv 0$  and  $W_{N}^{N}(p^{B},p^{N};k_{N},k_{I}) \equiv 0$ . Totally differentiating these identities with respect to  $k_{B}$  yields,

$$p_B^B \equiv \partial p^B(k_B, k_N, k_I) / \partial k_B = -p^B(k_N + 2k_I) / \Delta_W < 0$$
(6)

$$p_B^N \equiv \partial p^N(k_B, k_N, k_I) / \partial k_B = -p^B k_I / \Delta_W < 0$$
<sup>(7)</sup>

Thus, an increase in  $k_B$  will reduce the equilibrium charges of both ports. The intuition behind this result is as follows. First, it can be easily seen that the first-order conditions (5) generate two upward-sloping reaction functions – noting that  $W_{BN}^B = W_{NB}^N = k_I > 0$  and so strategy variables  $p_B$  and  $p_N$  are strategic complements in the port game. Second, an increase in  $k_B$  reduces  $W_B^B$ , the marginal welfare increment with respect to  $p_B$ , thereby shifting port B's reaction function downward. Given that port N's reaction function remains un-shifted, the price equilibrium moves down along B's reaction function, leading to a fall in both  $p^B$  and  $p^N$ . Moreover, we have

$$p_B^B - p_B^N = -p^B (k_N + k_I) / \Delta_W < 0$$
(8)

Consequently, the reduction in  $p^{B}$  – following an increase in  $k_{B}$  – is greater than the reduction in  $p^{N}$ , reflecting the fact that port *B*'s reaction function is steeper than port *N*'s.

As for the effects of 
$$k_I$$
 on port charges  $p^B$  and  $p^N$ , it can be calculated,  

$$p_I^B \equiv \partial p^B (k_B, k_N, k_I) / \partial k_I = -(d/2\Delta_W^2) [(k_N + 3k_I)^2 + k_N (k_N - k_B)]$$

$$p_I^N \equiv \partial p^N (k_B, k_N, k_I) / \partial k_I = -(d/2\Delta_W^2) [(k_B + 3k_I)^2 + k_B (k_B - k_N)]$$
(9)

And from (9),  

$$p_I^B + p_I^N = -(d/2\Delta_W^2)[(k_N + 3k_I)^2 + (k_B + 3k_I)^2 + (k_N - k_B)^2] < 0$$
(10)

Inequality (10) shows that an increase in  $k_I$  will reduce the equilibrium charges for at least one port. Further, by (9), an increase in  $k_I$  will reduce the equilibrium charges of both ports if and only if  $(k_N + 3k_I)^2 + k_N(k_N - k_B) > 0$  and  $(k_B + 3k_I)^2 + k_B(k_B - k_N) > 0$ , which hold if the two port regions are not too asymmetric. We shall assume this is the case for the remainder of the paper. The above comparative static results are summarized as follows:

**Lemma 1:** Assuming public ports, then (i) an increase in  $k_B$  reduces the equilibrium charges of both ports – and here, the reduction in  $p^B$  is greater than the reduction in  $p^N$ . (ii) The effects of an increase in  $k_N$  can be similarly given. (iii) An increase in  $k_I$  reduces the equilibrium charges of both ports.

The intuition behind the positive effect of  $k_B$ ,  $k_N$ , and  $k_I$  on port charges may be seen as follows. With the present demand and other specifications, the equilibrium port prices can be calculated as,

$$p^{B}(k_{B},k_{N},k_{I}) = \frac{(k_{N}+3k_{I})d}{2(k_{B}k_{N}+2k_{B}k_{I}+2k_{N}k_{I}+3k_{I}^{2})}$$

$$p^{N}(k_{B},k_{N},k_{I}) = \frac{(k_{B}+3k_{I})d}{2(k_{B}k_{N}+2k_{B}k_{I}+2k_{N}k_{I}+3k_{I}^{2})}$$
(11)

Assuming symmetric equilibrium, (11) reduces to

$$p^{B} = p^{N} = \frac{d}{2(k_{H} + k_{I})}, \qquad \qquad k_{H} = k_{B} = k_{N}$$
 (12)

Therefore, essentially an increase in  $k_B$ ,  $k_N$ , or  $k_I$  will make the demands more elastic, and thereby reduce the prices that the ports can charge.

#### 4. Non-cooperative Infrastructure Equilibrium

This section derives the equilibrium infrastructure investments rules when the social planers for the three countries simultaneously choose the level of infrastructure accessibility which in turn affects regional welfare through subsequent port competition. Taking the ports' price decisions into account, a port region's welfare is given by:

$$\phi^{H}(k_{B},k_{N},k_{I}) \equiv W^{H}(p^{B}(k_{B},k_{N},k_{I}),p^{N}(k_{B},k_{N},k_{I});k_{H},k_{I}), H = B,N$$
(13)

Social surplus of region *I*, the inland country, is just equal to its consumer surplus,  $CS^{I}$ , minus the infrastructure cost  $c_{I}(k_{I})$ :

$$\phi^{I}(k_{B},k_{N},k_{I}) \equiv CS^{I}(p^{B}(k_{B},k_{N},k_{I}),p^{N}(k_{B},k_{N},k_{I});k_{I}) - c_{I}(k_{I})$$
(14)

In (14),

$$CS^{I} = \int_{0}^{\tilde{z}} [V - p_{B} - (z/2k_{I})]dz + \int_{0}^{d-\tilde{z}} [V - p_{N} - (z/2k_{I})]dz$$
(15)

where  $\tilde{z}$  is the shipper of region *I* who is indifferent between using port *B* and using port *N*, and  $\tilde{z} = (d/2) + k_I (p_N - p_B)$ .

Governments decide on investment in accessibility, that is, the k's. In particular, the non-cooperative infrastructure equilibrium arises when each government chooses its welfare-maximizing infrastructure investment, taking the investment of the other governments as given at the equilibrium value. Specifically, it is characterized by the following first-order conditions,

$$\phi_B^B \equiv \partial \phi^B / \partial k_B = 0, \qquad \phi_N^N \equiv \partial \phi^N / \partial k_N = 0, \qquad \phi_I^I \equiv \partial \phi^I / \partial k_I = 0 \tag{16}$$

It can be shown that both the governments' second-order conditions and the stability condition are satisfied.

We now take a closer look at each of the marginal effects in (16), starting with port region *B*. The effects of  $k_N$  on region *N*'s welfare can be similarly analyzed. As indicated earlier, each port derives its revenue from both its own region and the common (competing) inland market. Since the revenue from the regional market represents an internal transfer, the effects of  $k_B$  on region *B*'s welfare consist just of the effect on the inland revenue  $p_B Q_{BI}$ , the effect on the (gross) benefit of *B*'s shippers, and the effect on infrastructure cost. The benefit function of *B*'s shippers is given by  $(V + p_B)Q_{BB}/2$ , with  $Q_{BB} = k_B(V - p_B)$  given by (2). Thus,

$$\phi_{B}^{B} = \frac{\partial}{\partial k_{B}} [(V + p^{B})Q_{BB} / 2] + \frac{\partial}{\partial k_{B}} (p^{B}Q_{BI}) - c_{B}^{'}(k_{B})$$
(17)

where

$$\frac{\partial}{\partial k_B} [(V + p^B)Q_{BB} / 2] = \frac{(V + p^B)(V - p^B)}{2} - k_B p^B p_B^B > 0$$
(18)

Therefore, an increase in  $k_B$  increases the (gross) benefit of *B*'s shippers. According to (18), this improvement consists of two sources: a direct benefit due to less transport friction (cost) – the first term on the right-hand side (RHS) of (18) – and an indirect benefit via the positive effect of price reduction (recall, by (6),  $p_B^B \equiv \partial p^B (k_B, k_N, k_I) / \partial k_B < 0$ ). On the other hand,

$$\frac{\partial}{\partial k_B} (p^B Q_{BI}) = k_I p^B \cdot (p^N_B - p^B_B) + Q_{BI} p^B_B$$
<sup>(19)</sup>

where the first term on the RHS of (19) is, by (8), positive: An increase in  $k_B$  will reduce the equilibrium charges of both ports but will reduce own port's charge more, thereby improving own port's market share in the inland market. The second term in (19) is negative: an increase in  $k_B$  will reduce the port's price and hence its revenue from the inland market. It turns out, after some lengthy calculation, that the negative price effect dominates the positive market-share effect, leading to a negative net effect on the port's revenue from the inland market.

We next consider the effect of  $k_1$  on region *I*'s welfare. From (14)-(15) we obtain,

$$\phi_{I}^{I} = \left[\frac{\partial CS^{I}}{\partial p_{B}}p_{I}^{B} + \frac{\partial CS^{I}}{\partial p_{N}}p_{I}^{N}\right] + \frac{\partial CS^{I}}{\partial k_{I}} - c_{I}^{'}(k_{I}) = \left[(-Q_{BI})p_{I}^{B} + (-Q_{NI})p_{I}^{N}\right] + \frac{Q_{BI}^{2} + Q_{NI}^{2}}{4k_{I}^{2}} - c_{I}^{'}(k_{I})(20)$$

where both the first and second terms on the RHS of (20) are, by Lemma 1, positive. While the second term reflects the direct effect of an infrastructure improvement, the first term represents the indirect effect of an infrastructure improvement (via its impact on the port charges, which in turn benefits region *I*'s shippers). The two positive terms are balanced against the cost of infrastructure improvement,  $c'_{I}(k_{I})$ .

The impact of infrastructure investment on other regions can also be derived. In particular, the effect of  $k_B$  on region N's welfare can be written as:

$$\phi_B^N \equiv \partial \phi^N / \partial k_B = W_B^N p_B^B = p^N k_I p_B^B < 0$$
<sup>(21)</sup>

Intuitively, an increase in  $k_B$  will lower port *N*'s profit due to substantial price-cut by port *B*. Although port *N* responses with lower price as well, but since the price reduction from port *B* is larger than port *N*, eventually, the revenue loss from region *I*'s market cannot compensate the surplus gain of shippers' in region *N*. As a result, the welfare of region *N* will decrease. The effect of  $k_B$  on region *I*'s welfare:

$$\phi_B^I = \frac{\partial CS^I}{\partial p_B} p_B^B + \frac{\partial CS^I}{\partial p_N} p_B^N = (-Q_{BI}) p_B^B + (-Q_{NI}) p_B^N > 0$$

$$\tag{22}$$

Therefore, an increase in  $k_B$  will benefit region *I*'s shippers since the port charges of both ports will decrease. Similarly, the effect of  $k_N$  on region *B*'s welfare is negative while that on region *I*'s welfare is positive.

The effect of  $k_1$  on region *B*'s welfare:

$$\phi_I^B \equiv \partial \phi^B / \partial k_I = W_N^B p_I^N + \partial W^B / \partial k_I = p^B k_I p_I^N + p^B (p^N - p^B)$$
<sup>(23)</sup>

The first term of the RHS of (23) is negative, because increasing the acceptability of the inland region leads to lower charge of port *N* so that some inland shippers will switch to port *N*. When the accessibility of region *B* is worse than region *N*, i.e.  $k_B < k_N$ , port *B* charges higher than port *N* and hence port *N* has competitive advantage over port *B* for inland shippers. Then, improving the accessibility of region *I* enhances this difference between port *B* and port *N* and more inland shippers will use port *N*; as a result, the second term of the RHS of (23) is negative. However, when  $k_B > k_N$ , we have  $p^N > p^B$  and increasing  $k_I$  makes port B more attractive to inland shippers and hence the second term of the RHS of (23) will be positive. We can obtain similar comparative static result for the effect of  $k_I$  on region *N*'s welfare. The above discussion leads to Proposition 1.

**Proposition 1:** Assuming public ports, then (i) an increase in  $k_B$  ( $k_N$ ) reduces the welfare of region N (region B); (ii) an increase in  $k_B$  or  $k_N$  raises region I's welfare; and (iii) an increase in  $k_I$  reduces the welfare of the port region with less accessible infrastructure, while may or may not increase the welfare of the other port region.

### 5. Infrastructure Equilibrium under Coalitions

This section examines the equilibrium infrastructure investment decisions given that the three regions cooperate in various forms. Without loss of generality, we consider three forms of coalitions.

#### Coalition 1: region B and region N coordinate while region I remains independent

The social planners of regions *B* and *N* choose  $k_B$  and  $k_N$  together to maximize the joint welfare of these two regions. The joint welfare of two port regions is  $\phi^{BN}(k_B, k_N, k_I) \equiv \phi^B(k_B, k_N, k_I) + \phi^N(k_B, k_N, k_I)$ . The optimal investment rule is characterized by:

$$\phi_{B}^{BN} \equiv \partial \phi^{B} / \partial k_{B} + \partial \phi^{N} / \partial k_{B} = \phi_{B}^{B} + \phi_{B}^{N} = 0$$

$$\phi_{N}^{BN} \equiv \partial \phi^{B} / \partial k_{N} + \partial \phi^{N} / \partial k_{N} = \phi_{N}^{B} + \phi_{N}^{N} = 0$$

$$\phi_{I}^{I} \equiv \partial \phi^{I} / \partial k_{I} = \phi_{I}^{I} = 0$$
(24)

From (21) and (24), we can derive that at equilibrium  $\phi_B^B > 0$  and  $\phi_N^N > 0$ . As the governments' secondorder conditions are satisfied, for given levels of  $k_I$  and  $k_N$ ,  $\phi_{BB}^B < 0$ . As a result, given fixed  $k_I$  and  $k_N$  (or  $k_B$ ),  $k_B$  (or  $k_N$ ) will be set below the non-cooperative scenario. This is because under coalition 1, the two port regions internalize the negative externality on each other, as improving accessibility will definitely reduce the other port's profit due to price war. Under this coalition, the optimal investment rule for the inland region remains the same as in section 4 by setting equation (20) equal zero.

#### Coalition 2: region B and region I coordinate while region N remains independent

The social planners of regions *B* and *I* choose  $k_B$  and  $k_I$  together to maximize the joint welfare of these two regions. The joint welfare of regions *B* and *I* is  $\phi^{BI}(k_B, k_N, k_I) \equiv \phi^{B}(k_B, k_N, k_I) + \phi^{I}(k_B, k_N, k_I)$ . The optimal investment rule is characterized by:

$$\phi_{B}^{BI} \equiv \partial \phi^{B} / \partial k_{B} + \partial \phi^{I} / \partial k_{B} = \phi_{B}^{B} + \phi_{B}^{I} = 0$$

$$\phi_{N}^{N} \equiv \partial \phi^{N} / \partial k_{N} = \phi_{N}^{N} = 0$$

$$\phi_{I}^{BI} \equiv \partial \phi^{B} / \partial k_{I} + \partial \phi^{I} / \partial k_{I} = \phi_{I}^{B} + \phi_{I}^{I} = 0$$
(25)

From (22) and (25), we can derive that at equilibrium  $\phi_B^B < 0$ . Therefore, given a fixed  $k_N$  and  $k_I$ ,  $k_B$  will be set above the non-cooperative scenario. This is because under coalition 2, regions *B* and *I* internalize the positive impact of better infrastructure in region *B* on the surplus of shippers in region *I* due to lowered port charge. However, the sign of  $\phi_I^I$  depends on the sign of  $(-\phi_I^B)$ , which is positive unless  $k_B$  is substantially larger than  $k_N$  as shown in Section 4. Thus, given fixed  $k_B$  and  $k_N$ ,  $k_I$  will be set below the non-cooperative scenario unless region *B*'s accessibility is sufficiently better than region *N*. This is caused by taking into account the impact of increasing  $k_I$  on the profit of port *B*. The investment rule for region *N* remains the same as in the non-cooperative case.

#### Coalition 3: all three regions coordinate

The central planner decides  $k_B$ ,  $k_N$  and  $k_I$  to maximize the total welfare across all the three regions. The total welfare of the three regions is  $\phi^{BNI}(k_B, k_N, k_I) \equiv \phi^B(k_B, k_N, k_I) + \phi^N(k_B, k_N, k_I) + \phi^I(k_B, k_N, k_I)$ .

The optimal investment rule is characterized by:

$$\phi_{B}^{BNI} \equiv \partial \phi^{B} / \partial k_{B} + \partial \phi^{N} / \partial k_{B} + \partial \phi^{I} / \partial k_{B} = \phi_{B}^{B} + \phi_{B}^{N} + \phi_{B}^{I} = 0$$

$$\phi_{N}^{BNI} \equiv \partial \phi^{B} / \partial k_{N} + \partial \phi^{N} / \partial k_{N} + \partial \phi^{I} / \partial k_{N} = \phi_{N}^{B} + \phi_{N}^{N} + \phi_{N}^{I} = 0$$

$$\phi_{I}^{BNI} \equiv \partial \phi^{B} / \partial k_{I} + \partial \phi^{N} / \partial k_{I} + \partial \phi^{I} / \partial k_{I} = \phi_{I}^{B} + \phi_{I}^{N} + \phi_{I}^{I} = 0$$

$$(26)$$

where

$$\phi_{B}^{N} + \phi_{B}^{I} = \frac{-d}{2\Delta_{W}} p_{B}^{B} (k_{B}k_{N} + 2k_{B}k_{I} + k_{N}k_{I}) - Q_{NI} p_{B}^{N} > 0,$$
  
$$\phi_{N}^{B} + \phi_{N}^{I} = \frac{-d}{2\Delta_{W}} p_{N}^{N} (k_{B}k_{N} + 2k_{N}k_{I} + k_{B}k_{I}) - Q_{BI} p_{N}^{B} > 0, \text{ and}$$
  
$$\phi_{I}^{B} + \phi_{I}^{N} = k_{I} (p^{B} p_{I}^{N} + p^{N} p_{I}^{B}) - (p^{N} - p^{B})^{2} < 0.$$

Note that though the effect of  $k_B$  on region *N*'s welfare is negative while that on region *I*'s welfare is positive, the positive impact on region *I* dominates and hence the net effect on those two regions is positive. Therefore, it is straightforward to show that given fixed  $k_N$  and  $k_I$ , the optimal  $k_B$  in coalition 3 is higher than the non-cooperative scenario. Note that  $0 < \phi_B^N + \phi_B^I < \phi_B^I$  implies that given fixed  $k_N$  and  $k_I$ ,  $\phi_B^B$  under coalition 3 is larger than  $\phi_B^B$  under coalition 2. Together with  $\phi_{BB}^B < 0$ , coalition 3 induces less infrastructure investment in region *B* than coalition 2. Similar analysis applies to the investment rule of region *N*.

Let *NC* denotes non-cooperative case and let C1, C2 and C3 denote coalitions 1, 2 and 3, respectively. Comparing the investment rules of each region under these four cases, we reveal Propositions 2, 3 and 4.

**Proposition 2:** Assuming public ports, given fixed levels of  $k_N$  and  $k_I$ ,  $k_B^{C1} < k_B^{NC} < k_B^{C3} < k_B^{C2}$ . That is, the infrastructure investment of a port region is the lowest if two port regions collude, followed by non-cooperative case, and both cases invest less than the social optimal level (coalition 3). If one port region colludes with the inland region, this port region will overinvest in infrastructure.

**Proposition 3:** Assuming public ports, given fixed levels of  $k_B$  and  $k_I$ ,  $k_N^{C1} < k_N^{NC} = k_N^{C2} < k_N^{C3}$ . That is, the infrastructure investment of a port region is the lowest if two port regions collude, followed by the cases that the port region does not collude with any other region and makes decision independently. All the three cases invest less than the social optimal level (coalition 3).

**Proposition 4:** Assuming public ports, given fixed levels of  $k_B$  and  $k_N$ ,  $k_I^{C3} < k_I^{NC} = k_I^{C1} < k_I^{C2}$  if  $k_B$  is substantially larger than  $k_N$ ;  $k_I^{C3} < k_I^{C2} < k_I^{NC} = k_I^{C1}$  otherwise. That is, the infrastructure investment of the inland region is the lowest if all the three regions collude, followed by the case of no collusion with inland region. If one port region colludes with the inland region, the inland region may invest more or less than the non-cooperative case depending on the difference between  $k_B$  and  $k_N$ .

One major implication of the above three propositions is that compared with the social optimum (coalition 3), the port regions are likely to underinvest in infrastructure accessibility while the inland region overinvest, given that full coordination among all the three regions is not achieved. The incentive of underinvestment by port regions comes from the ignorance of inland shippers' welfare improvement when port regions increase their infrastructure accessibility. The incentive of overinvestment by inland region comes from the ignorance of port regions' profit loss when inland region increases its infrastructure accessibility. This is especially the case for NC and C1 where region B and region N are treated symmetrically. In coalition 2, however, where only one port region will collude with the inland region, the port region in collusion will overinvest while the other port region will underinvest.

### 6. Concluding Remarks

This study investigates the strategic investment decisions of local governments on inland transportation infrastructure in the context of seaport competition. In particular, we consider two seaports with their respective captive catchment areas and a common hinterland for which the seaports compete. The two seaports and the common hinterland belong to three independent local governments, each determining the level of investment for its own regional transportation system. This setting is different from any work in the literature in the sense that we consider not only two competing seaports but also the infrastructure decision of the common hinterland that the ports compete for.

We find that increasing investment in the common hinterland lowers charges of both competing ports. Increasing investment in the captive catchment area of a certain port will cause severer reduction in its port charge than that of the rival port. As a result, an increase in investment in the port region will reduce the welfare of the rival port region but improve the welfare of the common inland region. However, an increase in investment in the inland region will harm the port region with poorer accessibility. We also examine the non-cooperative optimal investment decisions made by local governments as well as the equilibrium investment levels under various coalitions of local governments. In general, for port regions, the incentive of infrastructure investment is the lowest when two port regions collude. They will invest more once at least one of them colludes with the inland region. The inland region, on the other hand, always has high incentive to invest for low level of coordination.

The focus of the present paper is on public port. However, ownership plays in a key role in port competition (Yuen et al., 2013) and hence a natural extension of this study is to compare with the infrastructure investment rule under the context that seaports are privatized or even owned by foreign companies. Furthermore, it would also be interest to investigate local governments' incentives to form various types of coalitions and predict with the theoretical model whether and in which forms coalition will occur. Issues such as schedule delay cost and congestion cost can also be incorporated into this model in the future.

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# The Value of Route Choice in the Drybulk Market: A Real Option Approach

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#### Abstract

In the short run the spot freight market for the global transportation of drybulk commodities does not conform to the law of one price. Instead, there can be substantial differences in spot freight rates between geographical regions. This observation means there can be value created by moving tonnage between the major ocean basins in accordance with observed freight rate differentials. In this paper we model this decision as a real "switching" option where the shipowner can chose between operating his vessel in the Atlantic or Pacific basin, whilst incurring a switching cost when repositioning the vessel between the two main trading regions. We model the price differential as a continuous-time mean-reverting Ornstein-Uhlenbeck stochastic process and the entry-exit decision using the discount factor approach, which results in optimal trigger values for the entry/exit from each basin. Our empirical results suggest that the estimated switching value is created mainly by the historically observed bias toward higher spot freight rates in the Atlantic basin. If we adjust for the value of this passive trading strategy, the incremental value from active geographical switching is modest. We discuss how the Atlantic premium has recently disappeared despite ongoing trade imbalances and suggest that the lower volatility of the rate differential is the result of oversupply making the regional markets more integrated.

Keywords: switching, real option, uncertainty, drybulk

### 1. Introduction

Shipping is an inherently decision-intensive business involving highly capital-intensive real assets. Combined with the large volatility in fuel prices and freight rates, this makes the industry an interesting case for the application of real option analysis, a term first coined by Myers (1977). Real options represent the value of flexibility inherent in physical assets or projects - options that cannot be traded in a financial market. The motivation for this paper is to investigate a subset of the real options available to shipowners, namely the opportunity to switch between different geographical regions of the world to take advantage of short-term differences in the freight rate level.

The global bulk shipping markets are typically described as textbook examples of perfectly competitive markets, offering a homogeneous, fungible transportation service with a large number of suppliers and consumers (Stopford, 2009). In a perfectly competitive spot freight market without trade frictions and with symmetrical trade volumes we would not expect any differences between vessel earnings (\$/day) across the different global trade routes. If such differences were to occur, tonnage would "instantaneously" move to the more profitable route, increasing the supply of transportation and depressing prices to a global equilibrium level. In practice, of course, there are several reasons why there can be substantial regional price differences, as measured by the relevant timecharter-equivalent (TCE) spot freight rate, a situation that would imply there is potential monetary value to be extracted from geographical switching. Firstly, ships move slowly around the world and so short-run deviations will persist for as long as it takes to direct sufficient tonnage towards the loading area with a shortage of ships. Of course, ships do not need to be physically present for loading in order to resolve a shortage situation – it is sufficient that they have been fixed for the voyage, as the spot freight market always clears on the basis of the number of ships and cargoes available for a future time window. Secondly, only a small portion of the fleet will be available on the spot market and freely available to switch between geographical regions at any point in time. Most ships will be performing a previously fixed

voyage or may be dedicated (owned or chartered) to a particular trade. Thirdly, while individual shipowners are price takers in the spot freight market, regional spot prices will be influenced by the cumulative actions of all owners, and the contemporaneous actions of competitors are only partly observable (not all spot market fixtures are public, for instance). This means that inter-regional fleet movements often overshoot in the sense that an area that was the subject of a shortage of ships one month may be swamped by speculatively ballasting vessels the next month. Fourthly, trade volumes tend to be asymmetrical. In the drybulk freight market, for instance, the entrance of China as the main importer of iron ore and coal in the last decade, has led to eastbound cargo volumes from the Atlantic basin to the Pacific basin ("fronthaul") being an order of magnitude greater than the reverse cargo volumes ("backhaul"). The degree of asymmetry will influence the relative level of spot freight rates as the opportunity cost on the weak leg is necessarily low (the alternative being ballasting). Finally, there may be practical issues that prevent perfect competition on a geographical basis. For instance, an owner may be located in Hong Kong and only have past experience with Pacific trading, and without personnel stationed in the Atlantic it may be impractical to also seek business in the Atlantic market. For all of the above reasons we expect that the geographical switching option can have substantial financial value.

The analysis of switching options belongs to the broader research area of entry and exit decisions under uncertainty, which started with Mossin's (1968) analysis of the optimal lay-up policy for ships. This was generalized into a modern real option framework by Brennan and Schwarz (1985) and Dixit (1989). The main result from this early research is that optimal switching policy occurs at fixed trigger price levels that a) depend on entry/exit costs and the dynamics of the underlying price process and b) have higher absolute values than the Marshallian cost. The Marshallian cost is here equivalent to the entry cost plus the net present cost of production (see, for instance, Sødal, 2006). Theoretical variations hereof include Ekern (1993) who examines the impact of restricted reversibility, and Brekke and Øksendal (1994) who allow for decreasing production capacity over time. Bar-Ilan and Strange (1996) include a deterministic lag between the switching decision and the time revenue starts to flow from the mode switched to. Sødal et al. (2008) propose and apply a closed-form real option model to value the flexibility embedded in combination carriers, i.e. vessels that can (consecutively) carry both drybulk and oil cargoes. Sødal et al. (2009) investigate an asset play strategy switching between dry and wet bulk segments.

The literature is rich on studies trying to explain freight rates in general global terms. Beenstock and Vergottis (1993) give a comprehensive summary, from the early econometric applications by Tinbergen (1934) and Koopmans (1939), to other much cited works like Wergeland (1981) and Strandenes (1984). For more recent efforts, see also Kavussanos and Alizadeh (2001) and Adland and Strandenes (2007), among others. Research considering geographical price differences, on the other hand, is scarce, with Laulajainen (2006, 2007) as a notable exception. Laulajainen (2007) studies systematic geographical differences in profitability across routes from the ship owner angle. A significant difference between the Atlantic and Pacific basins is believed to reflect oligopolistic tendencies in the Pacific. In the current paper we take as given that regional differences in profitability may exist and proceed to estimate the monetary value of the geographical switching option embedded in ship operation.

The contribution of our paper is twofold. Firstly, we extend the empirical literature on entry/exit decisions under uncertainty to geographical switching of a mobile asset and, secondly, our application of the real option model proposed by Sødal et al.(2008, 2009) illustrates the financial value of optimal (geographical) chartering strategies in the drybulk market. The remainder of this paper is organised as follows. Section 2 introduces the methodology behind the valuation of the geographical switching option. Section 3 describes the data used in our analysis and the empirical results. Section 4 contains concluding remarks and a discussion of shortcomings and avenues for future research.

## 2. Methodology

The term switching option generally refers to the combined set of entry and exit decisions between modes of operation. In the context of real options, switching the mode of operation is typically a managerial decision that can be exercised, possibly multiple times, within the life of the asset (i.e. an American option). Consider the case where a firm is currently operating its ship on trans-Pacific trades and has the option to switch to

trans-Atlantic trading. Suppose that a switch can only be exercised once, so if the option is exercised the ship has to stay in the Atlantic forever. Denote TA and TP as the present value of expected earnings in the Atlantic and Pacific basins, respectively, and C as the cost of relocating the ship. The latter can be interpreted as the strike price of the option. The payoff of this option can be expressed in the following form:

$$Payoff = \max\left(0, TA - TP - C\right) \tag{1}$$

From the payoff-representation we see that the value of a switching option arises from the spread between the value of future earnings in each basin. Thus, optimal switching will depend on the rate differential and the cost of switching. In the general case the owner can switch more than once and, if there are no restrictions on the number of switches, the switching option can be viewed as an infinite portfolio of American call and put options. We assume herein that the shipowner has a choice only between the two modes of operation described above: either operating the vessel in trans-Atlantic or trans-Pacific trading. We follow market convention (see, for instance, Alizadeh and Nomikos, 2009) and further denote the transit from the Pacific basin to the Atlantic basin as the backhaul (BH) trade and the return voyage as the fronthaul (FH) trade.

In the first section we illustrated why, over time, TCE spot freight rates across the various geographical regions will tend to "equalize", even though in practice such a theoretical global equilibrium will never be reached. Consequently, the differential between any pair of spot freight earnings must be mean reverting. Indeed, it should be mean reverting towards zero in an ideal theoretical world, that is, deviations from a global mean will erode over time as tonnage is repositioned to take advantage of any better earnings in a particular geographical area. As in Sødal et al (2008), we assume that the spot freight rate differential (the geographical spread in our case) can be represented by the standard Ornstein-Uhlenbeck (O-U) process, which has the following stochastic differential equation (see, Vasicek, 1977):

$$dp(t) = \mu(m - p(t))dt + \sigma dZ(t)$$
<sup>(2)</sup>

where  $\mu$  is the speed of mean reversion, m is the long-run mean of the process p(t),  $\sigma$  is the standard deviation of the increment and dZ(t) is the increment of a standard Wiener process. The freight rate differential p(t) is defined as the trans-Atlantic tripcharter rate less the trans-Pacific rate. Future cash flows are discounted at a constant discount rate  $\rho > 0$ . This rate can be seen as a sum of a real interest rate, r, and rate of depreciation,  $\lambda$ , and a possible adjustment for risk. The depreciation rate encompasses all lifetime considerations for the ship (see Sødal et al., 2008, for a detailed discussion).

Now assume one (and only one) switch and remaining in the other market forever. Then, the expected discounted value of future freight differentials at time t, P<sub>t</sub>, for the given Ornstein-Uhlenbeck process, can be written as (Dixit and Pindyck, 1994):

$$P_{t} = E\left[\int_{t}^{\infty} p_{s} e^{-\rho s} ds\right] = \left[\int_{t}^{\infty} (m + (p_{s} - m)e^{-\mu s})e^{-\rho s} ds\right] = \frac{p_{t}}{\rho + \mu} + \frac{\mu m}{\rho(\rho + \mu)}$$
(3)

where  $E[\cdot]$  is the expectations operator and  $p_t$  is the current freight rate differential. In other words,  $P_t$  represents the expected net present value of remaining in the market, by the gain from a switch as well as the opportunity cost of a return to the initial market. Having the rate differential  $p_t$  as the only variable, Equation (3) shows that the discounted value  $P_t$  is a linear function of the current differential  $p_t$ . By Ito's Lemma, the net present value  $P_t$  follows the O-U process (Sødal et al., 2009):

$$dP = \mu(\tilde{m} - P)dt + \tilde{\sigma}dz \tag{4}$$

where  $\tilde{m} = m/\rho$  and  $\tilde{\sigma} = \sigma/(\rho + \mu)$  by net present value representation. As noted by Sødal (2006), drift and volatility parameters may pay depend on p(t) but not explicitly on time, and so we omit the time subscripts from here on.

In order to determine the optimal switching policy we have to define the value function for the switching option. A switch can be exercised by investing the switching cost. Formally, if a ship starts in the Pacific

basin, the ship owner may switch to the Atlantic by investing an amount denoted B (the backhaul rate), and switch back to the Pacific by an amount denoted F (the fronthaul rate). Each switch is assumed to be instantaneous for the sake of model tractability and this will generally overestimate option values. The optimal switching decision will be to enter the Atlantic when the freight rate differential p(t) reaches some fixed value  $p_H$  from below, and switching back whenever the lower value  $p_L$  is reached from above. This implies that  $p_H>p_L$ . When p(t) is between the two triggers the ship will remain in the current geographical state. As noted in Sødal (2006), this general result is argued by Dixit (1989) and proven rigorously by Brekke and Øksendal (1994). Dixit et al (1999) show that the value of this switching option can be expressed as:

$$W_{0} = \frac{Q(p_{0}, p_{H})(P_{H} - B - Q(p_{H}, p_{L})(F + P_{L}))}{1 - Q(p_{L}, p_{H})Q(p_{H}, p_{L})}$$
(5)

Here,  $p_0(< p_H)$  is the current freight rate differential and  $P_H$  and  $P_L$  are expected net present values of future price differentials evaluated at the threshold rates  $p_H$  and  $p_L$ , assuming no further switches (cf. Equation 3). Q(x,y) are discount factor functions, relating to the motion from a current freight rate x to a future freight rate y. It follows that Q(x,y) = 1 for x = y and  $0 \le Q(x,y) < 1$  for  $x \ne y$ . It is also required that  $B + F \ge 0$ , such that the maximum value cannot be obtained from simply continuously switching back and forth.

While the value function in Equation 5 holds generally for Ito-processes, the discount factor functions Q(x,y) are specific to the underlying stochastic process. Sødal (2006) derives discount factors for the geometric Brownian motion, while Sødal et al. (2009) derives the discount factor functions for the Ornstein Uhlenbeck process. Following the latter paper, the discount factors in our case are:

$$Q(p_{L}, p_{H}) = \frac{M(p_{L}) + U(p_{L})}{M(p_{H}) + U(p_{H})}$$
(6)  

$$M(p_{U}) - U(p_{U})$$

$$Q(p_{\rm H}, p_{\rm L}) = \frac{M(p_{\rm H}) - U(p_{\rm H})}{M(p_{\rm L}) - U(p_{\rm L})}$$
(7)

Here,  $p_H > p_L$  as earlier noted, and  $M(\cdot)$  and  $U(\cdot)$  are given by:

$$M(p) = H\left(\frac{\rho}{2\mu}, \frac{1}{2}, \frac{\mu}{\sigma^2}(p-m)^2\right)$$
(8)

$$U(p) = \frac{2(p-m)\sqrt{\mu\Gamma((1/2) + (P/2\mu))}}{\sigma \Gamma(P/2\mu)} \times H\left(\frac{1}{2} + \frac{\rho}{2\mu}, \frac{3}{2}, \frac{\mu}{\sigma^2}(p-m)^2\right)$$
(9)

where  $\Gamma(\cdot)$  is the Gamma function and  $H(\cdot)$  is the confluent hypergeometric (Kummer) function of the first kind. For the latter function, Sødal et al. (2009), following Slater (1960), shows that the series representation of the Kummer function can be written as:

$$H(a, b, x) = 1 + \frac{a}{b}x + \frac{a(a+1)x^2}{b(b+1)2!} + \frac{a(a+1)(a+2)x^3}{b(b+1)(b+2)3!} + \dots$$
(10)

We now have the complete set of equations needed to value the switching opportunities by the discount factor approach in the case of a mean reverting O-U process. By maximizing the value function with respect to  $p_H$ and  $p_L$ , we obtain the optimal trigger levels  $p_H$  and  $p_L$  and the optimal switching policy. As the value function is typically quite smooth and yields a unique global maximum, the optimisation problem was solved numerically in Matlab by way of iteration through a grid of possible values for  $p_H$  and  $p_L$ . We note that the optimal policy is independent of the initial price ( $p_0$ ), i.e. the values of  $p_H$  and  $p_L$  are not affected by a change in  $p_0$  (Sødal, 2006).

#### 3. Data and Empirical Results

For the numerical valuation we use input data from the spot freight market for Capesize drybulk carriers (i.e. bulk vessels above 100,000 DWT that carry mainly coal and iron ore). This market has a well-defined trading pattern consistent with the setup outlined above: intra-basin trade in the Atlantic and Pacific Oceans, as well as active cross trading between the two main geographical regions (fronthaul and backhaul trips). Our empirical analysis is based on daily tripcharter rates for the trans-Atlantic and trans-Pacific routes as provided by the Baltic Exchange (2013). Baltic Exchange tripcharter rates represent the daily average of rate assessments provided to the Baltic Exchange by a panel of shipbrokers for a 172,000 DWT Capesize ship with standardized technical specifications (the "Baltic type") for each of the four main routes. Figure 1 below shows the calculated freight rate differential p(t) over the sample period from November 1, 2002, to September 26, 2012, a total of 2,471 daily observations.





Source: Calculated from Baltic Exchange data

Figure 1 clearly shows the kind of dynamic behavior expected from the outset, where the two basins are integrated in the long run through the mobility of tonnage such that very large deviations from the mean are short lived. However, despite the potential for supply adjustment, there are also intervals over which the freight rate spread is relatively persistent, a situation which would be the source of any gains from an optimal switching strategy. The reasons for slow regional adjustments in supply were laid out in the introduction. However, there is an additional anomaly observable from Figure 1, which is a clear Atlantic bias in tripcharter rates. Overall, TA rates are greater than TP rates about 73% of the time and the arithmetic average freight rate spread is a high \$4,507/day, though this average is strongly affected by a period of very high spreads near the market peak in 2008. This Atlantic bias is not a new observation, and several theories have been put forward to explain it. Notably, Laulajainen (2007) suggests that the asymmetry is tied to the Pacific region's dominance in terms of shipyards. New vessels try to find the first cargo close to the shipyard and, even if this fails, the mere existence of newbuildings induces some initial, excess supply relative to the Atlantic basin. (Laulajainen, 2007, p. 218) further states that "the phenomenon is routinely explained by the healthy economic growth of the Far East and its relative lack of raw materials which has created a sustained oversupply of empty tonnage and depressed rates on shipments originating there". Both of these arguments, while intuitively elegant, appear to be incomplete. We note from Figure 1 that the Atlantic bias actually disappears toward the end of the sample despite a continuing imbalance in the East-West trade volumes and a large influx of new tonnage. Indeed, the observed average freight rate differential in 2012 was a *negative* \$615/day meaning that the Pacific market was on average higher. To illustrate the imbalance in drybulk trade volumes that has developed over the past decade, Figure 2 shows the estimated share of the four main trade routes in the Capesize market (by weight of cargo). According to Figure 2, 84% of Capesize cargoes (by weight) were destined to the Pacific basin in 2012, up from 59% in 1999. Thus, the graph clearly illustrates the shifting center of gravity of international drybulk trade to Asia and the decreasing importance of the Atlantic economies, particularly in the aftermath of the 2008/09 financial crisis. However, the point we want to make here is that the bias towards higher Atlantic basin freight rates has recently disappeared in spite of these trade imbalances being greater than ever before. We believe that the large and more volatile freight rate spreads observed during the commodity and freight market boom in the middle of the last decade were instead

a result of the tight freight market conditions themselves, in the sense that the fleet had little or no spare capacity that could (or saw the need to) opportunistically seek out marginally better trading opportunities in other geographical regions. It was already "all hands on deck" to use the maritime vernacular. This has changed in the current oversupplied freight market, where there are plenty of ships that will chase after any perceived opportunity to improve on dismal spot earnings, even if it means speculative repositioning or periods of idleness. The result is a more geographically efficient and integrated market.



Figure 2: Share of Main Trading Routes in the Capesize Market

#### Private industry source

The large trade imbalances will also have an impact on our definition of the switching cost, i.e. the cost (or revenue as it may be) to reposition your vessel from the Pacific basin to the Atlantic or vice versa. The switching cost is here simply an assumed fixed \$/day freight rate for the fronthaul or backhaul voyage, respectively, multiplied by a fixed number of days for the trip duration (assumed to be 65 days as per standard Baltic Exchange assumptions). If we compare the estimated cargo volumes of fronthaul relative to backhaul trade in 2002 versus 2012 we see a change in the ratio from about 3:4 to a bit more than 6:1. Put differently, for every six vessels doing a fronthaul trip currently, five vessels must return to the Atlantic in ballast (though possibly under orders for a return cargo). These imbalances have caused backhaul TCE spot freight rates to turn negative for the Baltic standard Capesize ship as the voyage is priced at the marginal cost of the most efficient ships, as discussed in Adland (2012). A typical backhaul voyage is therefore, as of early 2013, a true switching cost. Because of the trade imbalance, fronthaul rates, on the other hand, are generally the highest of the four routes, both because of higher relative demand but also to entice owners to take their ships to the historically less attractive Pacific basin. However, the switching option model applied herein requires that F + B < 0 which means we are bound to assume a fronthaul freight rate for switching to the Pacific that is lower than the (absolute value) of the backhaul rate, given that trip durations are the same. This is clearly an unfortunate feature of the model that is not supported by the data and it is, along with stochastic switching costs, a topic for future research.

Before we proceed with the numerical valuation of the switching option it is necessary to formally check for the presence of a unit root in the freight rate differential process p(t) depicted in Figure 1. For this purpose we use the following version of the augmented Dickey-Fuller (ADF) test (see, for instance, Greene, 1997):

$$\Delta p_t = d_t + \beta_0 p_{t-1} + \sum_{j=1}^k \beta_j \Delta p_{t-j} + \varepsilon_t$$
(11)

where the term  $d_t$  picks up deterministic components,  $\varepsilon_t$  is the error term, and  $\Delta$  is the lag operator such that  $\Delta p_t = p_t - p_{t-1}$ . In this case we can exclude explosive behavior and so the unit root test is a one tailed t-test with a null hypothesis that  $p_t$  follows a random walk ( $\beta_0 = 0$ ). Critical values are tabulated for the Dickey-Fuller-distribution, originally introduced by Dickey and Fuller (1979) and later refined by others. We choose

the number of lags k using Ng and Perrion's (1995) 'last significant'-criterion in combination with a rule of thumb for lag-length proposed by Schwert (1989). Specifically, this corresponds to setting an upper bound for the number of lags included in the test, and reducing number of lags until the last lag is found to be significantly different from zero. The test-indicator of the ADF test is given by the t-statistic  $\hat{\tau}_{ADF} = \hat{\beta}_0 / \hat{s}_{AR}$ , where  $\hat{\beta}_0$  is estimated by OLS and  $\hat{s}_{AR}$  is the estimated standard deviation of  $\hat{\beta}_0$ . Using the full data sample and k = 7 lags, we get the test statistic  $\hat{\tau}_{ADF}$  = -8.933 with a critical value of -2.86 at the 5% significance level. This, the ADF test clearly rejects the null of non-stationarity and indicates that the mean-reverting O-U process is a valid candidate for the freight rate differential.

In order to calibrate the continuous-time model in Equation 2 we estimate the corresponding parameters of its discrete-time counterpart. Following Sødal et al. (2008) the discrete-time version of the O-U process is the first-order autoregressive AR(1) process where the price differential  $p_t$  follows

$$p_t = A + Cp_{t-1} + \varepsilon_t \tag{12}$$

where A and C are constants and  $\varepsilon \sim N(0, S^2)$ . The estimated parameters from the OLS regression of Equation 12 based on daily observation for the freight rate differential (in \$/day) are given in Table 1 below. We have also included three subsamples according to the distinct shifts in market circumstances in mid-2003 and at the start of 2009, where the middle period corresponds to the drybulk freight market boom.

Table 1: Parameter Estimates for Discrete-time p(t) Process									
	С	А	S	Ν					
Full sample									
2002-2012	0.979 (237.68)	94.97 (2.25)	1881.43	2471					
Sub samples									
2002-2003	0.993 (65.72)	-9.57 (-0.37)	264.87	161					
2003-2008	0.978 (181.06)	101.04 (1.51)	2263.78	1375					
2009-2012	0.971 (126.55)	128.03 (0.97)	1344.72	935					
t-values in parenthesis	* - significant at 5% level								

significant at 5% level t-values in parentnesis,

The relationships between the discrete-time parameters in Table 1 and their continuous-time counterparts are given by (see, for instance, Sødal et al., 2008):

-lnC	(12)
$\mu =$	(13)
$\Delta$	

 $m = \frac{A}{1 - e^{-2\mu\Delta}}$ (14)

$$\sigma = \sqrt{S^2 \frac{2\mu}{1 - e^{-2\mu\Delta}}} \tag{15}$$

where S is the standard deviation of the residuals of the regression, and  $\Delta$  is the time between observations. Here,  $\Delta = \frac{1}{250}$  (i.e. scaled according to index days within a year). Using the parameter estimates for the full sample in Table 1, the corresponding continuous time parameters are given by estimated parameters  $\hat{\mu} = 5,34$ ,  $\hat{m} = 4439$  and  $\hat{\sigma} = 30063$ .

Before presenting some scenarios for the value of the geographical switching option it is worth considering what the benchmark should be for the switching value. Given the observation that average trans-Atlantic spot freight rates have been higher over the course of our sample, the natural benchmark would be to simply stay put in the Atlantic and capture the differential without incurring any switching costs. The value of this passive policy (i.e. we consider a ship that is stripped of its ability to switch between geographical modes of operation) is simply given by Equation 3. In the tables of numerical results below, the term "benchmark value" refers to the case of continuous Atlantic trading and  $W_0$  refers to the computed switching value based on optimal entry/exit decisions according to Equation 5. We consider the difference between the active and passive strategy as the true "option value". Table 2 below illustrates the calculated option values for the three sub-samples along with the estimated optimal trigger levels  $p_L$  and  $p_H$ .

		Tabl	e 2: Opt	ion Values a	nd Trigger L	evels acro	oss Sub-sa	amples		
Sub period parameters	σ	μ	т	В	F	W <sub>0</sub>	Benchmark	Option	$p_L$	$p_H$
2002 - 2003	4202	1.65	1000	500,000	-325,000	3.66	3.11	0.55	-2158	1901
2003 - 2009	36192	5.56	5100	625,000	-405,000	19.93	16.53	3.39	-10311	7977
2010 - 2012	21573	7.30	4300	1,118,000	-730,000	12.99	14.00	-1.01	-13194	5099

While the results are not easily comparable across sub-periods due to varying input factors we note that by far the biggest contribution to the calculated switching value  $W_0$  is not related to switching at all but rather a result of the observed added value from simply staying put in the Atlantic. In fact, the incremental option value from pursuing an active strategy is negligible in the first subsample and negative in the final subsample. We note that the increasing backhaul switching cost is a function of the increasingly lopsided East-West trade volumes and the corresponding lower probability of getting a paying cargo on the traditional backhaul leg, along with increasing fuel costs for a pure repositioning voyage. Conversely, the revenue from every fronthaul switch is underestimated as the model requires F + B < 0 when in reality the absolute level of F >> B. While there are multiple ways to perform sensitivity analysis of the input variables (see details and discussion in Bjerknes and Herje, 2013) we here include only the sensitivity with respect to the level of the freight differential mean m in Table 3 below.

m	$W_0$	Benchmark	Option	$p_L$	$p_H$	
(\$/day)	(million \$)	(million \$)	(million \$)	(\$/day)	(\$/day)	
0	8.47	0	8.47	-7260	7571	
2250	12.54	7.29	5.25	-7818	7028	
4500	17.53	14.58	2.95	-8390	6508	
6750	23.30	21.86	1.44	-8970	6013	

 Table 3: Sensitivity with regards to Mean Freight Rate Differential

As expected, increasing asymmetry in favour of the Atlantic basin will increase the value of pursuing the passive benchmark strategy and lower the option value from active switching until, at some point, there is no positive incremental value to be extracted from switching at all.

## 4. Concluding Remarks

While the entry/exit decision model used herein has some shortcomings, mainly the inability to incorporate realistic levels of the fronthaul and backhaul switching "costs" and the assumption that each switch is instantaneous, the empirical results and observations as regards the recent development of rate differentials all lead in the same direction. Principally, the value that could be extracted from optimal positioning of tonnage over the previous decade, either by pursuing a passive Atlantic-only strategy or by actively switching between the two main basins, was mainly an artefact of the extremely high fleet utilisation levels (and corresponding extreme freight rate levels) during this time. In an oversupplied freight market, as is the case currently, the presence of excess tonnage ensures that deviations between regional freight rate levels are smaller in

magnitude and reverts quicker to equilibrium. As a result of a more geographically efficient market, the real option value from optimal switching has largely disappeared. We anticipate that this result would be further strengthened if we properly account for the time lag between initiating a switch (the repositioning voyage) and fixing the next voyage in the "new" basin. As the spot freight rate differential is shown to be mean reverting, any such time lag would necessarily lead to a reduction in the present value of future earnings. Future research in this area should try to address these shortcomings. However, due to the rapidly increasing complexity of any analytical solution to the valuation problem if such features were added, this would likely require alternative methodological frameworks such as the optimisation of technical chartering rules.

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# Choosing the Optimal Bunkering Ports by Liner Shipping Companies: A Hybrid Fuzzy-Delphi-TOPSIS Approach

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### Abstract

With sustained high bunker price and the increasing attention on green shipping, how to choose optimal bunkering ports for saving total operating cost and minimize fuel emissions are research issues arising in the liner shipping companies. Generally speaking, the bunkering port selection problem is solved by ship planning software, which can only work optimally when the ship arrivals can be forecasted rather accurately, but ignoring some unforeseen circumstances in actual operations. There are no fixed rules for the bunkering port selection among several alternatives yet. To address this problem, this paper develops a benchmarking framework that evaluates the bunkering ports' performance under the regular liner route to choose the optimal ones. Owing to bunkering port selection is typically a multi-criteria group decision problem, and in many practical situations, decision makers cannot easily express their judgments under incomplete and uncertain information environment with exact and crisp values, and thus fuzzy numbers are proposed in this paper. A hybrid Fuzzy-Delphi-TOPSIS based methodology which divides the whole benchmarking into three stages is employed to support the entire framework. Finally, sensitivity analysis is performed. The proposed framework can facilitate decision makers to better understand the complex relationships of the relevant key performance factors and assist managers to comprehend the present strengths and weaknesses in their strategies.

Keywords: Bunkering port, Key performance factor (KPF), Liner Shipping companies, Fuzzy-Delphi-TOPSIS

## 1. Introduction

Bunker fuel is used by international seagoing ships. Given that 90 percent of world trade is carried by sea (IMO, 2009) and the increasing international sea transportation requirement, the bunker demand of the world is increasing. Bunker prices have risen considerably in recent years and fuel costs form more than half of a liner shipping company's total running costs (Yao et al., 2012). In addition, the appeared environmental policy is another difficulty for the operation of liner shipping companies. Since the high bunker price and the attention of green shipping, what should liner shipping companies do to save fuel through some operational adjustments including: (1) redeployment of ships, (2) consolidating services, (3) speed adjustment, (4) reducing resistance, (5) bunkering ports selection (Mazraati, 2011). Among of these methods, optimal bunkering ports selection is of significance (Besbes and Savin, 2009) for saving total running cost and minimizing fuel emissions.

Generally speaking, vessels visit a port for various purposes, such as taking bunkers, going to shipyards for repair, stevedoring cargoes at a terminal or a combination of the above (Huang et al., 2011). In the case of tramp route, bunkering service is only required when the fuel is not enough or the bunker prices are attractive, therefore, the bunkering port selections are simple. However, about the regular liner route, the bunkering port

selection processes are complicated due to liner shipping companies prefer a combination purpose to both getting bunkering services at the ports and berthing for stevedoring cargoes, there should have more influence factors under considering (Hu, 2005). It is important to undertake studies on liner routes for the liner shipping companies to both keep the shipping schedule at each port and reduce expense costs.

Hence, this paper aims to develop a benchmarking framework to choose optimal bunkering ports for liner shipping companies under the regular liner route by evaluating the bunkering ports' performance. Therefore, some key performance factors (KPFs) are identified and via case study analysis, the strengths and weaknesses of these alternative bunkering ports can be revealed and whether the developed benchmarking rule is appropriate or not can be checked. Finally, sensitivity analysis is performed. Also some implications for continuous improvement of the bunkering ports will be given. Bunkering port selection is a fundamental issue for liner shipping companies and also it is a hard problem since bunkering port selection is typically a multi-criteria group decision problem which has two types of uncertainties: (1) weighting values to proxy KPFs and (2) crisp input data. The first type of uncertainty may arise during decision making under stakeholders with different interests. The second type can result after transferring data to crisp values (Jun et. al, 2012). This paper develops a hybrid fuzzy-Delphi-TOPSIS model to overcome these uncertainties. First, decision makers were only selected from the shipping line company as questionnaire respondents. Therefore the worry about different interests among stakeholders is not necessary. About the second uncertainty, fuzzy members are transferred to crisp values at the end of the assessment step and only do once to maintain the original opinions of decision makers.

## 2. Literature Review

In the previous research, much interest focuses on what factors affect the performance of bunkering ports when liner shipping companies get bunker supply in these ports. Acosta et al. (2011) explored that the factors affecting bunkering competitiveness include low bunkering price, few legal restrictions, quick bunkering and geographical advantage. Yao et al. (2012) proposed a case study revealing that the bunkering port decisions mainly affected by the bunker fuel prices evolution along the service route and speed of the ship. The liner shipping companies are likely to choose the first port after long voyage as bunkering port due to the geographical advantage. Bunkering associated conditions as weather, access to port, security, bunker fuel capacities, bunkering facilities and fueling speed are also considerable because of the short port time (Notteboom and Vernimmen, 2009; Wang and Meng, 2012a). Chang and Chen (2006) developed a knowledge-based simulation model to improve the bunkering service capacity in the port of Kaohsiung. Average bunkering service time, mean waiting time, bunker barge usage and berth utilization efficiency are important indicators. And the type of fuel, the amount needed, the schedule of arrival and departure are vital information before getting bunkering service. Dinwoodie et al. (2012) proposed that reciprocal information sharing among stakeholders would enhance efficiency, and thus reducing the risk of bunkering operation. Also, the quality of marine fuel oils affects ship handling, engine operation, bunker consumption and environmental impact of emissions (Fu, 2009; Wang, 2012; Yuan, 2012; Anfindsen et al, 2012).

The oil spillages and leakages during bunkering operations may raise pollution harms to the environment and is costly to clean. Safe bunkering to prevent pollution, fire and avoid potential risks is essential for both the vessels and the port (You, 2008; Dong et al., 2011; Talley et al., 2012). In Hu (2005), he supported that the bunkering ports selection depended on fuel quality, port charges and the efficiency of the bunkering supply. Also, the bunkering suppliers in the ports are significant. The liner shipping companies prefer to get bunkering services in domestic rather than in foreign. In addition, more advanced bunkering equipment may bring more efficient bunkering, faster refueling speed and higher level of security (Wu, 2011).

Researches before mostly address the bunkering port selection problem by ship planning software only use real data such as shipping routes (Wang and Meng, 2012b), distance between port of calls (Wang and Meng, 2012c), bunker prices (Notteboom and Cariou, 2011), emission tax (Kim et al., 2012; Corbett et al., 2009), ship time costs (Kim et al., 2012), inventory carrying costs (Psaraftis and Kontovas, 2010), fixed ordering costs, port time (Du et. al., 2011; Qi and Song, 2012; Wang and Meng, 2012d), name nut a few. However, bunkering operations involve a combination of transportation and fueling services with a dynamic data element (Chang and Chen, 2006). There are many hypotheses (for instance, all ships deployed in the service

are homogenous, a penalty is not incurred, the terminal handling costs per box do not alter with vessel size or route length) and limiting conditions (for instance, known port time at each port of the service route, the same load cost, discharge cost and transshipment cost, the container handling efficiency of each port of call) in software analysis and it cannot take liner shipping companies' preferences into account. There are no fixed rules for the bunkering port selection among several alternatives yet and decision making may be based on liner shipping companies' preferences, but such preferences are often unknown to ports. It is not easy to summarize a comprehensive set of rules that emulate the preference of liner shipping companies when they select among the alternative bunkering ports due to unforeseen circumstances in actual operations. This paper attempts to develop a rule about how to choose optimal bunkering ports for liner shipping companies under the regular line route.

## 3. Methodology

### 3.1. A hybrid Fuzzy-Delphi-TOPSIS approach

Bunkering port selection is a decision making problem basing on liner shipping companies' preferences. In many cases the preferential model of decision makers is uncertain, and it is difficult for decision makers to provide exact numerical values for comparative ratios (Tsai et al. 2010). This study proposes fuzzy theory to resolve the uncertainty and imprecision of performance evaluations, where the comparison judgments of a decision maker are represented as fuzzy triangular numbers. For more accurately catch the original opinions of decision makers, an integrating quantitative content (Delphi method) and qualitative analysis (Fuzzy-Delphi-TOPSIS) is used.

Delphi Method was widely applied to select performance factors in many fields (Ma et al., 2011). It is strength is that it can effectively create a consensus about an issue through knowledge of experts and collect, modify judgments using a series of data collection, analysis techniques and brainstorming (Prusty et al. 2010). Fuzzy-Delphi-TOPSIS is a methodology combined by Fuzzy Delphi and fuzzy TOPSIS method using for optimal decision making strategies. Fuzzy Delphi method can improve uncertainty on decision space and combine advantages of statistical methods (Duru et al., 2012). It has four advantages: (1) to decrease the times of questionnaire survey, (2) to avoid distorting the individual expert opinion, (3) to clearly express the semantic structure of predicted items, and (4) to consider the fuzzy nature during the interview process (Chang and Wang, 2006). Fuzzy TOPSIS, one of the MCDM techniques, is widely used to quantify the performance measures of the alternatives by many researches (Kim et al., 2013). This method can embody the fuzzy nature of the comparison or evaluation process and strengthen the comprehensiveness and rationality of the decision making process (Bao et al., 2012).

### 3.2. Research process

The research process can be found in fig.1. A hybrid Fuzzy-Delphi-TOPSIS based methodology divides the whole benchmarking into three stages. The first stage includes identification, synthesize and prioritization of the KPFs which may affect the bunkering port selection for liner shipping companies by the Delphi method. The second stage is to set up the fuzzy matrix and computes the weights of each KPF by Fuzzy Delphi Method. And, the third stage is to undertake a fuzzy TOPSIS based assessment of possible alternative bunkering ports for saving operation costs and time.



Figure 1: Generalized Framework through Fuzzy-Delphi-TOPSIS Based Approach

### 3.2.1. Delphi Method

The procedure of Delphi Method is shown as follows:

- (1) Collect all possible KPFs, which may affect bunkering service when the vessels in the port and ask domain experts select assign a number ranged from 1 to 7 to each KPF.
- (2) Questionnaire reliability test. When survey questionnaires are performed, the degree of importance of each KPF can be obtained. Also, the reliability of the expert questionnaires needs to be tested. Cronbach's Alpha was applied to test reliability (Chong et al., 2012) in this paper. If any Cronbach's Alpha is less than 0.35, the corresponding datum is not reliable and will be deleted. Those more than 0.35 are viewed as reliable (Wang and Lin, 2008).
- (3) Obtain the importance of the KPFs by the geometric mean so that the impact of extreme values could be avoided, a higher value indicated a higher importance and a lower value indicated a lower importance. The threshold value r was determined. If the geometric mean value of the KPF is no less than r, the KPF is accepted, and vice versa. In this paper, the threshold value r is set as 4, then the selection KPFs are as follows:

If *geometric mean*  $\geq$  *r* = 4, this appraisal KPF is accepted. If *geometric mean* < *r* = 4, this appraisal KPF is rejected.

#### 3.2.2. Fuzzy Delphi Method

The process of Fuzzy Delphi is shown as follows:

- (1) The importance of KPFs was obtained by a 10 point scale (Kuo and Chen, 2008), a higher point indicated a higher importance and a lower point indicated a lower importance.
- (2) Set up the triangular fuzzy numbers (TFNs)  $\widetilde{w}_{ij}$  as defined in equation (1). In this work, the TFNs representing the pessimistic, moderate and optimistic estimate is used to represent the opinions of experts for each activity time (Hsu and Yang, 2000).

$$\widetilde{w}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right), a_{ij} \le b_{ij} \le c_{ij} \tag{1}$$

$$a_{ij} = \min(M_{ijk}) \tag{2}$$

$$b_{ij} = \sqrt[n]{\prod_{k=1}^{n} M_{ijk}}, k = 1, 2, ..., n$$
(3)
# $c_{ij} = max(M_{ijk})$

where  $M_{ijk}$  indicates the appraisal value of the *k*th expert for the KPF,  $a_{ij}$  indicates the bottom of all the experts' appraisal value;  $b_{ij}$  indicates the geometric mean of all the experts' appraisal and  $c_{ij}$  indicates the ceiling of all the experts' appraisal value, *n* is the number of experts in consisting of a group.

#### 3.2.3. Fuzzy TOPSIS

The fuzzy TOPSIS steps are as follows:

(1) Choose the linguistic values  $(\tilde{x}_{ij}, i = 1, 2, ..., n, j = 1, 2, ..., m)$  for alternatives concerning the KPFs via expert questionnaires. The fuzzy linguistic rating  $(\tilde{x}_{ij})$  keeps the ranges of normalized triangular fuzzy numbers that belong to [0, 10] shown in Table 1 (Buyukozkan and Cifci, 2012).

8	
Linguistic scale	Fuzzy score
Poor (P)	(1, 1, 2)
Medium poor (MP)	(2, 3, 4)
Fair (F)	(4, 5, 6)
Medium good (MG)	(6, 7, 8)
Good (G)	(8, 9,10)

Table 1: Linguistic Variables for the Preference of each Alternative

In the condition of the KPF has the crisp quantity value for each alternative, we should also transform crisp quantities for the KPFs into fuzzy numbers. Let  $R_{ij}^o = (c_{ij}^o, a_{ij}^o, b_{ij}^o)$  be the crisp quantity from the real data to alternative  $A_n$ , where  $c_{ij}^o = a_{ij}^o = b_{ij}^o$ . The KPFs are determined in various units and must be transformed into dimensionless indices (or numbers) to ensure compatibility with the linguistic numbers of the KPFs. The alternative with the maximum benefit (or the minimum cost) should have the highest number. In the paper, we will adopt the transform method provided by Chou (2010) as follows:

$$\bar{R}_{ij} = \left\{ R^{\sigma}_{ij} / \max_i \left\{ b^{\sigma}_{ij} \right\} \right\} \times 10 \tag{5}$$

Where  $\max_i \{b_{ij}^o\} > 0$ ,  $\overline{R}_{ij}$  denotes the transformed fuzzy number of objective benefit  $R_{ij}^o$ ,  $\overline{R}_{ij}$  becomes larger when objective benefit  $R_{ij}^o$  is larger.

 $\bar{R}_{ij} = \{\min_i \{c_{ij}^o\} \times 10$ (6) Where  $\min_i \{c_{ij}^o\} > 0$ ,  $\bar{R}_{ij}$  denotes the transformed fuzzy number of objective benefit  $R_{ij}^o$ ,  $\bar{R}_{ij}$  becomes smaller when objective cost  $R_{ij}^o$  is larger.

(2) Compute the weighted normalized fuzzy-decision matrix by

$$\tilde{v} = \left[\tilde{v}_{ij}\right]_{n \in i'} i = 1, 2, \dots, n, j = 1, 2, \dots, m$$
(7)

$$\tilde{v}_{ij} = \tilde{x}_{ij} * \tilde{w}_j \tag{8}$$

We was obtained from the fuzzy Delphi Method via expert questionnaires shown before.

(3) Determine the positive-ideal (FPIS, A\*) and negative-ideal (FNIS, A<sup>-</sup>) solutions from the equations below:

$$A^{*} = \{v_{1}^{*}, ..., v_{i}^{*}\} = \{(\max_{j} v_{ij}, i \in \Omega_{b}), (\min_{j} v_{ij}, i \in \Omega_{c})\}$$

$$A^{-} = \{v_{1}^{-}, ..., v_{i}^{-}\} = \{(\min_{j} v_{ij}, i \in \Omega_{b}), (\max_{j} v_{ij}, i \in \Omega_{c})\}$$
(9)
(10)

 $\Omega_b$  are the sets of benefit criteria and  $\Omega_c$  are the sets of cost criteria

(4) Calculate the distances of each alternative from the ideal solution and the negative-ideal solution:  $D_i^* = \sum_{j=1}^m d(\tilde{V}_{ij}, \tilde{V}_i), i = 1, 2, ..., n$ (11)

$$D_i^- = \sum_{j=1}^m d(\tilde{V}_{ij}, \tilde{V}_i), j = 1, 2, ..., m$$
(12)

$$d(\tilde{a}, \tilde{b}) = \sqrt{(1/3)[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]}$$
(13)

 $\tilde{a}$  and  $\tilde{b}$  are two triangular fuzzy numbers, which is shown by the triplet  $(a_1, a_2, a_3)$  and  $(b_1, b_2, b_3)$ .

(5) Determine the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative  $A_i$  in relation to  $A^*$  is characterized as below:  $FC_i = D_i^- / (D_i^* + D_i^-), i = 1, 2, ..., n$ (14)

## 4. A Case Study

To some extent, environmental policies may limit the development of liner shipping companies. The Emission Control Areas (ECAs) have established in Baltic Sea area, North Sea area and North American area but not East Asia (Schinas and Stefanakos, 2012). In addition, ports in the Asia Pacific will serve as the regional marine transportation center under the substantial growth of marine traffic. As such, the number of ships calling to ports with bunkering requests is expected to increase in the near future (Schinas and Stefanakos, 2012). Considering this, in this section, a case study under the regional route in East Asia but not intercontinental route is performed to check whether the developed benchmarking rule is appropriate or not. A representative regular shipping route: China-Korea-Japan shipping route is chosen as the evaluation object shown in Fig.2. According to the port time and the container volumes in the ports of call, four alternative bunkering ports (Xingang, Dalian, Busan and Niigata) are selected for future evaluation.



Figure 2: A Representative China-Korea-Japan Regular Shipping Route<sup>1</sup>

#### 4.1. Selection of appraisal KPFs

Under the Delphi method, 21 KPFs were collected via previous researches and expert interviews. The suitable sample size of expert questionnaire should not be too large which should be about 10-15 experts (Adler and Ziglio, 1996, Ng, 2006, Ma et al., 2011), 30 questionnaires were distributed to the top 20 liner shipping companies who are represent about 74% of the global market shares (containerization year book, 2012). 12 questionnaires were returned between 2 Nov. 2012 and 3 Dec. 2012, and the relevance of the target questionnaire respondents consisted of CEOs, General Managers, Operation Managers, etc. with the position higher than the department managers who possessed more than 15 years of professional experience. Cronbach's Alpha is applied to test the reliability of questionnaire before appraisal KPFs selection. The value

<sup>&</sup>lt;sup>1</sup> A sample China-Korea-Japan regular liner shipping route taken from CK Line (http://www.ckline.co.kr/) is applied, with sequence of the voyage being Xingang-Dalian-Busan-Pohang-Niigata-Naoestu-Toyamashinko-Busan-Ulsan-Kwan gyang-Xingang-Dalian.

of 0.687 more than 0.35, is viewed as reliable<sup>2</sup>. After the 7 point scale questionnaire, the scores of each factor from 12 experts can be obtained and also the geometric mean value. As the KPF bunker price as an example: Geometric mean value of "bunker price" =  $\sqrt{7*6*7*7*7*6*6*7*7*7*7*7} = 6.735$ 

After the geometric mean value calculation, 15 KPFs which have the value more than 4 are selected as bunkering ports performance evaluation criteria shown in Table 2.

Order	Factors	Geometric value
1	Bunker price	6.74
2	Geographical advantage	5.97
3	Port bunker fuel capacity	5.85
4	Supply waiting time	5.57
5	Bunker quality	6.38
6	Volume of containers	6.14
7	Safety of bunkering	6.22
8	Port bunker suppliers	4.25
9	Port bunkering supply regulations	4.08
10	Port tariffs	5.84
11	Information sharing among stakeholders	5.29
12	Port weather condition	5.17
13	Efficiency of bunker supply	5.98
14	Environmental restrictions effects	5.32
15	Port time	6.23

**Table 2: Key Performance Factors** 

#### 4.2. Determination of KPFs' weights

Since decision making of bunkering port selection is based on liner shipping companies' preferences but not service suppliers, perspectives from liner shipping companies are significant. In this paper, among top 20 liner shipping companies, eight of them come from China, Korea and Japan are chosen as respondents to determine the weights of KPFs. Under the Fuzzy Delphi Method, the triangular fuzzy numbers of KPFs can be collected by equation (1) to (4) as shown in Appendix A. It indicated that respondents regard the KPF bunker price, bunker quality, safety of bunkering, and port tariffs as important factors in selecting bunkering port.

#### 4.3. Fuzzy ratings under each KPF

The selected 15 KPFs contain subjective and objective factors. To confirm the accuracy and objectivity of the result, analysis would prefer to employ objective factors which have the crisp quantity value as far as possible. However, in the real world, most of the factors have no crisp quantity value and need people to judge by subjective idea. In this section, an integrating quantitative and qualitative analysis is employed to evaluate the performance of alternative bunkering ports for avoiding too subjective results. The evaluation of subjective KPFs performed by judgment of decision makers via fuzzy theory and the objective KPFs are evaluated by the crisp quantity value. The fuzzy ratings under each subjective KPF can be given by the decision makers according to the linguistic variables shown in Table 1. In the condition of the KPFs have the crisp quantity value for each alternative, we should transform crisp quantities for the KPFs into fuzzy numbers to ensure compatibility with the linguistic numbers of the KPFs. The crisp quantities for objective KPFs transformed into fuzzy ratings are shown in Table 3.

 $<sup>^{2}</sup>$  If any Cronbach's Alpha is less than 0.35, the corresponding datum is not reliable and will be deleted. Those more than 0.35 are viewed as reliable (Wang and Lin, 2008).

Objective KPFs	Quantity	Fuzzy rating						
Bunker price (\$USD)								
Xingang	690	(9.7,9.7,9.7)						
Dalian	687	(9.8,9.8,9.8)						
Busan	670	(10.0,10.0,10.0)						
Niigata	677	(9.9,9.9,9.9)						
Volume of containers (TEU)								
Xingang	8562600	(5.3,5.3,5.3)						
Dalian	4628200	(2.7,2.7,2.7)						
Busan	16175000	(10.0,10.0,10.0)						
Niigata	204960	(1.3,1.3,1.3)						
Port bunker suppliers (	Bunker companies)							
Xingang	3	(2.5,2.5,2.5)						
Dalian	7	(5.8,5.8,5.8)						
Busan	12	(10.0,10.0,10.0)						
Niigata	6	(5.0,5.0,5.0)						
Port time (Hour)								
Xingang	44	(10.0,10.0,10.0)						
Dalian	17	(3.9,3.9,3.9)						
Busan	30	(6.8,6.8,6.8)						
Niigata	35	(8.0,8.0,8.0)						

Table 3: Fuzzy Ratings for Alternatives under Objective KPFs

Source: websites such as Bunker World, Containerisation Yearbook 2012, Bunker Ports News World-wide, and CK Line

#### 4.4. Assessment of alternatives

The global fuzzy rating based on the fuzzy ratings multiplied by fuzzy weights can be obtained by equation 10 shown in Appendix A. In addition, the positive-ideal ( $A^*$ ) and negative-ideal ( $A^-$ ) solution under each KPF can be determined by equation 11 to 12 shown in Appendix B. The distances of each alternative from the positive-ideal solution ( $D_i^*$ ), the negative-ideal solution ( $D_i^-$ ) and the relative closeness of each alternative to the ideal solution ( $FC_i$ ) can be calculated shown in Table 4.

	$D^*$	D <sup>-</sup>	FC <sub>i</sub>	Ranking
Xingang	248.3783	234.6274	0.485765	2
Dalian	287.2261	195.6024	0.405118	4
Busan	83.36617	399.2777	0.827272	1
Niigata	168.5924	120.0256	0.415863	3

**Table 4: The Final Ranking of Alternatives** 

## 5. Discussion and Conclusion

The final ranking of alternatives is determined according to the  $FC_i$  values shown that under the four alternative bunkering ports, the port of Busan ranked first as the most competitive bunkering port in the target China-Korea-Japan regular liner route, followed by the port of Xingang, Niigata and Dalian. In the actual operation, the liner shipping companies normally get bunkering services at the port of Busan. And if the port of Busan is unavailable for vessel bunkering, sometimes bunker services are obtained from the ports Xingang or Niigata. Such results illustrate that the developed benchmarking rule is appropriate and helpful to liner shipping companies to make optimal decisions on the choice of bunkering ports.

After the analysis, the strengths and weaknesses of the target bunkering ports and strategic recommendations can be provided. The results indicated that under most of the KPF, the port of Busan is superior to other ports except for the KPF supply waiting time and efficiency of bunker supply. The port of Busan should improve

the efficiency of port operation under the limited port capacity to enhance the bunker supply efficiency and shorten the waiting time. The port of Xingang is taking advantage of the KPF volume of containers and long port time but also face the problem of long supply waiting time and port bunker suppliers. The port operators should improve the efficiency of the port operation, but at the same time to lead some powerful bunker suppliers locating in the port is also necessary due to their partnership with liner shipping companies will attractive more liner shipping companies getting bunker service at this port. The port of Dalian has bunker capacity advantage and a set number of bunker suppliers but lack of volume of containers and port time. The port of Niigata has high bunker quality and few supply waiting time but limited bunker capacity and container volume.

To find out the changes in the final alternative selection with variation taken from expert opinions, sensitivity analysis is performed. Then the variation effects on the final selection of alternative can be judged. The result of sensitivity analysis in Table 5 shown that, instead of the port Xingang, the port of Niigata would rank as the second competitive bunkering port if it increases the capacity of bunker fuel (KPF 3). At present, most of the bunkering capacity in the port of Niigata is used for the domestic but not international vessels (Niigata port authority). On this occasion, it will limit the needs of liner shipping companies and in the future these companies will not consider the port of Niigata as an optional bunkering port for service. Therefore, to expand the capacity of bunker fuel is crucial. Also, if the port of Dalian relaxes the strict regulations about port bunkering supply (KPF 9), it will overstep the port of Niigata. By 2012, the bunker suppliers in China who have been approved by the Chinese government to supply bunker for international vessels are only 5. The strict control of foreign exchange and restricted bunker supply regulations, i.e., bunker fuel produced in domestic cannot be supplied to international vessels directly lead to the bunker fuel for international vessels can only be imported. The additional transport and transfer fees cause higher bunker price in China than other adjacent countries (Dong et al., 2011). Also the non-unified bunker supply management regulations may limit the efficiency of bunkering process. In the future, what the port operators should do is how to make the restricted bunker supply regulations looser under the negotiation with government to provide more flexible and high quality bunker service for the liner shipping companies.

Altornativa	KPF 3: Port bunker fuel capacity									
Alternative	$D^*$	D	FC <sub>i</sub>	Ranking	Changed Ranking					
Xingang	263.41	212.82	0.45	2	3					
Dalian	302.38	174.23	0.37	4						
Busan	83.37	377.67	0.82	1						
Niigata	135.82	120.03	0.47	3	2					
	KPF 9: Port bunkering supply regulations									
	$D^*$	D	FC <sub>i</sub>	Ranking	Changed Ranking					
Xingang	262.67	234.63	0.47	2						
Dalian	272.93	224.17	0.45	4	3					
Busan	83.37	399.28	0.83	1						
Niigata	168.69	120.03	0.42	3	4					

 Table 5: Sensitivity Analysis Results

With sustained high bunker price and the increasing attention on green shipping, how to choose optimal bunkering ports for saving total operating cost and minimize fuel emissions are research issues arising in the liner shipping companies. Generally speaking, the bunkering port selection problem is solved by ship planning software which can only work optimally when the ship arrivals can be forecasted rather accurately but ignoring the liner shipping companies' preferences. By using a hybrid Fuzzy-Delphi-TOPSIS methodology, this paper has developed a benchmarking framework for liner shipping companies operating regular liner routes so as to evaluate the performance of bunkering ports. The results indicate that the KPF bunker price, bunker quality, safety of bunkering, and port tariffs are regarded as important factors in selecting bunkering port. Busan ranked first as the most competitive bunkering port, followed by Xingang, Niigata and Dalian. In addition, the sensitivity analysis reveals that port Niigata can enhance the competitiveness by increasing the capacity of bunker fuel (KPF 3) and port Dalian should relax the strict regulations about port bunkering supply (KPF 9). There are some implications in this paper: as liner shipping companies (1) the proposed

framework can facilitate them to better understand the complex relationships of the relevant KPFs, (2) more clearly understand the condition and changes of alternative bunkering ports, (3) check whether the bunkering services they received from the most efficient bunker ports and make prompt adjustments to meet their development strategies; as bunkering port managers (1) assist them to comprehend the present strengths and weaknesses of the port, and (2) help them to make future strategies to enhance the competitiveness of the port.

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KPFs	Fuzzy weights	Alternatives	Fuzzy ratings	Global ratings
		Xingang	(9.7,9.7,9.7)	(97.0,97.0,97.0)
Developer region	(10.0, 10.0, 10.0)	Dalian	(9.8,9.8,9.8)	(98.0,98.0,98.0)
Bunker price	(10.0,10.0,10.0)	Busan	(10.0,10.0,10.0)	(100,100,100)
		Niigata	(9.9.9.9,9.9)	(99.0,99.0,99.0)
		Xingang	(4.6,5.6,6.6)	(36.6, 46.4, 59.4)
Gaagraphical advantage	(909300)	Dalian	(3.6,4.7,5.8)	(29.1,39.2,51.9)
Geographical advantage	(0.0,0.3,9.0)	Busan	(6.6,7.6,8.6)	(52.8,63.2,77.6)
		Niigata	(2.0,3.0,4.0)	(16.0,24.9,36.0)
		Xingang	(3.2,4.2,5.2)	(34.5,40.0,52.8)
Port hunker fuel conseity	(707780)	Dalian	(4.9,5.2,6.6)	(36.7,48.2,58.1)
Fort bulker fuel capacity	(7.0,7.7,8.0)	Busan	(5.2,6.3,7.3)	(42.0,53.9,64.0)
		Niigata	(2.0,2.5,3.6)	(14.0,19.0,29.1)
		Xingang	(3.2,4.2,5.2)	(25.4,39.2,52.4)
Supply waiting time	(8003100)	Dalian	(4.6,5.6,6.6)	(36.6,52.0,66.0)
Suppry waiting time	(8.0,9.3,10.0)	Busan	(4.6,5.6,6.6)	(36.6,52.0,66.0)
		Niigata	(6.0,7.0,8.0)	(48.0,65.1,80.0)
		Xingang	(4.0,5.0,6.0)	(40.0,50.0,60.0)
Bunker quality	(10.0, 10.0, 10.0)	Dalian	(4.0,5.0,6.0)	(40.0,50.0,60.0)
Bunker quanty	(10.0.10.0,10.0)	Busan	(6.6,7.6,8.6)	(66,76.1,86.2)
		Niigata	(6.0,7.0,8.0)	(60.0,70.0,80.0)
		Xingang	(5.3,5.3,5.3)	(42.4,42.4,42.4)
Volume of containers	(808080)	Dalian	(2.7,2.7,2.7)	(21.6,21.6,21.6)
volume of containers	(8.0,8.0,8.0)	Busan	(10.0,10.0,10.0)	(80.0,80.0,80.0)
		Niigata	(1.3,1.3,1.3)	(10.4,10.4,10.4)
		Xingang	(6.0,7.0,8.0)	(60.0,70.0,80.0)
Safaty of hunkaring	(10.0, 10.0, 10.0)	Dalian	(6.0,7.0,8.0)	(60.0,70.0,80.0)
Safety of builkering	(10.0,10.0,10.0)	Busan	(6.0,7.0,8.0)	(60.0,70.0,80.0)
		Niigata	(7.3,8.3,9.3)	(72.7,82.8,92.8)

## **Appendix A: The Global Fuzzy Ratings of Alternatives**

		Xingang	(2.5,2.5,2.5)	(20.0,20.8,22.5)
Dout humbon our alions	(9,0,9,2,0,0)	Dalian	(5.8,5.8,5.8)	(46.4,48.1,52.2)
Port bunker suppliers	(8.0,8.3,9.0)	Busan	(10.0,10.0,10.0)	(80.0,83.0,90.0)
		Niigata	(5.5.5.0,5.0)	(40.0,41.5,45.0)
		Xingang	(4.0,5.0,6.0)	(24.0,36.5,48.0)
Port bunkering supply	(607280)	Dalian	(4.0,5.0,6.0)	(24.0,36.5,48.0)
regulations	(0.0,7.3,8.0)	Busan	(6.0,7.0,8.0)	(36.0,51.1,64.0)
		Niigata	(1.6,2.1,3.2)	(9.5,15.2,25.4)
		Xingang	(2.5,3.6,4.6)	(25.2,35.6,45.8)
Dort toriffo	(10.0, 10.0, 10.0)	Dalian	(2.5,3.6,4.6)	(25.2,35.6,45.8)
Fort tainis	(10.0,10.0,10.0)	Busan	(3.2,4.2,5.2)	(31.7,42.2,52.4)
		Niigata	(2.0,2.5,3.6)	(20.0,24.7,36.3)
		Xingang	(2.5,3.6,4.6)	(22.7,32.0,41.2)
Information sharing among	(0,0,0,0,0,0)	Dalian	(2.5,3.6,4.6)	(22.7,32.0,41.2)
stakeholders	(9.0,9.0,9.0)	Busan	(6.0,7.0,8.0)	(54.0,63.0,72.0)
		Niigata	(2.5,3.6,4.6)	(22.7,32.0,41.2)
		Xingang	(6.0,7.0,8.0)	(36.0,55.3,72.0)
Dort weather andition	(60700)	Dalian	(6.0,7.0,8.0)	(36.0,55.3,72.0)
Port weather condition	(0.0,7.9,9.0)	Busan	(5.2,6.3,7.3)	(31.4,49.4,65.4)
		Niigata	(5.2,6.3,7.3)	(31.4,49.4,65.4)
		Xingang	(7.3,8.3,9.3)	(65.4,77.0,92.8)
Efficiency of hunker supply	(0,0,0,2,10,0)	Dalian	(7.3,8.3,9.3)	(65.4,77.0,92.8)
Efficiency of bulker suppry	(9.0,9.3,10.0)	Busan	(6.0,7.0,8.0)	(54.0,65.1,80.0)
		Niigata	(4.0,5.0,6.0)	(36.0,46.5,60.0)
		Xingang	(7.3,8.3,9.3)	(43.6,62.9,83.5)
Environmental restrictions	(607600)	Dalian	(7.3,8.3,9.3)	(43.6,62.9,83.5)
effects	(0.0,7.0,9.0)	Busan	(6.0,7.0,8.0)	(36.0,53.2,72.0)
		Niigata	(2.5,3.6,4.6)	(15.1,27.0,41.2)
		Xingang	(10.0,10.0,10.0)	(90.0,93.0,100)
Port time	(0,0,0,3,10,0)	Dalian	(3.9,3.9,3.9)	(35.1,36.3,39.0)
	(9.0,9.3,10.0)	Busan	(6.8,6.8,6.8)	(61.2,63.2,68.0)
		Niigata	(8.0,8.0,8.0)	(72.0,74.4,80.0)

# Appendix B: Fuzzy Positive and Negative Ideal Solution (FPIS & FNIS)

KPFs	A*	A <sup>-</sup>
Bunker price	(100.0,100.0,100.0)	(97.0,97.0,97.0)
Geographical advantage	(52.8,63.2,77.6)	(16.0,24.9,36.0)
Port bunker fuel capacity	(42.0,53.9,64.0)	(14.0,19.0,29.1)
Supply waiting time	(48.0,65.1,80.0)	(25.4,39.2,52.4)
Bunker quality	(66.0,76.1,86.2)	(40.0,50.0,60.0)
Volume of containers	(80.0,80.0,80.0)	(10.4,10.4,10.4)
Safety of bunkering	(72.7,82.8,92.8)	(60.0,70.0,80.0)
Port bunker suppliers	(80.0,83.0,90.0)	(20.0,20.8,22.5)
Port bunkering supply regulations	(36.0,51.1,64.0)	(9.5,15.2,25.4)
Port tariffs	(31.7,42.2,52.4)	(20.0,24.7,36.3)
Information sharing among stakeholders	(54.0,63.0,72.0)	(22.7,32.0,41.2)
Port weather condition	(36.0,55.3,72.0)	(31.4,49.4,65.4)
Efficiency of bunker supply	(65.4,77.0,92.8)	(36.0,46.5,60.0)
Environmental restrictions effects	(43.6,62.9,83.5)	(15.1,27.0,41.2)
Port time	(90.0,93.0,100.0)	(35.1,36.3,39.0)

# Prompt Release of Detained Foreign Vessel and her Crew – The Novelty in Contemporary Law of the Sea

# *Heiki Lindpere* Professor, Rector of the Estonian Maritime Academy

Detentions of foreign vessels whether justified or not by authorities of coastal States always badly hit owners and/or operators of any kind of ships in their maritime activities as well as members of her crew. Obviously giving to the coastal States right to establish the EEZ or "outer continental shelf" with certain jurisdiction there the contemporary law of the sea had to be balanced somehow in favor of freedom in safe and sound navigation.

One of the significant achievements of the Third United Nations Conference on the Law of the Sea (hereinafter the Conference) has definitely been the development of a comprehensive system in Part XV for the settlement of the disputes that may arise in respect of the interpretation or application of the UN Convention on the Law of the Sea (hereinafter the UNCLOS). Disputes between States being parties to the Convention may be settled by peaceful means in accordance with Article 2, paragraph 3, of the Charter of the United Nations as a principle and, to this end, shall seek a solution by the means indicated in Article 33, paragraph 1, of the Charter. Failing in that States<sup>1</sup> could turn in certain cases to a comprehensive system for "Compulsory Procedures Entailing Binding Decisions" set out in section 2 of Part XV of the Convention and as the novelty – the new independent procedure – prompt release of detained foreign vessels and crews (hereinafter the PRP) has been set up in Article 292. So far this procedure has been elaborated in more detail in the Rules of Procedure at the International Tribunal for the Law of the Sea (hereinafter the ITLOS), established in 1996 in Hamburg.

During the Conference different delegations of States could not agree on single procedure for the settlement of their disputes and therefor according to Article 287 (1), there are four different types of procedures available to the States Parties<sup>2</sup>, including the newly established ITLOS consisting of 21 Members (Judges). This permanent international court of general jurisdiction on the law of the sea is acting according to the UNCLOS, abovementioned Part XV, Annex VI (as the Statute) and their Rules of Procedure.<sup>3</sup>

First part of the presentation will deal with the general characterization of PRP and the reasoning behind that speedy international procedure. Secondly the choice of a court or an arbitration for PRP will be discussed and the role of ITLOS in Hamburg as the "instance of last resort" or "default body" will be explained. Thirdly in the final part of this presentation some of the ITLOS PRP practice will be commented briefly together with the issues in determination of the amount of a reasonable bond or other financial security as the precondition for the release.

Important issues of the application of PRP or access to the ITLOS: Jurisdiction *ratione personae* and *ratione materiae* will be left for the future presentations. It should be stressed that the latter one contains the principle that the right to complain about detention is restricted to the cases expressly provided for in the substantive parts of the UNCLOS and the access to ITLOS is achievable if the allegations against the detaining State are in conformity with the "Limitations and exceptions to applicability" (Section 3, Part XV of UNCLOS) to the compulsory procedures entailing binding decisions in the previous Section 2 of this Convention.<sup>4</sup>

#### 1. PRP as a Speedy Independent International Settlement Procedure for certain Disputes

Article 292 of the Convention contains a special procedure for disputes relating to the prompt release of foreign vessels and crews detained by a State Party. These compulsory procedures and PRPs are of crucial importance for the law of the sea as a whole, and as Professor Alan E. Boyle wisely notes "designed to prevent fragmentation of the conventional law of the sea" and that "… binding compulsory settlement becomes the cement which should hold the whole structure together and guarantee its [the Convention's] continued applicability and endurance for all parties."<sup>5</sup> Whether we are dealing with PRP as an independent

procedure of the ITLOS the answer is "yes" because of it ends with nothing else but a judgment.<sup>6</sup> PRP is kind of *diplomatic protection* which the flag State is entitled and **may** provide for a detained vessel flying its flag and crew manned.

#### Article 292 reads:

- "1. Where the authorities of a State Party have detained a vessel flying the flag of another State Party and it is alleged that the detaining State has not complied with the provisions of this Convention for the prompt release of the vessel or its crew upon posting of a reasonable bond or other financial security, the question of release from detention may be submitted to any court or tribunal agreed upon by the parties or, failing such agreement within 10 days from the time of detention, to a court or tribunal accepted by the detaining State under article 287 or to the International Tribunal for the Law of the Sea, unless the parties otherwise agree.
- 2. The application for release may be made only by or on behalf of the flag State of the vessel.
- 3. The court or tribunal shall deal without delay with the application for release and shall deal only with the question of release, without prejudice to the merits of any case before the appropriate domestic forum against the vessel, its owner or its crew. The authorities of the detaining State remain competent to release the vessel or its crew at any time.
- 4. Upon the posting of the bond or other financial security determined by the court or tribunal, the authorities of the detaining State shall comply promptly with the decision of the court or tribunal concerning the release of the vessel or its crew."

The essence of Article 292, a carefully negotiated recent addition<sup>7</sup> to the contemporary law of the sea, is that PRP is applicable not always but where substantive provisions of the UNCLOS specifically foresee the prompt release of detained foreign vessels and their crews upon posting a reasonable bond or other financial security. While the right of **detention**<sup>8</sup> of foreign vessels is permitted or denied in several substantive provisions of the UNCLOS, the prompt release is only prescribed in five cases of permitted detentions: Articles 73(2), 220(7) and (8), 226(1) "b" and "c".<sup>9</sup> Article 292(1) stipulates as a precondition for PRP that "the detaining State has not complied with the provisions of this Convention for the prompt release of the vessel or its crew", which makes the commentators of the UNCLOS to remark: "Thus the right to complain about detention is restricted to the cases expressly provided for in the substantive parts of the Convention."<sup>10</sup>

PRPs are the proceedings before an international court or tribunal between the States Parties to the UNCLOS, in principle, "independent from domestic as well as from other international proceedings"<sup>11</sup> which can "only be excluded by agreement".<sup>12</sup> PRP is of a compulsory nature in the sense that an unilateral action of the flag State concerned is sufficient to institute proceedings. If the flag State and the detaining State within ten days of the detention have failed to reach an agreement on the court or tribunal to decide the dispute, the flag State will have the right to submit the question of release unilaterally to either the court or tribunal accepted by the detaining State under Article 287 or, which is most realistic, to the ITLOS.<sup>13</sup> Such action could be brought "only by or on behalf of the flag State".<sup>14</sup> Article 292 (2) is a very strict one and allows to make the application for release only by or on behalf of the flag State of the vessel. Determining who has the authority to bring an issue before an international court or tribunal on behalf of a particular State is purely a matter of domestic law. Nevertheless, the release can be asked not only for the vessel but also for the crew and, as we know, detained members of a crew could have different nationality. Because of the imperative nature of paragraph 2, Article 292 of the Convention, the only conclusion is that the flag State but not the State of nationality of the members of the crew, is granted *locus standi*.<sup>15</sup>

The history of the III UN Conference on the Law of the Sea shows that concept of PRP was first proposed by the United States in 1973 in its nine-article draft for a chapter on the settlement of disputes for the Convention.<sup>16</sup> In article 8 (2) it was stated:

"The owner or operator of any vessel detained by any State shall have the right to bring the question of the detention of the vessel before the Tribunal in order to secure its prompt release in accordance with the applicable provisions of this Convention, without prejudice to the merits of any case against the vessel."

This proposal which may be inspired by lengthy detention experience with a US tuna vessel in the Pacific,<sup>17</sup> was later changed at the Conference in a few, though very important aspects. Thus, PRP has as some one of its

basic approaches not to intervene with domestic procedures of the detaining State. It was also decided not to make any selection of preference for PRP among possible detentions or arrests (permitted or prohibited) within Article 292 of the UNCLOS, but leave this issue for the substantive provisions to decide in any particular case. This last principle leads us to examine relevant substantive provisions in the UNCLOS in order to find exact answers as to why PRP is not available in respect of all detentions in question but selected to a few limited cases only, and why such selectivity was considered necessary.

"The purpose of these new rules," notes Rainer Lagoni, "is to balance the interests of the detaining state in its measures against the flag state with the interests of the flag state in preventing an excessive detention of vessels flying its flag". PRP is aiming at the protection of vessel owners' or charterers' economic interests and the humanitarian needs of crew members, and it is intended to alleviate the impacts of the newly established institute – the EEZ of the UNCLOS.<sup>18</sup> It will serve private individuals and provide them with a measure to challenge actions by the coastal States and avoid serious consequences for the individual resulting from an infringement of the coastal States' respective rights. Consequently, it is seen as the "compensation" by the coastal States for extended jurisdiction,<sup>19</sup> or, in other words, "aiming at completing the balance of rights in the EEZ by preventing conduct of the coastal state which rises strong concerns of other states, and which could, in a broad sense, be considered as abusive".<sup>20</sup> Generally speaking, provisions on the release of a vessel and its crew accommodate economic and humanitarian as well as safety and environmental concerns.<sup>21</sup>

PRP is an extremely fast procedure for an international forum of dispute settlement. The procedure could be commenced immediately after ten days have lapsed from the date of detention and should be dealt with by a court or tribunal "without delay". PRP has a certain priority stipulated for it in Article 112 (1) of the Rules of the ITLOS as well as short time-limits for each important element of the procedure, including the adoption of the judgment. F. Wegelein has in 1999 calculated that there be no more than 32 days between a detention and the judgment. However, this figure is today 41 days because of the amendments of the Rules of 15 March 2001, where an additional five days were calculated for commencement of a hearing and four days more for the adoption of a decision. With these time-limits, even provisional measures provided for in Article 290 of the Convention could not compete.<sup>22</sup> One could agree that "arbitral tribunals are generally not appropriate for urgent detention cases".<sup>23</sup> It is worth mentioning that PRP is a separate procedure from any domestic one and therefore the principle of exhaustion of local remedies which is provided for in Article 295 of the Convention is conceptually not applicable to PRP cases (see Article 292 (3)).<sup>24</sup>

In this context use of the term fast or speedy is correct but it goes only for the procedure itself while instituted. In the "Camouco" case (Panama v. France; List of cases no. 5) in paragraph 54 of the Judgment of 7 February 2000, the ITLOS confirmed that there is no time limit for a flag State to present an application for release while the respondent argued that the applicant has been inactive for three months and has created a situation akin to estoppel. It is interesting to note that in the case of the "Volga" (Russian Federation v. Australia; List of cases no. 11) the detention was put into effect on 7 February, but the application for prompt release was made on 2 December, 2002 only (almost ten months later).

# 2. The Choice of a Court or an Arbitration for PRP

Being a part of the dispute settlement system in UNCLOS in general and specifically a part of section called "Compulsory Procedures Entailing Binding Decisions" the PRP could actually be invoked unilaterally by a flag State in principle in four different instances set in Article 287 (1). Those four are:

- (a) the International Tribunal for the Law of the Sea established in accordance with Annex VI, in Hamburg;
- (b) the International Court of Justice, in The Hague;
- (c) an arbitral tribunal constituted in accordance with Annex VII;
- (d) special arbitral tribunal constituted in accordance with Annex VIII for one or more categories of disputes specified therein.<sup>25</sup>

We note that the following paragraphs of that Article specify three important rules for submission of a particular dispute to a court or tribunal mentioned above. First, in cases where choice of procedure of the parties to the dispute differ, or, where one of them had not previously indicated its choice, the procedure to be

followed is arbitration in accordance with Annex VII of the UNCLOS. Second, if the parties to the dispute have accepted the same procedure for settlement of these disputes, this procedure shall be followed. Both rules are subject to the right of parties to agree otherwise. Third, when a State Party (to theUNCLOS) which is party to the dispute has not made any declaration (in force), it shall be deemed to have accepted arbitration in accordance with Annex VII. Furthermore, Article 288 (4) of the Convention confirms the customary rule of international law that any international court or tribunal has the competence to determine the scope of its jurisdiction, with no appeal available from such a decision.

Notwithstanding the critics of Judges Oda and Guillaume that ITLOS is "a futile" institution bringing the fragmentation in international law<sup>26</sup>, professor Alan E. Boyle considers this system "as the most important development in the settlement of international disputes since the adoption of the UN Charter and the Statute of the International Court of Justice." He contends this not only because it had created a new international court – the International Tribunal for the Law of the Sea – but because "it also makes extensive provision for compulsory dispute settlement procedures," nevertheless adding "to the potential for fragmentation both the substantive law and of the procedures available for settling disputes". This price had to be paid, he concludes after closer examination of this system with two main features, which characterize Part XV of the Convention: the "cafeteria approach" for the selection of procedure for the settlement of the dispute; and

- the "salami-slicing" of legal issues, requiring sometimes arbitrary categorization of different kinds of dispute, some of which will lead to binding compulsory settlement, others of which will not.

In particular, the inclusion of navigation and protection of the environment within compulsory settlement was intended to restrain the coastal State's claims to "creeping jurisdiction" over shipping within the EEZ. It reinforces a balance established by Parts V and XII in favour of freedom of navigation, in order to secure consensus on compulsory, binding dispute settlements.<sup>27</sup>

While the second part of Article 292 (1) stipulates for the flag State options for submission of an respective application that "*failing such agreement within 10 days from the time of detention, to a court or tribunal accepted by the detaining State under article 287 or to the International Tribunal for the Law of the Sea, unless the parties otherwise agree*" it seems to be obvious for any lawyer and politician that the flag State should be considered reluctant to choose the forum for settlement which is declared most suitable for the opposing party (respondent) in the dispute – the Detaining State. Therefore it is correct to consider the ITLOS as the instance of "last resort" or "default body" in PRP cases.

# **3.** Determination of the Amount of a Reasonable Bond or other Financial Security as the Precondition for the Release

List of cases of the ITLOS shows that there have been 20 submissions by 1<sup>st</sup> of January 2013. An analysis of current flag State practice of using PRP shows that there has been nine cases out of first 15 cases brought before and eight decided by ITLOS whereas the reason for the detention has been exclusively related to violation of coastal States' laws on fisheries.

If the Tribunal decides that the allegation made by the flag State that the detaining State has not complied with a provision of the UNCLOS for the prompt release of the vessel or the crew upon the posting of a reasonable bond or other financial security is well-founded, the next essential question is that *"it shall determine the amount, nature and form of the bond or financial security to be posted for the release of the vessel or the crew."<sup>28</sup> Giving priority to the Parties of the dispute to agree otherwise, the Tribunal shall determine whether the bond or other financial security shall be posted with the Registrar or with the detaining State. This security is to satisfy all the national court judgments and/or competent authorities of the detaining State.* 

Remarkable is that the amount, nature and form of the bond has the ITLOS to determine in relatively short period after two days of oral hearings having heard the opinion of the Parties. So far the ITLOS has not invoked any expert assistance in determining the value of detained vessels, for example. Practice of the ITLOS shows that in breaching fishery laws of a detaining State in determining the amount of the security the inputs for the ITLOS are the market value of delinquent fishing vessel, market value of the confiscated fish

and bite on board. Of course the Parties to the dispute have contrary interests in indicating the value of the vessel: owner of this vessel indicates usually up to 3-5 times less value than the detaining State.<sup>29</sup> It seems that the exact figure of the value of delinquent vessel is not so important for the ITLOS otherwise the 21 Judges and the Registrar have had used the assistance of impartial shipbrokers from the very beginning.

Among these nine PRP cases *the Grand Prince* (Belize v. France; no. 8 on the List of Cases by ITLOS) is remarkable not only because of the fact that the ITLOS for the first time denied using its jurisdiction, but also especially due to the fact that the Application of Belize dated 21 March 2001 had already "lost its object". Namely, the French criminal court had on 23 January 2001 ordered the confiscation of the Grand Prince and with immediate execution notwithstanding any appeal (execution provisoire) which prevailed over any civil proceedings in the court of first instance at Saint-Paul. Probably French authorities have learned their lessons while they had to release earlier two delinquent fishing vessels (*Camouco* – case no 5 and *Monte Confurco* – case no 6) and decided that the confiscation is a proper remedy in third time.<sup>30</sup> Sorry but the ITLOS had chance this time to escape from the deliberations whether the confiscation of such a vessel will prevent the case to be heard and decided at all. In paragraph 93 of the Judgment of 20 April 2001, it was stated "… *the Tribunal concludes that the documentary evidence submitted by the Applicant fails to establish that Belize was the flag State of the vessel when the Application was made. Accordingly, the Tribunal finds that it has no jurisdiction to hear the Application." The reason for such a statement was the fact that the <i>Grand Prince* has been deleted in the Ship Register of Belize as sanction for the repeated breach of international fishing regulations before the application for release has been made.

According to the Article 292 (4) upon the posting of the bond or other financial security in form of letter of credit or bank guarantee or in kind determined by the ITLOS, the authorities of the detaining State shall comply promptly with the judgment concerning the release of the vessel or its crew. The Rules of the ITLOS, Article 114 stipulates for the Registrar certain assignments while the security is posted with the ITLOS. Firstly he or she has to notify promptly the detaining State about the posted security. Secondly the Registrar shall endorse or transmit the bond or other financial security to the detaining State to the extent that it is required to satisfy the final judgment, award or decision of the competent authority of the detaining State. And thirdly, the Registrar has to retransmit the remaining amount of financial security to the party at whose request the bond or other financial security is issued.

# 4. Conclusion

Taking into account the said above and especially that the UNCLOS Article 292 (1) considers the ITLOS as "the instance of last resort" or "the default body" it is understood that the PRP seems to be and remain exclusively within the jurisdiction of the ITLOS. The UNCLOS Article 287 (1) provides States with four instances to settle their disputes in compulsory procedures entailing binding decisions: the ICJ and ITLOS as well as two kind of arbitration. To the best of my belief the ICJ has not yet elaborated any kind of procedure to deal with the speedy PRP and arbitration has been considered by many of experts not suitable for the PRP also.

<sup>3</sup> Web: www.itlos.org.

<sup>5</sup> *Ibid.*, pp 38, 39.

<sup>&</sup>lt;sup>1</sup> This article does not deal with the issues of activities on deep seabed and settlement of related disputes where party to the dispute could be also a private entity. See UNCLOS Part XI (as amended by the Implementation Agreement of 1994), especially Section 5.

<sup>&</sup>lt;sup>2</sup> Referred to as "the Montreaux (Riphagen) Compromise", as part of Article 287 of the Convention – see: the United Nations Convention on the Law of the Sea 1982. A Commentary. Vol. V. Myron H. Nordquist, editor-in-chief, Shabtai Rosenne and Louis B. Sohn, volume editors. Martinus Nijhoff Publishers. Dordrecht, 1989, p. 8; or what Professor Alan E. Boyle is calling "the cafeteria approach" – see Alan E. Boyle, "Dispute Settlement and the Law of the Sea Convention: Problems of Fragmentation and Jurisdiction," (1997), 46 *International and Comparative Law Quarterly*, pp. 39, 40.

<sup>&</sup>lt;sup>4</sup> Problems of applicability of PRP see, for example, in: H.Lindpere. Applicability of the prompt release procedure of the UN Convention on the Law of the Sea of 1982 in matters of prevention, reduction and control of pollution from vessels. In: Scandinavian Institute of Maritime Law Yearbook 2004, Marius no.321,Sjörettsfondet, University of Oslo, pp.209-265.

<sup>6</sup> See the Rules of Procedure of the ITLOS, Article 112 (4).

<sup>7</sup> See A Commentary, footnote 2, pp. 66-71.

<sup>8</sup> The term **"detention"** used in Article 292 of the Convention "is to be read according to its broadest meaning covering all cases in which the movement of a vessel or of persons is prevented by an authority," see Tullio Treves, "The Proceedings Concerning Prompt Release of Vessels and Crews before the International Tribunal for the Law of the Sea," (1996) 11 The International Journal of Marine and Coastal Law, p.182.

<sup>9</sup> No author is considering Article 220(8) of the Convention as a provision which violation makes PRP applicable, see for example Tullio Treves, op.cit., p. 179; Rainer Lagoni, "The Prompt Release of Vessels and Crews before the International Tribunal for the Law of the Sea: A Preparatory Report" (1996) 11 The International Journal of Marine and Coastal Law, pp. 147-164; David H. Anderson, "Investigation, Detention and Release of Foreign Vessels under the UN Convention on the Law of the Sea of 1982 and Other International Agreements," (1996) 11 The International Journal of Marine and Coastal Law, p. 165; Erik Jaap Molenaar. Coastal State Jurisdiction over Vessel-Source Pollution. Kluwer. The Hague, 1998, pp. 490, 491.

<sup>10</sup> See A Commentary, footnote 2, p 69 (Article 292.5).

<sup>11</sup> See Tullio Treves, op.cit., p. 179.

<sup>12</sup> See Rainer Lagoni, op.cit., p. 147.

<sup>13</sup> Article 292(1) of the Convention makes ITLOS the "default body" or gives ITLOS the competence of "instance of last resort", see Tullio Treves, op.cit., p. 187; Florian H. Th. Wegelein, "The Rules of the Tribunal in the Light of Prompt Release of Vessels," (1999) 30 Ocean Development & International Law, p.265; Shabtai Rosenne. "Establishing the International Tribunal for the Law of the Sea," (1995) 89 American Journal of International Law, p. 813.

<sup>14</sup> See Article 292(2) of the Convention; also, for example: Bernard H. Oxman, "Observations on Vessel Release under the United Nations Convention on the Law of the Sea," (1996) 11 The International Journal of Marine and Coastal Law, pp. 211-213.

<sup>15</sup> See Tullio Treves, op.cit., p. 182; Erik Jaap Molenaar, op.cit., p. 489.

<sup>16</sup> For further details, see A Commentary, footnote 2, pp. 66-71.

<sup>17</sup> See David H. Anderson, op.cit., p. 167.

<sup>18</sup> In this context B.H. Oxman writes: "In particular, the 200-mile exclusive economic zone represents a dramatic geographic and functional expansion of coastal state jurisdiction bringing a third of the marine environment within the limits of coastal state jurisdiction." See Bernard H. Oxman, op.cit., p. 202.

<sup>19</sup> See F. Wegelein, op.cit., pp. 265, 266.

<sup>20</sup> Tullio Treves, "The Exclusive Economic Zone and the Settlement of Disputes," in The Exclusive Economic Zone and the United Nations Convention on the Law of the Sea, 1982-2000: A Preliminary Assessment of State Practice. Edited by Erik Franckx and Philippe Gauthier. Brylant, Brussels, 2003, p. 90.

<sup>21</sup> See Bernard H. Oxman, op.cit., p. 203.

<sup>22</sup> See F. Wegelein, op.cit., pp. 263-265, 266.

<sup>23</sup> See Rainer Lagoni, op.cit., p. 151; there are of course other substantive reasons giving priority to PRP (commenced unilaterally, judgment is final etc.) over provisional measures.

<sup>24</sup> Inapplicability of this principle for PRP is also the view of ITLOS, stated in paragraph 57 of the 7 February 2000 Judgment on the Camouco (Panama v. France; List of cases no. 5).

<sup>25</sup> As of 7<sup>th</sup> January 2013 there are 163 State and the European Union as an international organization the Parties to the UNCLOS and around half of them have made declarations, but not all of those declarations are related to the Article 287.

<sup>26</sup> Judges S. Oda and G. Guillaume have argued that the ITLOS is a futile institution and that creation of a specialized tribunal may destroy the unity of international law, see S. Oda, "The ICJ Viewed from the Bench" (1993) 244- II Hag. Rec. 127-155; and S. Oda, "Dispute settlement Prospects in the Law of the Sea" (1995) 44 International and Comparative Law Quarterly, p 863; G. Guillaume, "The Future of International Judicial Institutions" (1995) 44 International and Comparative Law Quarterly, p. 848.

<sup>27</sup> This is the characterisation of the practical effects of Articles 297 and 298 of the Convention which leave binding compulsory settlement for EEZ disputes to those which are related to navigation or protection of the marine environment – see Alan E. Boyle, footnote .5, pp. 37-42; see also P.W. Birnie and A.E. Boyle, International Law & the Environment. Second edition. Oxford, Oxford University Press. 2002, chapter 7.

 $^{28}$  Rules of the ITLOS as amended on 17 March 2009, Article 113 (2).

<sup>29</sup> Actually in the first case of ITLOS – the prompt release of MV "Saiga" – the coastal State Guinea claimed that the Saiga was engaged in smuggling and customs violations for refuelling three fishing vessels within the EEZ of Guinea prior to the arrest. But the Tribunal found that offshore bunkering of fishing vessels is related to fishing activities according to the national laws of this coastal State. See also F. Wegelein, op.cit., pp. 275-277.

<sup>30</sup> Public International Law principle *pacta sunt servanda* seems to make that very doubtful.

# **Influential Indicators for Measuring Kaohsiung Port Resilience**

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#### Abstract

The changing structure of liner shipping services has significantly impacted the main ocean-going routes and consequently forced container shipping carriers to re-deploy their service routes. A container port links shippers and consignees and is an integral part of many logistics systems. In particular, having become more vulnerable in this dynamic marketplace, it is imperative for the container ports to evaluate their resilience. This study therefore applies the analytic hierarchy process (AHP) method to propose a resilience strategy-making framework for Kaohsiung port in Taiwan. A three-level hierarchical structure with 19 attributes is proposed and tested. The results indicate that adjusting shipping policy is perceived as the critical strategic dimension to enhance container port resilience; this is followed by increasing incentives; adjusting port operational strategy and exploiting market opportunities. Overall, the results show that the five most important resilience strategies for international container ports are the training of international marketing personnel; the deregulation of the shipping market across the Taiwan-strait; a subsidy of the throughput of transshipment; a subsidy of coastal shipping operations and the alteration of dedicated terminals for rent.

Keywords: Container port, Port resilience, Analytic Hierarchy Process, Kaohsiung Port

# 1. Introduction

The East Asia region, with its pivotal position between two major container trunk routes, namely the Trans-Pacific (T/P) and Far East-Europe (F/E), has long been regarded as the major shipping market in the world. Of the top 20 container ports in the world in 2011, 14 were based in Asia (UNCTAD, 2011). It is important to note that China's economic reform and open-door policy have increased regional imports and export container cargo volumes and attracted foreign investment in port and terminal operations. Shanghai port, therefore, has been one of the major container ports in Asia since 1999. Due to container vessel upsizing and the global financial crisis, the changing structure of liner shipping services has significantly impacted the deployment of service routes. The container port traffic report published by UNCTAD (2011) indicates that the container port industry in Asia has been growing in a sustained and dynamic manner. It is interesting to note that most of China's container ports were the original destination ports; however, more than half of the ports' traffic was transshipment cargos in the ports of Hong Kong, Singapore, Kaohsiung and Busan, these ports being the major transshipment hubs in the East Asia region. Compared to other regions around the world, the port sector in the Asia-pacific region has undergone significant change in the past few years. Kaohsiung Port, in particular, has suffered a major challenge from mainland China and its world ranking consequently dropped from third to thirteenth in 2012.

This study specifically focuses on Taiwan; as an island-based economic entity in the centre of the Asia-Pacific,

the country is highly dependent on foreign trade for its prosperity. Taiwan generated 1.51% of world trade in terms of value in 2009 and was ranked as the 18th largest (UNCTAD, 2010; Yang, 2012). Due to a significant growth in foreign trade, two years later in 2011 Taiwan controlled 2.63% of the world's fleet in terms of deadweight tonnage and was ranked as having the eighth largest container port traffic in the world (UNCTAD, 2010, 2012). However, due to the emergence of large-scale container ships; the re-deployment of service routes; the emergence of daily frequency services and the reorganisation of world shipping strategic alliances (MOTC, 2012b; Tai and Lin, 2013), Taiwan's container ports have faced several critical issues, such as a decrease in the number of ports of call and a decrease in frequency of sailings. At the beginning of 2012, therefore, the Taiwanese government decreed an organisational change in the ownership of the ports, forming the TIPC (Taiwan International Port Co., Ltd.) to increase efficiency and competitiveness.

Kaohsiung port is the main hub of container shipping in the Asia-Pacific region, handling over 70% of the country's cargo (MOTC, 2013). Although its dedicated terminal operation pattern is unique and has led to its ranking as the third container port in the world, it is imperative for the TIPC to realise the port's resilience in the face of the trend of vessel upsizing and the rapid development of ports in mainland China. The concept of vulnerability and resilience has been strongly emphasised in this dynamic marketplace. Notably, Taleb (2013) argues that the best way for firms to deal with uncertainty and dynamic issues is by adopting an antifragile instead of a forecast strategy. A number of previous studies have investigated vulnerability and resilience in the supply chain field (Wagner and Bode, 2006; Mansouri et al., 2010; Jüttner and Maklan, 2011). However, most of these studies are limited to natural disasters and there seems to be a lack of empirical studies examining the resilience of port systems in reacting to an uncertain financial and economic marketplace. Aside from analysing environmental pressure, the TIPC has to measure the resilience of container port systems to increase the port throughput and to improve competitive advantage. Thus, this study aims to identify the crucial indicators of container port resilience in this dynamic marketplace. The results can help the TIPC to create its resilience strategies and further to increase the port's adaptive capacity.

There are five sections in this study. Section 1 introduces the motivation and purpose of the research. Section 2 reviews the literature on port resilience. Section 3 describes the research methodology, including questionnaire design, sampling technique, and methods of analysis. Section 4 presents the results of analysis. The conclusions and implications are discussed in the final section.

#### 2. Port Resilience

Issues of vulnerability and resilience are frequently discussed in the field of safety and security management (Wagner and Bode, 2006; Mansouri et al., 2010; Farhan and Lim, 2011; Jüttner and Maklan, 2011; Steen and Aven, 2011). Some studies, however, have primarily focused on measuring the level of hazard resulting from natural disasters such as unfavourable climate conditions and earthquakes, and their impacts on people, property, and environmental and socioeconomic activities (Mansouri et al., 2010; Steen and Aven, 2011). Others have focused on the ability to cope with disasters or to recover from these events (GTZ, 2004; Gallopin, 2006; IPCC, 2007).

The topics of vulnerability and resilience have also garnered considerable attention in the field of maritime management (Barnes and Oloruntoba, 2005; Mansouri et al., 2010; Zhang et al., 2011; Laxe et al., 2012). Resilience, basically, implies a firm's ability to cope with the consequences of unavoidable risk in order to return to its original operations after being distributed (Jüttner and Maklan, 2011). Thus, resilience can be defined as "the adaptive capability to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" (Ponomarov and Holcomb, 2009, p. 131). An effective measurement of resilience can therefore help a firm to cope with unavoidable risk; decrease their vulnerability and increase their ability to quickly recover from disruptions.

A number of studies have investigated the issue of resilience. Mansouri et al. (2010) examines the resilience of port infrastructure systems. Three resilience strategies are proposed to decrease ports' vulnerabilities. These strategies are: (1) integrated security and safety design; (2) technological redundancy investment and (3) infrastructural redundancy and support investment. Jüttner and Maklan (2011) evaluate supply chain resilience

in the global financial crisis. Their results indicate that supply chain resilience could significantly decrease supply chain vulnerability. Thus, a firm could enhance their supply chain resilience by improving their flexibility, visibility, velocity and collaboration capabilities. To our knowledge, however, Hsieh et al. (2012) were the first to examine vulnerability in relation to port operations in Taiwan. They propose a model with four factors and 14 variables to evaluate the vulnerability of Taiwanese container ports. These four factors and 14 variables are detailed as follows: (1) accessibility (including ground access system, travel time and shipping route density); (2) capability (including gantry crane capacity, facility supportability and wharf productivity); (3) operational efficiency (including EDI connectivity, turnaround time, labour productivity and berth occupancy rate) and (4) industrial cluster/energy supply (including investment growth, FTZ business volume, electric power supply and gas supply).

It is important to note that the aforementioned studies have failed to take into account the shipping carriers' operations and global economic environment. Tai (2012b), therefore, took strategic and market structure factors into consideration to evaluate the potential vulnerability, resilience and adaptive capability of Taiwanese container ports. He found that the TIPC could enhance the ports' resilience by adjusting shipping policy, amending port operational strategies, exploring new markets and increasing incentives in relation to the dramatic change in the trunk route structure in Taiwan. Thus, reviewing the prior studies on port resilience could provide our study with a theoretical foundation for identifying resilience strategies for container ports.

Factors	Attributes	MOTC (2012a)	MOTC (2012b)	Tai (2012a)	Liu (2012)	Yang, et. al. (2012)	UNCTAD (2011/2012)	Chen, et. al. (2012)	Chiang (2010)	Cheon, et al. (2010)
F1: Adjustment of	deregulation of shipping market across Taiwan-strait	*			*			*		
shipping policy	deregulation of fleet capacity across Taiwan-strait	*		*	*	*		*		
	deregulation of port-investment from foreign and China capital	*		*				*		
	expanding cargo resources through regional trade agreements	*					*			
	deregulation of expanding foreign terminal investment	*	*				*		*	
	reinforcement of activities-connected on hinterland economy	*	*						*	
F2: Adjustment of	diversification of terminal fare construction	*				*		*		*
port operational	personnel training of ports' specialized staff	*	*	*	*					*
strategy	establishment of public container terminals		*	*	*	*				
	alteration of dedicated terminals for rental system		*	*	*	*		*		
F3: Exploring market	collaboration with shipping carriers on occupational activities		*	*	*			*		*
opportunities	collaboration with freight forwarders on logistics		*	*				*		
	personnel training of international marketing talent		*	*				*		*
	development of additional activities, such as real property		*	*						
F4: Increasing incentives	subsidy for trunk-route vessels calling		*		*	*			*	
	subsidy for feeder-route vessels calling		*		*				*	
	subsidy for throughput of transshipment		*		*				*	
	subsidy for state-run shipping companies		*	*	*	*		*	*	
	subsidy for coastal shipping operations		*	*		*		*	*	

 Table 1: Factors Measuring Container Port's Resilience

# 3. Methodology

#### 3.1 Influential indicators

An understanding of indicators measuring port resilience from the aforementioned studies assisted in the selection of criteria for use in the survey and in the formulation of the AHP hierarchy. To comprehensively identify resilience strategies for container ports, four container shipping executives working for the major Taiwanese container shipping companies, OOCL, EMC, WHL, YML and the newly founded TIPC, were interviewed for this study on a face-to-face basis in March 2012. Four factors and 19 indicators for measuring the resilience of Taiwanese container ports are thus identified from literature review and interviews with container shipping executives (see Table 1).

# 3.2 Data collection

The data were collected through an AHP questionnaire survey. Saaty (1980) recommends a nine-point scale of relative importance, ranging from "1=equal importance" to "9=extreme importance". The sample for this study was container shipping executives, including shipping carriers, research institutes and the TIPC. Accordingly, the AHP survey questionnaire, with a covering letter and a stamped addressed return envelope, was sent to the directors and managers of container shipping executives and experts in Taiwan in March 2012. The total usable number of responses was 16 and all analyses were carried out using the IT program *Expert Choice 11.5 for Windows*.

# 3.3 The Analytic Hierarchy Process (AHP)

The AHP, developed by Saaty (1980), is a multiple criteria decision-making (MCDM) method that has been widely used to solve port competition and shipping problems (Lirn et al., 2003; Notteboom, 2011; Yang et al., 2013). Thus, this study applied the AHP method to evaluate the importance of indicators influencing Kaohsiung port resilience. The statistical operations were performed using Expert Choice 11.5 for Windows. Applying the AHP method to a decision-based problem involves three steps: (1) constructing a hierarchy; (2) obtaining the weights in different hierarchies; and (3) synthesizing priorities (Saaty and Vargas, 1994; Lirn et al., 2003; Chen, 2006, Subramanian and Ramanathan, 2012; Yang et al., 2013). The first step, drawing on previous studies and personal interviews, a three-level hierarchical structure was constructed in this study and is shown in Figure 1.

As shown in Figure 1, the highest level of the hierarchy is the overall goal. Below the overall goal, the second level is the influential indicators for Taiwan container port resilience, including the adjustment of shipping policy, adjustment of port operational strategy, exploring market opportunities, and increasing incentives. Finally, 19 attributes associated with each factor in the second level are linked to the third level.

The second step involves making comparative judgments and obtaining the weights in different hierarchies. This step involves three phases: (a) developing a comparison matrix at each level of the hierarchy, starting from the top level and working down; (b) computing the relative weights of each element of the hierarchy; and (c) estimating the consistency ratio to check the consistency of the judgment. It is important to note that all CR values in this study were less than 0.1, suggesting that all judgments were consistent. The final step is a priority synthesis that constructs an overall priority rating. The global weights are synthesized from the second level down by multiplying the local weights by the corresponding criterion in the level above and adding them for each element in a level according to the criteria affected.



# Figure 1: The Evaluation Model of AHP

#### 4. The AHP Survey and Results

The 16 respondents of this study are actively involved in container shipping and have worked in the liner shipping industry for over 10 years. Thus, they had sufficient practical experience to answer the questions and to ensure the reliability of the survey findings. Among the 16 respondents, five were senior managers working for the TIPC, seven were managers working for various container shipping carriers and four were employees working for research institutes, namely the Harbor and Marine Technology Center of the Institute of Transportation and the Department of Shipping and Transportation Management at Kaohsiung Marine University.

The local weights of each factor are shown in Table 2. The results indicate that adjusting shipping policy (F1, 0.270) was perceived by the whole sample and specifically those employees from the research institute as the most critical factor (F1, 0.366) in improving port resilience. Adjusting the ports' operational strategy (F2, 0.277) and the need to increase incentives (F4, 0.321) were perceived by the representatives of the TIPC and shipping carrier firms as the most important strategies, respectively. It is important to note that the weight ranking judged by TIPC and shipping carrier employees was completely different. The major reason may be that the TIPC and shipping carriers' viewpoints are those of the supplier and customer, respectively. The shipping carrier managers thus perceived the increase of incentives as the most important factor for Taiwan's container ports to enhance their resilience. Additionally, renting a terminal has been viewed as a burden for terminal operators in the circumstance of cargo sources being insufficient. Therefore, if the TIPC cannot provide incentives to attract container carriers, only local container carriers, such as YML, EMC and WHL, will rent a terminal in Taiwan. Conversely, foreign shipping carriers will cease their operations in Kaohsiung port.

Factors	Total samples (16)		TIPC (5)		Shipping ca	arriers (7)	Research institute (4)	
Factors	Weight	Rank	Weight	Rank	Weight	Rank	Weight	Rank
F1	0.270	1	0.272	2	0.217	3	0.366	1
F2	0.237	3	0.277	1	0.197	4	0.252	2
F3	0.229	4	0.233	3	0.264	2	0.164	4
F4	0.264	2	0.218	4	0.321	1	0.218	3

**Table 2: The Weights for each Criterion** 

*Note:* \*Local weight is derived from judgments with respect to a single criterion

Table 3 shows the local weight and global weight for each attribute. The global weights were synthesised from the second level down by multiplying the local weights by the corresponding criterion in the level above and adding them to each element in a level according to the criteria affected. The findings show that training of international marketing personnel (F33, 0.0627); the deregulation of the shipping market across the Taiwan Strait (F11, 0.0626) and the subsidy of throughput of transshipments (F43, 0.0612) were perceived by the entire sample as the three most critical strategies in improving Kaohsiung port's resilience. With respect to the TIPC, the alteration of dedicated terminals for the rental system was judged as a crucial indicator (F25, 0.0706). On the other hand, the training of international marketing personnel (F33, 0.0776) and expanding cargo resources through regional trade agreements (F14, 0.1069) were perceived by the shipping carrier and research institute employees as the most crucial strategies, respectively.

Table 3: Local Weight and Global Weight for each Criterion
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	Total sa	mples (16)		TIPC (5	)		Shipping	g carriers ('	7)	Research	h institute	(4)
attributes	Local	Global	Donk	Local	Global	Donk	Local	Global	Donk	Local	Global	Donk
	weight	weight	Kalik	weight	weight	Nalik	weight	weight	Nalik	weight	weight	Nalik
F11	0.232	0.0626	2	0.229	0.0623	3	0.253	0.0549	7	0.195	0.0714	3
F12	0.204	0.0551	8	0.226	0.0615	4	0.186	0.0404	14	0.203	0.0743	2
F13	0.176	0.0475	15	0.182	0.0495	12	0.170	0.0369	15	0.170	0.0622	5
F14	0.199	0.0537	10	0.188	0.0511	10	0.161	0.0349	17	0.292	0.1069	1
F15	0.189	0.0510	13	0.175	0.0476	15	0.230	0.0499	10	0.140	0.0512	8
F21	0.179	0.0424	19	0.164	0.0454	17	0.177	0.0349	18	0.199	0.0501	9
F22	0.218	0.0517	11	0.196	0.0543	8	0.246	0.0485	11	0.199	0.0501	9
F23	0.184	0.0436	17	0.184	0.0510	11	0.179	0.0353	16	0.190	0.0479	13
F24	0.182	0.0431	18	0.201	0.0557	7	0.160	0.0315	19	0.198	0.0499	12
F25	0.238	0.0564	5	0.255	0.0706	1	0.239	0.0471	13	0.214	0.0539	6
F31	0.243	0.0556	7	0.245	0.0571	6	0.201	0.0531	8	0.323	0.0530	7
F32	0.244	0.0559	6	0.300	0.0699	2	0.216	0.0570	6	0.221	0.0362	15
F33	0.274	0.0627	1	0.248	0.0578	5	0.294	0.0776	1	0.260	0.0426	14
F34	0.239	0.0547	9	0.207	0.0482	13	0.289	0.0763	2	0.196	0.0321	18
F41	0.186	0.0491	14	0.155	0.0338	19	0.150	0.0482	12	0.312	0.0680	4
F42	0.194	0.0512	12	0.169	0.0368	18	0.226	0.0725	5	0.165	0.0360	16
F43	0.232	0.0612	3	0.214	0.0467	16	0.236	0.0758	3	0.230	0.0501	11
F44	0.175	0.0462	16	0.220	0.0480	14	0.160	0.0514	9	0.141	0.0307	19
F45	0.214	0.0565	4	0.243	0.0530	9	0.228	0.0732	4	0.152	0.0331	17

Note: \* Local weight is derived from judgments with respect to a single criterion

\*\*Global weight is derived from multiplication by the weight of the criteria

The priority of each strategy implemented to enhance Kaohsiung port's resilience as perceived by the different groups is summarised in Table 4. Taking the adjustment of shipping policy as an example, the strategy of the "deregulation of the shipping market across the Taiwan Strait (F11)" should be immediately implemented by the TIPC. As regards the adjustment of port operational strategy, the diversification of terminal fare construction (F22) was perceived by the container carrier companies' managers as the most important strategy to enhance port resilience, whereas other respondents judged the alteration of dedicated terminals for the rental system (F25) as the crucial strategy. Finally, with respect to F3 and F4, the necessity of implementing a resilience strategy was perceived differently by the representatives of the TIPC, the container carriers and the

research institute. Overall, the respondents suggested that the TIPC has to provide training for international marketing personnel and should subsidise the throughput of transshipment to enhance container ports' resilience in the short term.

Priority of attributes	Total samples	TIPC	Shipping carriers	Research institute
F1: Adjustment of shipping policy	deregulation of shipping market across the Taiwan Strait (F11)	deregulation of shipping market across the Taiwan Strait (F11)	deregulation of shipping market across the Taiwan Strait (F11)	expanding cargo resources through regional trade agreements (F14)
F2: Adjustment of port operational strategy	alteration of dedicated terminals for rental system (F25)	alteration of dedicated terminals for rental system (F25)	diversification of terminal fare construction (F22)	alteration of dedicated terminals for rental system (F25)
F3: Exploring market opportunity	personnel training for international marketing talent (F33)	collaboration with freight forwarders on logistics (F32)	personnel training for international marketing talent (F33)	collaboration with shipping carriers on occupational activities (F31)
F4: Increasing incentives	subsidy for throughput of transshipment (F43)	subsidy for coastal shipping operation (F45)	subsidy for throughput of transshipment (F43)	subsidy for trunk-route vessel calling (F41)

Table 4: The Priority of Attributes for each Criterion

## 5. Discussion and Conclusions

The structural changes to the liner shipping market in East Asia have led Taiwanese container ports to face several major challenges. To increase throughput and further maintain its mega hub port position, Kaohsiung port has to enhance its resilience in this dynamic marketplace. This study, thus, proposes an AHP model for decision makers to evaluate the importance of the various strategies to improve Kaohsiung port's resilience. The main findings derived from AHP are as follows. Result shows that adjusting shipping policy is the crucial strategy to enhance the resilience of the Kaohsiung port, followed by increasing subsidies, changing port operational strategies and exploiting market opportunities. Moreover, the training of international marketing personnel, the deregulation of the shipping market across the Taiwan-strait and subsiding the throughput of transhipment were perceived by the container shipping executives as the crucial strategies to enhance port resilience.

This study has several practical implications for the TIPC and government administrators. First, given the fact that adjusting shipping policy appears to be the crucial strategy to enhance Kaohsiung port's resilience, the Taiwanese government must continue negotiating with mainland China regarding the deregulation of the shipping market and fleet capacity. Specifically, allowing foreign shipping carriers to carry cross-strait transhipment cargo could mean that the former continue to rent the terminal in Kaohsiung port and treat this as a mega hub port in the East Asia region. If the limitation of foreign shipping carriers carrying transhipment cargo cannot be eliminated, this study suggests that the Taiwanese government should adopt Hong Kong's model. This model views the service route between Hong Kong and Taiwan not as a cabotage issue in 1997 and allowed foreign carriers to operate in the service route. Thus, the trunk routes between Taiwan and China should also be defined as a *special route* and both foreign and domestic shipping carriers be freely allowed to move between the ports across the Taiwan Strait.

Second, favourable incentives and subsidies are also needed to increase the number of container carriers' call at Kaohsiung port. In this way, trunk route and feeder route vessels are likely to call here more often, which in turn will increase the port's transhipment cargo. Finally, the Taiwanese port authorities, which adopted an organisational change in the ownership of the ports and formed the TIPC in March 2012, could be more flexible in their strategic operations. Thus, they should train international marketing talent and work with members of the logistics industry to provide a one-stop logistics service.

One of the major contributions of this study is that it is the first attempt to propose a resilience

strategy-making framework for a container port. Moreover, this study contributes to supporting the design of a series of policy measures to enhance container port resilience. Hence, a series of policy measures, such as the training of international marketing personnel; the deregulation of the shipping market across the Taiwan-strait and subsidies of the throughput of transshipment should be implemented and marketed by government administrators or port authorities to enhance port resilience. Finally, several major container ports, such as Kobe, LA, Long Beach and Felixstowe, have become more vulnerable in this dynamic marketplace and a resilience strategy-making framework based on this study could be generalised to other ports such as these.

From a theoretical perspective, this study contributes to the literature by proposing a resilience strategy-making framework for international container ports. However, it has several limitations. First, methodologically, it uses the AHP process to identify the importance of various resilience strategies and to rank them. The use of regression analysis or structural equation modelling might be helpful for identifying causal relationships between strategies and port resilience or adaptive capacity in a future study. Finally, this study proposes only a three-level hierarchical structure with 19 attributes and focuses solely on Kaohsiung port in Taiwan. For model generalisation purposes, further studies should take regional factors and other criteria into account.

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# Impacts of Port Productivity and Service Level on Liner Shipping Operating Cost and Schedule Reliability

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#### Abstract

Operating cost and schedule reliability are the two major concerns of container liner shipping operations. Port congestion and port productivity below expectations are among the main causes of schedule unreliability in the liner shipping industry, and they also result in higher operating cost of shipping lines. So far, little research has been conducted to quantify the impacts of port productivity and service level on liner shipping operating cost and schedule reliability. The problem is difficult because liner shipping operations involve many uncertainty time factors and relationships between these factors often lack closed-form expressions. This research builds a discrete event simulation model for quantitative analyses. Port productivity is measured by the number of moves per hour during a vessel's berth time window. Port service level is measured by the percentage of "berth-on-arrival" for the service of arriving vessels. The simulation model incorporates bunker cost functions and three major time components, namely sailing time, port time and buffer time. Extensive simulation experiments with an Asia-Europe route show the significant effects of port productivity and service level on liner shipping operating cost and schedule reliability.

Keywords: Liner shipping; schedule reliability; port productivity; berth-on-arrival; simulation

## 1. Introduction

A fundamental characteristic of liner shipping is to provide regular and quality services. Among the service requirements by the customers, there has been an increasing emphasis on schedule reliability since schedule unreliability can cause substantial losses for the shippers and consignees especially for those who practise just-in-time production and delivery (Lam & Van de Voorde, 2011; Wang & Meng, 2012 b). On the other hand, higher schedule reliability in most cases also means higher operating cost for the liner companies of which the rise in fuel cost is often the most substantial. Depending on the market economics (demand and supply of liner transportation) and total operating cost, the optimal schedule reliability adopted by liner companies may also change.

Despite a steady improvement over the last few years, the overall schedule reliability of the liner shipping industry is still low. According to the survey conducted by the Drewry Shipping Consultant (2012) based on more than 5000 ship arrivals, the average schedule reliability is only 72.3%. Although low schedule reliability can be caused by a number of reasons, in the survey conducted by Notteboom (2006), it is found that over 90% of delayed arrivals are related to port access and terminal operations. This suggests that given higher port productivity and service level, the schedule reliability and cost performance of liner companies can be significantly improved. However, it remains problematic as to how much benefit liner companies can receive from port service improvement, or to what extent ports should improve their services.

This research is motivated by the aforementioned challenges faced by major hub ports currently. Ports are expected from shipping lines and shippers to achieve and improve container loading/unloading productivity (Lam and Dai, 2012). However, we do not find any research in quantifying the direct benefits of port productivity that can be brought to port operators in terms of economic performance. Particularly, it is useful

for a port operator to measure how much it can charge shipping lines for port service improvements, which can be based on the quantifiable benefits to shipping lines. This research attempts to address this practical need by examining how the increase in port productivity and service level would affect the liner shipping operating cost and schedule reliability. Port productivity is measured by the number of moves per hour during a vessel's berth time window. Port service level is measured by the percentage of "berth-on-arrival" for the arriving vessels.

To the best of our knowledge, this paper is the first quantitative analysis on liner shipping operating cost and schedule reliability in view of port productivity and service level. Changes in operating cost and schedule reliability are simulated and analyzed under different port conditions. Secondly, this paper addresses the practical problems of port service level and productivity planning by estimating the resulted benefits for liner companies at various port service levels. The simulation experiments are conducted for an Asia-Europe route. However, the simulation model can be easily adapted for any other shipping routes and thus serves as a useful planning and reference tool for both port operators and liner companies.

This paper is organized in five sections. Section 2 presents a review of previous work in liner shipping and simulation as contrasted to optimization. Section 3 explains the details of the simulation model. In section 4, the simulation results are analyzed and discussed. Lastly, conclusions are drawn in section 5 to summarize the study.

# 2. Literature Review

Maritime transportation consists of two major stages: ship sailing at sea and ship staying in ports. To increase operating efficiency and reduce transportation cost, numerous studies have been conducted to simulate or optimize shipping and port operations (Alexis, 1981). However, limited research effort has been dedicated to liner shipping operations (Christiansen, Fagerholt, & Ronen, 2004; Wang & Meng, 2012a).

Among optimization studies, an early work was done by Boffey et al. (1979) to solve the liner scheduling problems on the route from North West Europe to North East Coast and Canada. By considering speed of the ships and different conditions of ports to be called, an optimization model was built to provide information about optimizing the profitability, transit time, and total buffer time of the route. The model was relatively easy to understand and has been used to by managers to calculate port charges and other values. Perakis and Jaramillo (1991) developed a linear programming model to minimize the annual operating costs for a fleet. The cost components include port dues, canal fees, bunker cost, crew and other costs. Consequently, different methods for adjusting service frequency and vessel speed were also provided. Another example is presented by Ting and Tzeng (2003). In their study, a dynamic programming model was formulated to determine optimal scheduling strategy including cruising speed and quay crane dispatching decisions. Recently, Qi and Song (2012) studied how to design an optimal vessel schedule. The objective function of their optimization model was to minimize the total fuel cost and emission while taking into account the uncertainty of port times and service frequency requirements.

An optimization approach has the merit of finding the optimal or near optimal solutions. However, the effectiveness of an optimization model for analyzing liner operations was limited by several constraints. Firstly, due to the high degree of uncertainty and complex geographical and economic constraints on liner operations (Gkanatsas, 2004), the construction and application of an optimization model may be extremely difficult or sometimes even unfeasible at all. Secondly, the complexity of planning and implementation of liner operations lies often not in the optimization of a single objective of cost or profit, but in achieving a fine balance between several inter-related or even contradicting objectives (e.g. speed and cost). As a result, simulation is often preferred and extensively used to evaluate liner shipping and container port operations (Carranza, 2008; Gkanatsas, 2004; Mclean & Biles, 2008).

Next, we review the relevant literature on cost performance and schedule reliability of liner operations with simulation approaches. Despite the extensive literature on maritime transportation using simulation methods, there is a dearth of operational research on liner shipping operations (Mclean & Biles, 2008; Wang & Meng, 2012a). Among the relevant scarce literature, an early study on liner operation using simulation modeling was

conducted by Datz et al.(1964). In this research, a simulation model was developed to generate and evaluate the profitability of a liner service schedule by taking into account cargo availability. In the research conducted by Bendall and Stent (1999), a simulation model approach was adopted to determine the optimal container fleet type and deployment for a short haul hub-and-spoke transport network. In the quest to achieve an efficient design of schedules and routes, Gkanatsas (2004) developed a discrete event simulation model to help decision making for more robust shipping schedules and to cope with disruptions. A "cost penalty function" was incorporated to explore and evaluate all possible alternatives (e.g. omit a port, increase nominal speed) to increase the robustness of shipping schedules. In the process, it also considered the tradeoff between the cost of increasing schedule robustness and customers' inventory cost which signifies their willingness to pay. A more recent simulation study in liner shipping was conducted by Kleywegt et al. (2005). In this research, a discrete event computer simulation of ocean container movements including liner shipping was developed to evaluate all shipping events including vessel events and container events. Voyage costs are evaluated by incorporating separate cost functions and charges on containers such as lashing, lifting and wharfage fees are also considered. The main performance criteria in this model are the total voyage cost and total freight revenue. Recently, Mclean and Biles (2008) developed a simulation model to evaluate the operational costs and performance of liner shipping by considering the movement of intermodal containers, operation in ports and the contribution of each service route to the operation of the network. The results showed that their model can considerably reduce the operating cost of the network without significant effects on the fleet performance.

In summary, existing simulation studies focused on the design of schedules and routes in liner shipping. However, it is unclear how port productivity and service level would impact liner shipping operating cost and schedule reliability. Given the great influence of port operations on liner shipping operations and the growing emphasis on schedule reliability, there is an urgent need to quantify the impact of port productivity and service level on liner operating cost and schedule reliability.

# **3.** Model Description

The Simulink Software under Matlab is used to develop the discrete event simulation model. The model simulates the stochastic times that a vessel spent at ports and sea legs. The schedule reliability and operating cost of the entire route service are evaluated under different sailing schemes and port conditions. In this study, the AE9 (Asia-Europe) round-trip currently operated by Maersk Line is chosen. Table 1 shows the sequence of westbound port calls evaluated in the application. The container ship specifications are summarized in Table 2.

Table 1. Cannig I of t Dequence				
Calling ports	Distance to the next port call (nautical miles)			
Ningbo				
Shanghai	101			
Yantian	760			
Tanjung Pelepas	1460			
Suez Canal	5313			
Rotterdam	3342			
Bremerhaven	212			
Felixstowe	300			
Zeebrugge	83			

#### Table 1: Calling Port Sequence

Table 2:	Container	Ship	<b>Parameters</b>	for	Simulation

Capacity (TEU)	Туре	LOA (m)	Designed service speed (Knots per hour)	Fuel consumption rate at designed speed (Metric tons per hour)
8112	Post-Panamax	332	18	8.75

*3.1 General assumptions to the liner shipping model* 

Due to the focus of port productivity and service level, the simulation model and its application are based on the following assumptions:

- 1. The routes and distances between container ports do not change during the simulation.
- 2. The bunker price does not change during simulation and the fuel cost is only affected by the ship speed and sailing time. For the rest of the group (e.g. docking fees, canal transit, routine maintenance and other operation costs), the cost remains constant.
- 3. The service speed of the container ship is not affected by the weather, sea, or vessel conditions.
- 4. The vessel will call at each port according to the predetermined sequence and schedule, and will not change or skip any calling ports.

# 3.2 Definition of variables

In this model, two sets of time variables are identified and defined (as shown in figure 1).

The first set of variables is termed real time variables. These variables represent the actual time that a ship has spent going through each of the ship operations, defined as follows:

Port to Port Time (PPT) is defined as the duration in hours starting from the time when the ship has just berthed at one terminal to the point where the ship was berthed in the terminal of the next calling port. The PPT was further divided into seven components:

- Port Time (PT): the total time for unloading, movement and loading of containers.
- Pilot Out (PO): the time for the ship to sail out of the port. Its length is modeled as following a uniform distribution.
- Sailing Time (ST): the time spent for the movement of container ship from a departing port to the next port in the sequence.
- Anchorage Time (AT): the time that the ship needs to wait for berthing. It is modeled as a probabilistic event of which the chance of berth-on-arrival depends on the total capacity and congestion level of the calling port as well as the punctuality of the arriving ship.
- Pilot In (PI): the time for the ship to sail from anchorage to berth in the port. Its length is modeled as following a uniform distribution.
- Window Time (WT): the time that a ship needs to wait to transit through the Suez Canal when it fails to arrive at the canal within its allocated time slot. In this experiment, it is assumed that the time slot allocated to a container ship to transit through the Suez Canal is the same on each day. This means that if a ship misses the allocated time slot, say 1:00pm to 3:00 pm today, it will have to wait until 1:00pm on the next day to pass through the canal.
- Cargo Ready Time (CRT): the time that a ship needs to wait until the cargo is ready. This happens when the ship arrives at a port so early that the cargo has not been ready to be loaded onto the ship. In this experiment, it is assumed that for every calling port, the cargo will be ready two days before the scheduled arriving time.

On the other hand, before the ship actually starts moving containers between ports, the ship operator must plan on the amount of time needed for the aforementioned processes. These pre-planned time components are defined as planned time variables, including Estimated Port to Port Time (EPPT), Estimated Port Time (EPT), Estimated Pilot-out (EPO), Estimated Pilot-in (EPI), Estimated Sail Time (EST), Estimated Anchorage Time (EAT) and Buffer Time (BT). The Buffer Time is defined to account for the sum of Window Time, Cargo Ready Time and normal delays due to their probabilistic or contingent nature.



Since the actual amount of time is uncertain, the planned time variables can only be estimated based on historical data with certain confidence levels. Confidence level is defined as the probability that the actual amount of time spent will be less than the planned amount of time. It follows that the more the amount of time assigned to a particular shipping process, generally the higher the confidence level will be, which also leads to higher overall schedule reliability.

# 3.3 Model Logic

For the  $i_{th}$  voyage segment in which the container ship travels from port i to port i+1, the two sets of time variables defined in section 3 satisfy

$$PPT_i = PT_i + PO_i + ST_i + AT_i + PI_i + (CRT_i + WT_i)$$

$$\tag{1}$$

$$EPPT_{i} = EPT_{i} + EPO_{i} + EST_{i} + EPI_{i} + BT_{i}$$
<sup>(2)</sup>

Note that for CRT and WT in formula (1), only  $WT_i$  will be considered when the  $(i+1)_{th}$  destination is Suez canal. In other cases, only  $CRT_i$  is considered. Here we define the difference (DIF<sub>i</sub>) as

DIF<sub>i</sub>= PPTi - EPPT<sub>i</sub>

(3)

Consequently, the DIF of a particular voyage segment will have a cascading effect on all the following voyage segments. A negative DIF for the previous voyage segment means the ship now has more time for the next voyage segment. Thus the ship can choose either to sail at a lower speed to save fuel cost or sail at the planned speed to ensure higher schedule reliability. In the second case, the ship will either have to increase speed to catch up with the planned schedule (higher fuel cost) or does not speed up and face a greater risk of delay during subsequent voyage segments.

# *3.4 Service attribute and sailing modes*

To analyze how the experiment results may be affected by the service attributes, the ship would be required to sail through the voyage under two different total voyage time, namely 10 weeks and 11weeks.

Under each case, the ship was designed to sail through the voyage with either constant speed mode or variable speed mode. Thus, it will be much more convenient for us to quantify and compare the impact of port operations on liner schedule reliability and voyage fuel cost.

# 3.4.1 Constant speed model

Under constant speed mode, the ship would sail with a predetermined speed between two container ports regardless of any contingent events (the fuel cost being unchanged). Ergo the impact of port productivity (measured by container handling rate) and service level (measure by percentage of berth-on-arrival) on the schedule reliability can be quantified and analyzed. The schedule reliability is computed as

schedule reliability = 
$$\frac{number of ports upon which the ship arrives on time}{the total number of calling ports}$$
 (4)

Where the ship is considered on time if it arrives within 24 hours of the scheduled time of arrival.

# 3.4.2 Variable speed mode

Under the variable speed mode, the ship will automatically adjust its speed based on the estimated sailing time available so as to ensure an optimal level of schedule reliability. Since the schedule reliability is maintained on a relatively constant level, the impact of port operations on liner shipping cost (e.g. fuel cost) can be assessed under different port conditions. The ship will adjust its speed based on the following calculations. Firstly, for the  $i_{th}$  segment, the available sailing time (AST) is estimated by

$$AST_i = PPPT_i - PT_i - EPI_i - BT_i$$

(5)

Since the distance (D) between port i and i+1 is known, the resulting sailing speed (Vi) can be determined:

$$v_i = \frac{D_{i,i+1}}{AST_i} \tag{6}$$

However, the speed of the container ship can only be adjusted within a certain operation range (e.g. 14knots/h  $\sim$  24knots/h). Hence, if the above speed is within this operational range, the ship will sail at the estimated speed. Otherwise the ship will sail at either its lower or upper speed limit.

#### 3.5 Container ship consumption model

The fuel consumption of a ship is estimated according to the cubic rule (Stopford, 2009):

$$F = F^* \times \left(\frac{s}{s^*}\right)^3 \tag{7}$$

Where

F = actual fuel consumption rate at metrics tons per hour; S = actual speed:

 $F^*$  = designed fuel consumption;

 $S^* = designed speed.$ 

#### 4. **Results and Discussion**

The simulation results are organized into four sections. The influence of port productivity and service level on schedule reliability was examined in scenarios 1 and 2. In scenarios 3 and 4, the impact of port productivity and service level on total voyage fuel cost was investigated. Due to the stochastic nature of each time component, the simulation model was run 100 times for each of the four scenarios and the average values of schedule reliability and voyage total fuel cost were computed.

Scenario 1: the ship adopts the constant speed mode under a 10 week service schedule

In this case, the total voyage time is 10 weeks and the ship sails at a constant speed of 17 knots per hour. The total fuel cost remains constant at 7.7 million US dollars since the total distance of the voyage does not change.

#### Figure 2: Average Schedule Reliability vs First Port Productivity with BOA = 0.3 for All Other Ports



Figure 3: Average Schedule Reliability vs First Port Productivity with BOA = 0.5 for All Other Ports



As shown in figure 2, when the berth-on-arrive (BOA) rate of the first port is at a low or medium level (0.3 and 0.5 respective), the average schedule reliability increases more rapidly at the two ends as the productivity of the first port increases (1 represents a cargo handling rate of 120 containers per hour and 2 represents a cargo handling rate of 240 containers per hour). However, when the BOA of the first port reaches a very high level (BOA = 0.8), the impact of its productivity on average schedule reliability becomes less significant and uncertain (as the curve fluctuates more against changes in port productivity).

When the average BOA of all other ports was increased to 0.5, the average schedule reliability all improved significantly regardless of first port BOA levels (see figure 3). Notice that in some cases, an increase in port productivity actually resulted in a decrease in average schedule reliability. This may be explained as follows. Firstly, due to the uncertainty of port time and other voyage time components, the ship arrives within schedule for some calling ports and generally arrives behind schedule for the others. Due to the increase in port productivity, the ship will tend to arrive earlier at all the subsequent ports. As a result, for those ports where the ship previously arrives late, the schedule reliability tends to be increased because the ship now has a greater chance of arriving earlier (the positive side). On the other hand, for those ports where the ship previously arrives within schedule, there is a risk of decline in schedule reliability since the ship may tend to arrive too far ahead of schedule (the negative side). Nevertheless, it was observed that the positive effect generally outweighs the negative effect for a given voyage. It is also possible that by adjusting port productivity and liner voyage schedule, the negative effects will be reduced to minimum.

In addition, it is found that the pattern of change in average schedule reliability is also dependent on the service level of other calling ports (measured by BOA). This means for different voyages the optimal combination of productivity and service level for a particular port may also change.

#### Scenario 2: the ship adopts the constant speed mode under a 9 week service schedule

Due to the decrease in the total voyage time, the ship now must sail at a higher speed to compensate for the time reduction. As a result, a speed of 19.5 knots per hour was adopted and the total voyage fuel cost is 10.4 million US dollars.

When the BOA of the first port equals 0.3 and 0.5, it was observed that the schedule reliability generally increases with port productivity (see figures 4 and 5). However when the BOA of the first port is increased to a high level of 0.8, the schedule reliability decreases as the port productivity increases. The results in both scenario 1 and scenario 2 show that a mere improvement on the port side may not lead to higher schedule reliability without operational adjustment in liner operations.



Figure 4: Average Schedule Reliability vs First Port Productivity with BOA = 0.3 for All Other Ports

Figure 5: Average Schedule Reliability vs First Port Productivity with BOA = 0.5 for All Other Ports



Scenario 3: the ship adopts the variable speed mode under a 10 week service schedule

In the following two scenarios, the ship will constantly adjust its actual speed to the planned schedule. The resulting schedule reliability at each port service level was between 0.8091 and 0.8092.

As clearly shown by the solid curves in figure 6, at each BOA level for the first port, the average total voyage fuel cost would decrease as the first port productivity increases. In addition, by comparing each curve with a straight line connecting their respective endpoints (the dotted lines), it was observed that the rate of decrease in voyage fuel cost gradually diminishes as the productivity of the first port increases to higher levels.



Figure 6: Average voyage fuel cost vs First Port Productivity with BOA = 0.3 for All Other Ports

In addition, when the schedule reliability and fuel cost in scenario 3 were compared to those in scenario 1 at each level of port productivity and service level, an average increase of 83% in schedule reliability was observed. On the other hand, the average increase in total fuel cost was only about 10% to 12%.

## Scenario 4: the ship adopts the variable speed mode under a 9 week service schedule

Given a shorter voyage time, the resulting schedule reliability not only decreased at each port service level (between 0.7835 and 0.8053) when compared to scenario 3, but also became much more sensitive to both changes in port productivity and service levels. In addition, it was found that the voyage fuel cost at each port service level and port productivity also increased significantly when compared to the results in previous scenario (see figures 6 &7).





# 6. Conclusion

A quantitative analysis on liner shipping operating cost and schedule reliability in view of port productivity and service level is conducted with the simulation approach. The discrete event simulation model simulates the stochastic times that a vessel spent at ports and sea legs. Port productivity and service level are measured by container handling rate and the percentage of "berth-on-arrival" (BOA) for arriving vessels, respectively. To the best of our knowledge, this is the first simulation study that quantifies the impact of port productivity and service level on liner shipping operating cost and schedule reliability. The study is beneficial to both port/terminal operators and shipping lines in an era when there is growing competition in cost and schedule reliability in the liner shipping industry.

The key findings are summarized as follows. Firstly, schedule reliability can be enhanced by improving either port productivity or service level, and their effects are interrelated. This implies that the improvement of port productivity and service level must be synergized to arrive at the most cost-effective solution. In addition, the impact of a particular port's productivity on liner shipping schedule reliability is affected by other ports' service levels. This implies that port/terminal operators should consider other ports' conditions for their port development planning. On the other hand, as far as liner schedule performance is concerned, the potential benefits of an improvement on the port side will not be fully exploited without a corresponding adjustment in liner operations. In other words, close cooperation must be present for both parties to achieve better operational performance.

Secondly, when the ship sails at a variable speed mode, an increase in either port productivity or port service level would lead to a decrease in fuel cost. However, the rate of decrease in total voyage cost gradually diminishes with the increase in port productivity (at a constant port service level).

Lastly, at each level of port productivity and service level, a shorter total voyage time will result in higher fuel

cost and lower schedule reliability. The schedule reliability will also become more sensitive to port productivity and service level with a shorter total voyage time.

This study may be extended by future studies in two dimensions. Firstly, the analysis may be expanded to an entire liner shipping network. Secondly, the cost benefit analysis may be extended to include indirect benefits received by liner companies in view of the entire logistics chain including customers and service partners affected by the chain.

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# An Exploratory Analysis and Visualization of U.S. Global Trade Patterns through Maritime Freight Movement between U.S. Ports and World Ports: 1997-2007

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# Abstract

Using data mining, data integration, geographical information systems (GIS), Google Earth, and common transportation flow assignment methods (i.e., all-or-nothing, system optimal), this paper first reports a novel model of combining various databases (i.e., U.S. Maritime Administration, World Port Index, Oak Ridge National Lab) into a complete 1997-2007 time-series port-level maritime freight origin and destination database in a GIS environment (i.e., TransCAD). Important database issues in the model development and implementation are discussed as well.

This paper then performs freight flow assignments between foreign ports and U.S. ports and investigates the total freight movement and commodity specific freight flows. The total flows from all ports of a country to and from all U.S. ports are considered as U.S. imports and exports, or international trade between this country and the U.S. Similar flow aggregations are done at the regional levels (i.e., Asia, Europe, or South America), by country (i.e., China), and by port (i.e., Hong Kong). The patterns of U.S. international trade are then explored and visualized by port, county, and region, in total or by commodity or commodity group for some years in 1997-2007.

The results show that U.S. imports outpaced exports in the period. China, Canada, Mexico, Europe are the top countries shipping commodities to the U.S. during 1997-2007. Panama Canal was perhaps the most important canal in ocean freight movement to and from U.S. Asia, Europe, and South America were among the top in exchanging commodities with the U.S. At the port level, Long-Beach and Los Angeles ports were the most important, followed by New York City Port, Houston, New Orleans, San Francisco, etc. Top world ports, such as Hong Kong, Shanghai, Singapore, Pusan were the most interactive foreign ports with U.S. ports.

Finally, it would be interesting to see future research through simulation results for alternative freight flow movements, hence altered U.S. international trade patterns, under scenarios such as zero imports and exports from a country with the U.S. (i.e., cutting diplomatic/economic ties), an extended shut-down of Panama Canal (i.e., due to political/military conflict), a major natural or man-made event (i.e., earth quake or port worker strike) in Long Beach/Los Angela, particularly if these results are highlighted in comparison with normal conditions and visualized in Google Earth<sup>TM</sup> 3D.

Keywords: Global Trade Pattern, Maritime Freight Flow, Data Mining and Integration, Ports, GIS

# 1. Introduction

The international trade growth rate was approximately twice the average growth rate of the world gross domestic product (GDP) during 1995 to 2005 (BERA, 2007; WTO, 2008). The value of the U.S. international trade in 2007 rose to \$3,992 billion, of which exports accounted for \$1,646 billion and imports for \$2,346 billion, with a trade deficit of \$700 billion (Nanto et al. 2009). Amadeo (2009) showed that 87% of the trade deficits came from petroleum-related and consumer-oriented products and China was the country with which

the U.S. had the largest trade deficit in the past decade. This research studies U.S. international maritime freight flows to highlight the U.S. international trade patterns during 1997-2007.

Maritime transportation is the predominant mode for U.S. international freight flow. Over 90% of international trade is carried by maritime vessels and 70% maritime cargo shipping is realized by containerized transportation (Kite-Powell, 2001; Maritime Transportation and Shipping Talk, 2008). Compared to other modes such as air, rail, and highway, maritime shipping is considered as the most energy-conservation and low carbon-emission mode for freight (Frankel, 1989; Corbett, 2004).

Ocean ports are very important factors in maritime transportation since most vessels carrying freight move through ocean waterways between maritime ports. In the U.S., there are over 300 maritime ports and quite a few of them engage in international trade. They are governed by "a state, a county, a municipality, a private corporation, or a combination" (Maritime Administration, 2012). In the world, there are over 4,000 ports engaging in international maritime shipment.

International trade is physically realized through freight movement through a global maritime transportation network and is a critical component of the U.S. import and export economy. Global freight flows to and from the U.S. has a significant impact on the economy, business, quality of life, and national security. Since 9/11, the concern of maritime security has been shifted to possible terrorist attacks to large freight ships and maritime logistics facilities that could paralyze global maritime commerce (Frittelli, 2005). Accordingly, the U.S. government and port authorities are taking steps to track the movement of maritime freight and hope to reduce risks (Voort et al. 2003; Finley, 2006).

This paper attempts to provide an exploratory analysis and visualization of U.S. import and export patterns and best maritime shipment routes during 1997-2007. The paper starts with a concise review on maritime freight transportation databases which contain the relevant information of U.S. international freight. Then, it develops a data mining framework to integrate these databases to analyze the global freight flows to and from the U.S., hence the U.S. international trade patterns. Some important database mining, integration, and visualization issues, such as origin-destination (O-D) matrices, commodity codes, measurement units, spatial scales, and software integration in TransCAD<sup>TM</sup>, ArcGIS<sup>TM</sup>, and Google Earth<sup>TM</sup>, are discussed. All-or-Nothing (AON) assignment using TransCAD<sup>TM</sup> was performed to generate and visualize the best global freight movements of U.S. international trade.

#### 2. Maritime Freight Databases and Issues

Many databases from governments and/or private agencies exist for U.S. global freight flows. In general, these databases can be classified into three groups: freight, port, and network databases.

#### 2.1. Freight Databases

They are mostly import and export freight flow data with attributes such as commodity codes, units, O-D matrices, and transportation modes, tons, and values. Primary freight databases containing valuable information of U.S. international freight flow are summarized below.

Freight Analysis Framework database version 3 (FAF<sup>3</sup>) is an open database, which was produced and is updated by the Federal Highway Administration (FHWA, 2012) for U.S. international freight flow estimates for 2002 and 2007 and forecasts from 2010 to 2040 by five-year interval.

Maritime Administration Database (MARAD) is developed by the U.S. Maritime Administration (2012). MARAD provides the maritime freight flow information from 1997 to 2007 by "U.S. custom ports" and "trade partners" separately. All imports and exports in MARAD are presented by tonnage or container units. However, MARAD does not classify flows into different commodities and have some port-to-port O-D information missing.

USA Trade Online (2012), an official source for U.S. merchandise trade data, is provided by the Foreign Trade Division of the U.S. Census Bureau. This database provides freight data from 2003 on a monthly
frequency. It contains 6-digit North America Industry Classification System (NAICS) and 10-digit Harmonized Commodity Description and Coding System or Harmonized System (HS) by World Customs Organization (2012). As for O-D pairs, it collects the freight flow between foreign countries and U.S. ports.

Navigation Data Center (NDC) database by U.S. Army Corps of Engineers (2012) supplies a more completed collection of maritime freight data, which comprises the information on foreign cargoes, facilities, and other correlative sources. The yearly maritime freight flow information for 1997-2007 was available for this research. Furthermore, the O-D pairs in NDC database are port-to-port pairs, which include over 200 U.S. ports and over 1,000 foreign ports. Lock Performance Monitoring System (LPMS) by U.S. Army Corps of Engineers (2012) was used to classify commodities.

### 2.2. Port Databases

Since the global freight flow is mostly shipped between maritime ports, it is important to study port-to-port freight movement as a way to understand international trade. Here, the geographic information of maritime ports is critical. Two databases, NDC and World Port Index by Landfall Navigation (2005), contain the geographic locations and other attributes for major U.S. ports and foreign ports.

Port locations in NDC (and its Schedule K files) are defined by longitudes and latitudes for most U.S. ports. However, NDC only provides very limited geographic information for foreign ports. Of the 1,813 foreign ports listed in the NDC, only a few of them have their longitudes and latitudes. Comparing with the NDC database, the WPI database has 4,043 port records with longitudes and latitudes. The 2005 version of WPI contains the geographic information for all U.S. and foreign ports. Since this research focuses on maritime transportation, thus a port in this paper refers to a maritime port.

#### 2.3. Network Databases

The NDC database contains some but very limited information of the global waterway, in which it only has very few ocean routes near U.S. coasts or inland waterways. By contrast, Oak Ridge National Laboratory (ORNL, 2009) provides a comparatively complete coverage of the global waterway network. In fact, the ORNL intermodal network unites the global waterway with U.S. domestic and intermodal networks and points.

### 3. Data Mining Framework and Data Integration Issues

The database review reveals that different databases have different attributes and quite few of them use a variety of units or formats. Also, the utility of attributes from each database varies. These observations call for data mining and integration to derive the target database with desired attributes. To derive this targeted database, a three-step data mining model is developed. The model framework is shown in Figure 1. The operation process of deriving the desired attributes is summarized in Figure 2. The integration of selected databases for the targeted maritime freight flow and network database is shown in Figure 3 and 4 respectively.

The three-step data mining and integration model is a cohesive system, and it constructs the data mining and integration flow from the top down, with three main phases: data filtration, data integration, and data integration. The data filtration step is to select a valid set of data sources from all available sources. The data integration step is to implement specific integration techniques to build the target database for a specific purpose. In the data interaction step, the target database is used to provide data analyses, such as scenarios and forecasts or modeling and reporting.

### 3.1. Database Integration Issues

In the three-step data mining and integration model, data integration step is the key. Data integration is the process of combining useful attributes residing at different sources for a necessary attribute set of the target database, and the primary action is to map the sources (Lenzerini, 2002). In applying data integration for this research, the following important issues are identified and addressed.



**Figure 1: Data Mining and Integration Framework** 



Figure 3: Maritime Freight Database Integration







Figure 4: Maritime Freight and Network Flowchart

### 3.1.1. Various Spatial Scales

The issue of various spatial scales is mainly from the definition of O-D pairs in the source databases. For example, one database records O-D data at the levels of region, country, or state, while another database provides freight information at the scales of metropolitan or port or port district. Thus, there is a need to bridge freight data at different spatial levels into a common spatial scale good for the target database. This issue can be addressed by aggregating or disaggregating O-D matrices of different geographic scales suitable for the target database.

### 3.1.2. Commodity Code Mapping

There are different commodity code systems adopted in different freight databases, hence, commodity code mapping is needed in data integration. The frequently-used code systems include Standard Classification of Transported Goods (SCTG) by Statistics Canada (2010), Standard International Trade Classification (SITC) by United Nations Statistics Division (2008), LPMS and HS. Through the technique of commodity code mapping, we could bridge different commodity code systems. Table 1 illustrates an example of code mapping for cereal grains commodity among SCTG, LPMS, and HS codes.

			SCTG		LPMS				HS
		2100	Wheat	62	Wheat			1001	Wheat and Maslin
		2200	Corn(except sweet)	63	Corn			1002	Rye in the grain
		2901	Rye					1003	Barley
2	Cereal	2902	Barley		Domlary Dria			1004	Oats
		2903	Oats	-	54 Oats, Rice 54 and 55 Grains	10	Cereals	1005	Corn (maize)
2	Grain	2904	Grain Sorghum	64				1006	Rice
		2909	Other Cereal Grain,	04				1007	Grain sorghum
			including rice (excludes soy beans, and other oil seeds)					1008	Buck wheat millet & canary seed

 Table 1: Code Mapping Example (SCTG-LPMS-HS)

### 3.1.3. Various Units

Three units are commonly used in maritime freight transportation, namely value (\$), tonnage (TON), and number of containers (TEU). These different units can be mutually convertible in theory, but hard to be accurate in practice. Given various types of commodities and often mixed containers, it is hard to convert TON to TEU to \$ or vice versa, so in practice, different conversion ratios are often used.

#### 3.1.4. Missing and Mismatched Data

The missing data and mismatched data are another two important issues for database integration (Brain, 2009; Shen and Aydin, 2012). For example, the NDC freight flow database, as one of the most completed databases, still contains many records with missing data on U.S. ports. Besides, during integrating the NDC and the WPI databases to acquire foreign port information, lots of mismatched foreign port names, such as misspellings, multi-names, or various language translations, were encountered.

### 3.1.5. Other Data and Software Integration Issues

To use TransCAD<sup>TM</sup>, ArcGIS<sup>TM</sup>, and Google Earth<sup>TM</sup> software on spatial integration for proper spatial visualization and exploratory analysis, it is necessary to unify different coordinate systems for various databases. Also, the data duplication issue needs to be addressed during integration. In addition, the vague definition of some attributes in databases also complicates data integration. Moreover, the provided geographic positions for the same ports fall far apart. All these add difficulties to the data integration.

### 4. Highlights of U.S. International Freight Flows during 1997 to 2007

This research is not restricted to containerized maritime freight flow, but considers all kinds of international maritime freights in tonnage, including non-containerized commodities (i.e., Petroleum Oil), hence, all inbound and outbound maritime commodity flows, or simply maritime imports and exports. For national level total maritime freight, Figure 5 portrays the U.S. imports and exports in tonnage respectively from 1997 to 2007. It is clear that the U.S. trade deficit was widening almost consistently during this period primarily due to the fast increasing of imports and flat exports.

For the region-level maritime freight, Figure 6 shows U.S. imports from nine world regions in 1997, 2002 and 2007. South America led other regions in U.S. imports due partially to its short shipping distance to the U.S. Asia, while on par with Europe and Middle East and North Africa regions, the fastest growth in U.S. imports from 1997 to 2007. The U.S. imports in tonnage increased consistently in the past 11 years, although imports from Mexico, Africa, and Australia & Oceania fluctuated. North American Free Trade Agreement (NAFTA) countries Mexico and Canada had significant exports to the U.S.





Figure 5: U.S. Maritime Exports vs. Imports in Millions of Tons 1997-2007

Figure 6: U.S. Maritime Imports from World **Regions In Millions of Tons 1997-2007** 

Figure 7 shows the total tonnage of U.S. exports from nine world regions during 1997 to 2007. Asia led all other regions for U.S. exports, Europe was the next, and Australia and Oceania was the last one. Comparing U.S. imports, South America received much smaller U.S. exports. Figure 8 clearly shows South America, Europe and Asia were the three largest trade regions with the U.S. in 2007.



In Millions of Tons, 1997-2007

World Regions, 2007

For the country-level maritime freight, Figure 9 charts U.S. trade with various other countries in 2007. The map shows that Canada, Mexico, Venezuela and China were the largest four trade partners to U.S. and they had a trade deficit with the U.S. in 2007. Japan is another important trade partner to U.S. with more imports from than exports to the U.S.



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Figure 9: 2007 U.S. Trades with Selected Countries



Note: AG=Algeria, BE=Belgium, BR=Brazil, CA=Canada, CH=China, CO=Colombia, EG=Egypt, IT=Italy, IZ=Iraq, KS= Korea, Republic of, MX=Mexico, NL=Netherlands, SA=Saudi Arabia, SP=Spain, TD=Trinidad, UK=United Kingdom,

For the port-level maritime freight, Figure 10 shows U.S. import freight flows at selected major U.S. ports in 2007. Houston was the largest port for U.S. imports in 1997, 2002, and 2007. Some ports played an important role both for imports and exports, for example Houston remained the Top 1 port for imports during 1997-2007. Similarly, the Port of South Louisiana occupied the first place for exports during 1997-2007. And some ports made different contributions to imports and exports; for example Long Beach and Los Angeles contributed more exports than imports during 1997-2007.

Table 2 shows the detail of U.S. port ranks of imports and exports during 1997 to 2007 with the index of U.S. ports. While some ports were consistently ranked in the top 10, others were ups and downs in the ranking. Also, within the top 10 ports were changing in the ranks. However, ports such as CA1-2, LA1-5, TX1-5, NY were among the top 10 ports during 1997-2007.

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Year	Label	Top1	Top2	Top3	Top4	Top5	Top6	Top7	Top8	Top9	Top10
1997	Import	TX1	TX2	NY	TX3	OT	PA	LA1	TX4	TX5	LA2
	Export	LA2	TX1	LA3	VA1	CA1	VA2	OR	CA2	AL	FL
2005	Import	TX1	NY	OT	TX4	TX2	CA1	LA2	TX3	CA2	LA5
	Export	LA2	TX1	CA1	VA1	WI	WA1	CA2	OR	LA3	NY
2007	Import	TX1	NY	OT	TX4	CA1	TX2	LA2	CA2	TX3	LA5
	Export	LA2	TX1	CA1	VA1	CA2	NY	LA3	LA4 WI OR		OR
Code	U.S. Port	Name		Code	U.S. Po	ort Name		Code	U.S. Port Name		
TX1	Houston S	hip Chann	el, TX	LA3	Port of	New Orles	ans, LA	OR	U.S. Port Name Port of Portland, OR		OR
TX2	Corpus Ch	nristi, TX		LA4	Port of	Plaquemin	nes, LA	AL	Mobile I	Harbor, A	1L
TX3	Texas City	y Channel,	TX	LA5	Calcasi	eu River, I	LA	FL	Tampa H	Harbor, F	L
TX4	Beaumont	, TX		CA1	Long B	each Harb	or, CA	WI	Duluth-Superior, MN/ W		MN/ WI
TX5	Port Arthu	ır, TX		CA2	Los An	geles Hart	oor, CA	NY	Port of New York		κ.
LA1	Port of Ba	ton Rouge	, LA	VA1	Elizabe	th River, V	VA	OT	LA Offs	LA Offshore Oil Port	
LA2	Port of So	uth Louisia	ana, LA	WA1	Tacoma	a Harbor, '	WA	PA	Philadel	phia Harl	oor, PA

Table 2: Top 10 U.S. Port for Imports/Exports (1997-2007)

Table 3 lists the top 10 foreign ports for imports and exports respectively in1997, 2002, and 2007. For imports from the U.S. at foreign ports, Ras Tanura, Saudi Arabia took the first place in 1997, but Cayo Arcos Terminal became the top port by replacing Ras Tanura in 2005. Tokyo, Japan had been the top port for exports for the past eleven years. Wei Hai, China made to the top 10 ports in 2002.

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Year	Im/Ex	Top1	Top2	Top3	Top4	Top5	Top6	Top7	Top8	Top9	Top10
	Import	51727	30771	20152	99930	20184	20154	30100	30753	30704	30763
1997	Export	58886	42157	58309	58840	42305	58023	06645	58029	58201	20199
	Import	20152	30700	99930	51727	30771	23645	20154	72105	14065	30140
2005	Export	58886	58309	06645	57000	58201	42157	58000	58023	20199	42305
	Import	20152	51727	30700	99900	99930	30771	72105	57035	14065	75300
2007	Export	58886	58309	42157	57000	06645	42305	72900	20199	58029	58201

#### Table 3: Top 10 Foreign Ports\* for Imports/Exports from 1997 to 2007

\*Ports are listed by port code and grouped by county with port code in () after each port.

<u>Venezuela</u>: All Other Venezuela Ports (30700), Bahia De Amuay (30704), La Salina (30753), Puerto Miranda (30763), Puerto La Cruz (30771); <u>Mexico</u>: Altata (20100), Cayo Arcos Terminal (20152), Dos Bocas (20154), Pajaritos (20184), Tuxpan (20197), Veracruz (20199); Bahamas: South Riding Point (23645); Trinidad: Point Fortin (27420); <u>Canada</u>: Nanticoke (06645), Algoma, Ont (08525), Point Tupper, CBI (14065), Whiffen Head, NF (15230); <u>Colombia</u>: All Other Colombian Caribbean Region Ports (30100), Covenas (30110), Santa Marta (30140); <u>Norway</u>: Mongstad (40373); <u>Netherlands</u>: Rotterdam(42157); <u>Belgium</u>: Antwerp (42305); <u>Iraq</u>: Al Bakir (50505), Al Basrah (50525); <u>Singapore</u>: Singapore (55976); <u>China</u>: Weihai (5700), Shanghai (57035); <u>South Korea</u>: Cheju (58000), Pusan (58023), Jinsen (58029); <u>Egypt</u>: All Other Egypt Mediterranean Region Ports (72900); <u>Hong Kong</u>: Hong Kong (58201); <u>Taiwan</u>: Kaohsiung (58309); <u>Japan</u>: Itozaki (58800), Kobe (58840), Tokyo (58886); <u>Nigeria</u>: Akassa (75300), Kwaibo Terminal (75389); <u>Saudi Arabia</u>: Al Juaymah (51723), Ras Tanura (51727); <u>Neth Antille</u>: St. Eustatius (27730); <u>Algeria</u>: Arzew (72105); <u>Unknown</u>: High Seas (99900), High Seas, Gulf of Mexico (99930)

LPMS	Commodity Description	1997	1999	2001	2003	2005	2007
10	Coal, Lignite & Coal Coke	10.2	11.6	19.9	25.0	31.2	37.5
21	Crude Petroleum	425.8	437.7	488.9	515.7	522.8	521.5
22	Gasoline, Jet Fuel, Kerosene	24.3	24.5	36.2	36.5	64.6	61.4
68	Other Agricultural Products; Food and Kindred Products	21.6	22.4	22.9	25.0	27.8	28.1
70	All Manufactured Equipment, Machinery and Products	32.8	42.4	47.7	58.5	73.6	74.3
99	Unknown or Not Elsewhere Classified	0.5	0.6	4.4	6.3	5.9	5.9
Total	All Commodities	779.5	851.8	951.8	1004.8	1096.9	1069.1

 Table 5: U.S. Imports by Commodity from 1997 to 2007(Million Tons)

 Table 6: U.S. Exports by Commodity from 1997 to 2007(Million Tons)

LPMS	Commodity Description	1997	1999	2001	2003	2005	2007
10	Coal, Lignite & Coal Coke	78.4	58.5	55.8	42.6	50.2	55.7
21	Crude Petroleum	3.6	5.7	1.3	1.2	0.5	0.1
22	Gasoline, Jet Fuel, Kerosene	7.1	5.1	8.0	7.4	10.2	13.1
68	Other Agricultural Products; Food and Kindred Products	15.2	13.8	15.9	15.5	16.1	18.2
70	All Manufactured Equipment, Machinery and Products	13.6	11.2	12.8	12.8	16.6	20.3
99	Unknown or Not Elsewhere Classified	0.4	0.7	3.7	3.3	2.7	3.7
Total	All Commodities	118.4	95.0	97.4	82.9	96.2	111.0

Table 5 and Table 6 list a portion of U.S. imports or exports by LPMS code commodity. Table 5 shows that LPMS 21 - Misc. Edible Preparations - was the biggest proportion in U.S. imports, and LPMS 45 - Cork & Articles of Cork - was the least one. Most imported commodities increased from 1997 to 2007, however, a few of them, such as LPMS 24-Tobacco&Manuf. Tobacco Substitutes, LPMS 44-Wood&Articles of Wood, Wood Charcoal, and LPMS 49-Printed Books, Newspapers, Pictures, Typescripts & Plans-decreased. Some commodity imports changed little in the past 11 years, i.e., LPMS 61-Articles of Apparel & Clothing Accessories.

Table 6 shows that LPMS 32- Tanning or Dyeing Extracts, Dyes, Pigments, Paints, Paints & Varnishes, Putty - had the largest share in U.S. exports, and LPMS 45-Cork & Articles or Cork had the smallest share. Like the imports, most commodities increased in exports from 1997 to 2007. However, a few of them, such as LPMS 21 – Misc. Edible Preparations, and LPMS 67- Prepared Feathers, Human Hair & Articles - decreased. Some commodities had little change in the past eleven years in exports, for example LPMS 29 – Organic Chemicals.

### 5. U.S. International Maritime Freight Flow Movement

The U.S. trade patterns can be spatially visualized by displaying import and export freight flows between U.S. ports and foreign ports. We assumed there was no capacity limitation for each route, and the shortest path was considered as the best route between any two ports. Under this assignment, all freight flows between two ports would be assigned to the shortest path connecting the pair.

Figure 11 – Figure 16 show assignment results for U.S. all commodity exports and imports in 2002, either in total commodity, or between specific country ports, or specific commodities. The selected maps provided snapshots of the port-to-port freight flows between the U.S. and foreign ports at the world, country, port, and commodity levels. Figure 11 and Figure 16 clearly show that Panama Canal is very important for shipments from many countries in North Africa, Middle East, Europe, and Asia.





Figure 11: World View of U.S. All Commodities Exports, 2002





Figure 13: All Commodity Exports from U.S. to China, 2002



Figure 14: All Commodity Imports to U.S. Ports from Shanghai Port, 2002



Figure 15: Least Import Commodity (LPMS45: Cork & Articles of Cork), 2002



Figure 16: Top Import Commodity (LPMS21: Articles of Stone, Cement, or Similar), 2002



Figure 17: Google Earth 3D Visualization of U.S.-China (A, B) and U.S.-World Trade (C), 2002

#### 6. Conclusions and Remarks

This paper conducted a concise review of maritime freight transportation databases, developed a data mining and integration framework, and performed some exploratory analyses and visualizations of the U.S. global maritime import and export freight. The research provided an alternative way to understand and highlight U.S. international trade patterns. The databases were identified and the data mining and integration model was developed and implemented for the target database with desired attributes. Important data integration issues, such as spatial scales, measurement units and their conversions, missing data and date mismatches were discussed. Selected U.S. international trade patterns at the world, regional, country, and port levels were summarized. Sample best maritime freight movement routes for all commodities and specific commodities were visually mapped. Sample freight movements for trade between the U.S. and China and the world were shown in Google Earth<sup>TM</sup> in 3D.

This research can be improved in many ways. First, the freight flows were analyzed yearly, but seasonal, monthly, or weekly trends shown or highlighted for a better understanding of U.S. maritime imports and exports dynamics. Second, the international freight flows are very complicated in the real world; some ports play more important roles in the trade than others, indicating a hierarchic system of ports over time. Third, the mapping of countries, ports, and the network is mostly 2-dimensional, while 3-dimensional and real-time visualization is definitely better in displaying and analyzing freight flows. Fourth, since the U.S. maritime import and export flows are shipped to and produced at demand and supply points within the U.S., the linkage of international maritime port-to-port flows to their demand and supply points through U.S. intermodal networks, i.e., highway, rail, and water, certainly warrants further research. Finally, it would be interesting to see simulations of this model for various special situations.

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## Economic Impact of Port Sectors on South African Economy: An Input-Output Analysis

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#### Abstract

The port sectors in a country play an important role in its economy. This paper presents an input-output analysis on how the port sectors impact a concerned economy using the South African case. Moreover, this paper reports how a rectangular Supply and Use Table system of national accounts can be converted to a traditional square symmetric matrix type system. A range of models, such as demand-driven, supply-driven and price models, were derived for the estimation. From these models, the production effect together with the forward and backward linkage effects, price change effects and employment effects were estimated to determine the impact of port sectors.

Keywords: South African economy, Port sectors, Input-output analysis

#### 1. Introduction

The port sectors in a country play an important role in its economy, which is particularly true when a country develops its port as a regional hub. For example, Singapore and Hong Kong have developed their ports as regional hubs in Asia, and the Netherlands has developed their ports as a regional hub in Europe. Similarly, Los Angeles and Long Beach function as regional hubs in North America. These ports make utmost efforts in continuously maintaining their ports as hubs and improving them to make them more attractive than competing ports due to their important roles in economic development. Most of these regional hub ports are located in the northern hemisphere. Ports in the southern hemisphere have not reached the status of becoming regional hubs due to relatively underdeveloped economic integration in that region. In recent years, some countries in the southern hemisphere have attempted to develop their ports as regional hubs. On the other hand, the idea of a hub port strategy cannot be justified when people are unsure if this project can bring enough economic benefits to the country. A more problematic case is that people do not understand how port sectors contribute to their economy in terms of the impact of port sectors on other industries, employment effects, price change effects etc. South Africa is the case of this kind when they considered developing a hub port shifting from a traditional a set of gateway port system. (Notteboom, 2011) The main container ports in South Africa are Durban, Cape Town and Port Elizabeth, whereas East London and Richards Bay handle small container volumes. The country plans to develop a hub port in a new site, called Ngqura, which is the home town of President Nelson Mandela. Despite this hub development strategy in South Africa, the government and people have wondered how important their port sectors are in their economy in terms of the impact on other industries, employment and price effects.

Surprisingly, despite that there are several studies in the area of port sectors' economic impact analysis available, the extant studies are too narrowly focused on the impact of the sectors (Moon, 1995), merely on employment effect of port sector in regional cases (Hughes, 1997; Musso et al., 2000; Acciaro, 2008), or are focused on broader maritime industries than port sectors (Kwak et al., 2005) or only the shipping sector (Van Der Linden, 2001). One study reported only a descriptive method without a detailed methodology so that

replication of the research elsewhere is infeasible. (Van Der Linden, 2001) This paper intends to contribute to the literature by presenting an input-output analysis on how the port sectors can affect a concerned economy using the South African case. Musso et al. (2000) proposed a technique to assess the employment impact of the Port of Genoa dealing with several types of ships. But this paper handles more comprehensive economic impacts of port sector in a nation. Moreover, this paper outlines how the rectangular Supply and Use Table system of national accounts can be converted to a traditional square symmetric matrix type system, using the national account data in South Africa. In 1993, South Africa changed their national account system to a Supply and Use Table system recommended by the United Nations (United Nations, 1993). Therefore, this converting approach is differentiated from the previous port impact studies.

The next section explains the methodology and data. Section 3 presents the results and Section 4 discusses the implications and concludes the paper.

#### 2. Methodology and Data

The main methodology of this paper is static input-output analysis. Acciaro (2008) lists up various methods used in assessing economic impact analysis of port sector and briefly explains the merits and drawbacks of each method. As he pointed out, it is true with input-output analysis that a certain level of subjective classification of disaggregating port sectors from general industry classification system is needed. However, compared with other methodologies in capturing various inter-linkage between sectors and also production-inducing effect, value-added effect, employment effect etc. the input-output analysis is more proper to be used for estimating economic impacts and contribution to the South African economy. In addition, using the Supply and Use table, the input-output analysis is the most proper one to capture these effects. The Input-Output (IO) model shows the relationship between the productive sectors of a given economy in a linear, inter-sectoral model. The relationship between the productive sectors and demand can be expressed as follows:

$$X_{i} = \sum_{j=1}^{N} X_{ij} + F_{i} = \sum_{j=1}^{N} a_{ij} X_{j} + F_{i}$$
(1)

$$X_{j} = \sum_{i=1}^{N} X_{ij} + V_{j} = \sum_{i=1}^{N} r_{ij} X_{i} + V_{j}$$
(2)

where  $X_i$  is the total gross output in sector i=1,..., N:  $a_{ij}$  are the direct input or technical coefficients that divide  $X_{ij}$ , the inter-industry purchases of producing sector *i* from supply sector *j* by  $X_j$ , which is the total gross output in sector *j*;  $r_{ij}$  are the direct output coefficients that divide  $X_{ij}$ , which are the inter-industry purchases of producing sector *i*, from the supply sector *j* by  $X_i$ , which is the total gross output in sector *i*; and  $F_i$  is the final demand for products in sector *i* and  $V_j$  is the final value-added by sector *j*. Therefore, Eq. 1 shows demand-driven model as viewing IO tables vertically, whereas Eq. 2 expresses the supply-driven model as viewing IO tables horizontally.

Eq. 1 can be rewritten in an abbreviated matrix form as  $X=(I-A)^{-1}F$  (Chiang, 1984). I denotes the *N x N* identity matrix and  $(I-A)^{-1}$  is called the Leontief inverse matrix. The standard demand-driven model of this matrix form, however, cannot assess the net effects of port sector activities precisely. Hence, the individual port sector needs to be handled as exogenous and placed into the final demand group (Han et al., 2004; Kwak et al., 2005). Therefore, port sector-based IO model or exogenized IO model for port sector can be expressed as  $X_e = (I-A_e)^{-1}(F_e+A_mX_m)$ , where subscript *e* refers to an exogenized matrix and *m* refers to the port sector. Assuming  $\Delta F_e = 0$ , results in

$$\Delta Xe = (\mathbf{I} - \mathbf{A}_{e})^{-1} \mathbf{A}_{M} \Delta X_{M}$$
(3)

Eq. 3 can be used to estimate the relationship of inter-industries impacted by a change in port investments, i.e. the production inducing effect.

Similarly, the exogenized Leontief's price model can be used for the port price change effect and the exogenized supply driven model can be used for the impact of limited capacity. The models can be explained

as follows:

$$\Delta \tilde{\mathbf{P}} = (\mathbf{I} - \mathbf{A}_{e})^{-1} \hat{\mathbf{A}}_{M} \Delta \hat{\mathbf{P}}_{M}$$
(4)

where,  $\Delta \tilde{\mathbf{P}}$  is the matrix of normalized price, and  $\hat{\mathbf{A}}_M$  is the port sector's matrix treated as exogenous.

The equation shows that the port sector can be treated as exogenous and placed into the primary input group. This is a rewritten form of the conventional Leontief price model without price changes in the value-added sector. If it is assumed that the cost change of each sector can be transferred completely and the annual production of each sector is given, one can assess the effects of a change in wholesale price on the economic system caused by a cost change in the port sector using the following equation: (Kwak et al., 2005)

$$\Delta \mathbf{X}_{e}^{'} = \mathbf{R}_{M} \Delta \mathbf{X}_{M} \left(\mathbf{I} - \mathbf{R}_{e}\right)^{-1}$$

(5)

where *R* is the output coefficient matrix and  $(I-R_e)^{-1}$  is the output inverse matrix of which elements  $ij=\partial X_j/\partial V_i$  represent the total direct and indirect requirements in sector *j* per unit of final value added in sector *i*. (Han et al., 2004; Kwak et al., 2005) The port sector is also treated as exogenous to disaggregate its impact on other industries. This equation can enable an estimation of the impacts of a unit shortage in the port sector on the output of all other sectors, and can be used as a basis to estimate the macroeconomic impact of the limited capacity.

Up to 1993, South Africa published traditional IO tables. Since 1993, the Supply and Use Tables (SUT) have been used according to the recommendations of UN 1993 System of National Accounts (SNA)(United Nations, 1993). The 2002 SUT was used in the present study, as these tables are the most updated and detailed data published by Stat SA during the timing of this research (Statistics South Africa, 2006). The SUT shows how products have been supplied and used by industry in the benchmark year. Unlike the squared characteristics of the former IO tables, the SUT shows different number of rows and columns in the respective Supply and Use Tables. The Supply table shows 153 products in the rows and 94 industries in the columns, whereas the Use Table shows 95 products in the rows and 94 industries in the columns in 2002. It is important to convert the SUT into square symmetric IO tables to analyze the macroeconomic impact arising from port industry's economic activities.

To carry out this task, it is vital to adjust the different number of rows or columns between the Supply and Use Tables. For example, as is often the case, when analyzing the inter-industry economic impact, it is important to convert the SUT into the symmetric industry IO tables. This process estimates how Supply products along the same number of industries have been used in the Use Table for these industries. This estimation can be undertaken either by collecting further detailed data in addition to SNA data or by mathematically calculating the conversion. Since Stat SA was in its early stages when publishing the SUT, it did not appear to possess sufficient levels of information and data enough to produce IO tables. Therefore, in the present study, the mathematical conversion was selected due to the lack of detailed data.

Basically, two methods can be used to combine the use and supply matrices mathematically to generate the traditional symmetric input-output matrix. These methods are based on either an industry technology assumption or a commodity technology assumption. The industry technology assumption assumes that the inputs are consumed in the same proportion by every product produced by a given industry. This assumption has been used in many countries based on the recommendations made by the 1968 SNA, mainly for two attractive reasons. First, the method always generates positive symmetric input-output tables. Second, it is also applicable to the case of rectangular input-output tables. In contrast, the commodity technology assumption assumes that the industry technology that produces a given product is the same regardless of where it is produced. Although this assumption appears economically more reasonable than the industry technology assumption, it is not used widely because it tends to generate negative symmetric input-output tables and requires the make and intermediate matrices of the Use Table to be squared (United Nations, 1999). In other words, the commodity technology assumption requires that the domestic production part of the supply table (herein refer to as matrix, M) should be invertible to calculate the input-output table. M is invertible only if M is square or the number of industries must equal the number of products. Since the Use Table in South Africa is rectangular and not squared due to the different number of rows and columns between the product

and industry numbers, respectively, the industry technology assumption was used to calculate the input-output tables from the SU tables.

The mathematical process adopted can be explained using the same notations from the United Nations (United Nations, 1999):

#### Notations

m: number of productsn: number of industries $U_{mxn}$ : intermediate matrix of the Use Table (product by industry) $B_{mxn}$ : use coefficient matrix (product by industry) $M_{mxn}$ : make matrix (product by industry), part of the supply matrix describing domestic production $D_{subnxm}$ : market share matrix (industry by product) $g_n$ : vector of industry output $q_m$ : vector of product output $\hat{g}$ : diagonal matrix of industry output

 $\hat{q}$ : diagonal matrix of product output

The matrix with a '^' is a diagonal version of the vector with the same notation; all off-diagonal elements are zeros. For example:

$$\hat{g}_{n} = \begin{pmatrix} g_{1} & 0 \\ \vdots \\ 0 & g_{n} \end{pmatrix}$$
(6)

As explained in the notations, the use coefficient matrix and the market share matrix are first defined:

$$\mathbf{B} = \mathbf{U} \cdot \overset{\wedge}{g_n}^{-1} \tag{7}$$
$$\mathbf{D} = \mathbf{M}' \cdot \overset{\wedge}{q}^{-1} \tag{8}$$

First, it is important to equalize the dimension of the rows (number of products: 153 in year 2002) in the Supply Table with the dimension of the rows (number of products: 95 in year 2002) in the Use Table. Once the same number of products or rows are made in both the Supply Table (henceforth, called the adjusted Supply Table, and denoted as M referring to the adjusted make matrix of the Supply Table) and Use Table, the matrix multiplication of Eq. 7 can be calculated by multiplying the U matrix with the industry output in the Use Table:

<b>S</b> <sub>(153×94)</sub> =	$\begin{vmatrix} S_{11} \\ S_{21} \\ \vdots \\ S_{1531} \end{vmatrix}$	$S_{12}$ $S_{22}$ $\Box$ $S_{1532}$	 : 	$s_{194}$ $s_{294}$ $\vdots$ . $s_{15394}$
$U_{(95\times94)} =$	$\begin{bmatrix} u_{11} \\ u_{21} \\ \vdots \end{bmatrix}$	$u_{12}$ $u_{22}$	  :	$u_{194}$ $u_{294}$ $\vdots$ .
$M_{(95\times94)} =$	$\begin{bmatrix} u_{951} \\ \vdots \end{bmatrix}$	<i>u</i> <sub>95 2</sub> □	$\overline{m_{19}}$	$u_{9594}$
$(93\times94)$	$\begin{bmatrix} m_{951} \\ m_{11} \\ \vdots \\ m_{941} \end{bmatrix}$	  	$m_{95}$ $m_{195}$ $\vdots$ . $m_{9495}$	) ) ) ]

Eq. 12 shows the transposed matrix of M to allow the multiplication of the Use Table and Supply Table and produce a product-by-product input-output table. The product-by-product input-output table can be calculated using Eqs. 7-8, Eq. 10 and Eq. 12 as follows:

$$\mathbf{A}_{(95\times95)} = \mathbf{B}_{(95\times94)} \bullet \mathbf{D}_{(94\times95)} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{195} \\ a_{21} & a_{22} & \cdots & a_{295} \\ \vdots & \vdots & \ddots & \vdots \\ a_{951} & a_{952} & \cdots & a_{9595} \end{bmatrix}$$
(13)

When completing the product-by-product IO table, the final demand can be calculated using the following equation.

$$\mathbf{YC} = (\mathbf{I} - \mathbf{BD}) \cdot \mathbf{q} \tag{14}$$

where, YC is final demand of products

Matrix S is the rows and columns in the Supply Table. As can be seen in the dimensions of the matrix, the number of products in the rows in 2002 was 153 and the number of industries in the columns was 94. Similarly, the number of products in the Use Table was 95 and the number of the industries in matrix *U* was 94. To make possible the conversion of the SUT into a symmetric IO table, which was target in the present study, the number of rows in the Supply Table (153) was first equalized with the number of rows in the Use Table (95) by reducing the number in the Supply Table to the same number in the Use Table. This is shown in matrix M. Once the same number of rows in the new M matrix is equalized with the number of rows in the Use Table, the matrix multiplication can be used to derive the symmetric IO table. First, the M matrix is transposed before multiplying it with the Use Table matrix, U, as shown in Eq. 12. This transposed matrix, M', is now composed of industry rows and product columns. B (the use coefficient matrix) is multiplied by D (the market share matrix) to calculate the intermediate product-by-product matrix, A, as shown in Eq. 13. This intermediate product-by-product matrix, A, is the most fundamental one to make calculations for a macroeconomic impact. Once the A matrix is calculated, the next process can be performed through an exogenous treatment of the port sector and follow the price model and supply-driven model explained in Eqs. 4-5.

After exogenizing the port sector, the general procedures of calculating the technology matrix,  $(I-A_e)$  and its inverse matrix,  $(1-A_e)^{-1}$  can then be performed (Chiang, 1984). By multiplying the inverse matrix,  $(1-A_e)^{-1}$  with the exogenized port sector matrix,  $A_m$ , the employment effect, income effects, linkage effects, production inducing effects etc. can be estimated once the respective data can be collected across the product rows in employment, income, production etc of the SUT. The employment effect, for example, can be denoted in the following notation:

(15)

$$\mathbf{L} = \hat{\mathbf{l}}(\mathbf{I} - \mathbf{A}_{e})^{-1}\mathbf{X}_{m} + \mathbf{l} \cdot \mathbf{X}_{m}$$

where,

L : employment effect induced by the port sector's activities;

 $\hat{\mathbf{l}}$  : diagonal matrix of product groupwise employment coefficient;

 $(I - A_{e})^{-1}$ : inversed technology matrix after exogenizing the port sector

X<sub>m</sub>: exogenized port sector vector

#### 3. Results

To derive the adjusted make matrix, M, the original Supply product classification was regrouped based on a similar classification to the Use Table. Eqs. 7-8, Eq. 12 and Eq. 13 were used to calculate the symmetric Product-by-Product IO matrix. From this matrix, the inter-industry linkage effect, such as the forward linkage and backward linkage effects, could be derived and estimated, and demand and supply driven model could be derived to estimate the production-inducing effects and supply shortage effects, respectively. Finally the Leontief price model could be used to estimate the impact of a change in the port sector's price on the other products and employment-inducing effects etc.

The conversion from SUT to symmetric IO tables is the first critical task to estimate the macroeconomic impact. Before placing a mathematical application into the STAT SA's SUT, an attempt was made to validate if the mathematical calculation process was correct using the Irish SUT and their converted IO tables (Government of Ireland, 2004). The calculation process was found to be correct. Once the SUT is converted into symmetric Input-Output tables, the next important task in estimating the macroeconomic impact is to disaggregate the port sector's economic activities from the general Standard Industrial Classification (SIC) product groups because the port sector's activities are scattered in various sectors of the product groups due to the SIC's broad classification system. This is a general problem faced by economists estimating the macroeconomic impact of a specific industry. To disaggregate the port sector, this study examined how the SIC is classified further into smaller group products by STAT SA and came to the conclusion that the port sector is dispersed into five major product groups, such as Other transport (I77), Buildings (I83), Other construction (I84), Trade (I85) and Transport Services (I87). Of these, how each group consists of its respective subgroup products and how much the economic activities were incurred was traced by examining further details of the other statistics data published by STAT SA and other relevant government agencies. As there are a range of sources available over these times, it was assumed that the proportion of port sector's activity in each SIC group would have been stable. The proportion was estimated after breaking down these SIC group products and calculating the proportion of the port sector in each SIC group. Based on the disaggregation process, the coefficient matrix, A<sub>e</sub>, was calculated after exogenizing the port sector.

The production-inducing effect was calculated and the result is presented in Tables 1 and 2. For example, if the port sector is produced by a single unit, the insurance sector would have 10% of impact by the production in port sector. Table 2 lists top 10 production-inducing effect groups based on the 2002 IO table. Insurance services, petroleum products, other business services, and communication are in descending order the most production-inducing groups. The insurance sector would have 10% impact by a one unit product (i.e. one million Rand) in the port sector. Table 2 also shows the direct, indirect and induced production-inducing effect by the port sector in 2002 was estimated to be 4.027 billion Rand and the indirect effect was 3.854 billion Rand, giving an induced effect (direct + indirect) of 7.88 billion Rand. The multiplier effect was estimated to be 1.95717. This means that if the port sector spends one unit of money, e.g. one million Rand, this expenditure would induce a 1.95717 unit, i.e. 1,957,170 Rand production for the entire SA economy.

Table 3 lists the backward and forward linkage effects by product group. The overall forward linkage effect of the port sector is 0.97 and the backward one is 0.48 indicating that the port sector does not appear to use other sectors much in producing its activities due to the low backward linkage effect, whereas the port sector is used relatively more by other industries owing to its relatively high forward linkage effect. The top 10 forward linkage effect product groups are as follows: Other business services; Transport services; Iron and steel products; Other mining products; Insurance services etc. The top 10 backward linkage effect groups are: Trade services; Handbags; Containers of paper; Buildings; Rubber tyres; etc.

The supply-driven model can be used to estimate how a supply restriction, e.g. not developing the port sector affects the other industries' activities. This is again to exogenize the port sector, as was the case with the demand-driven model, and evaluate the impact of a shortage in the port sector on the output of all other sectors. This model can be used as a basis to define the shortage or failure costs of port production. As in the supply-driven model equation, a shortage in the port sector can be estimated using 2002 data. The result is listed in Table 4. The table shows how a unit shortage in the port sector can impact other product groups from the coefficient figure. In addition, the table shows the direct and indirect impact amount for the shortage of the port sector by product group. If there were no port sector activities, it would have resulted in a 1.481 billion Rand direct loss to the entire economy and 1.734 billion Rand indirect loss, totalling 3.215 billion Rand. Again, the overall impact effect per unit shortage of port sector on all other products is 1.1705. Therefore, one unit shortage in the port sector would have incurred 17 % of loss to the entire economy in 2002. Without port producing activities in 2002 (4.3 billion Rand), the entire economy of SA would have suffered 3.22 billion Rand.

				Iau	ME I: LIOUUC	nniit-lion					
Code No.	Product	Coefficien t	Cod e No.	Product	Coefficien t	Code No.	Product	Coefficien t	Cod e No.	Product	Coefficien t
P1	Agricultural products	0.00628	P25	Footwear	16000.0	6†d	Iron and steel products	0.02552	P73	Radio and television products	0.00803
P2	Coal and lignite products	0.01296	P26	Wood products	0.0075	P50	Non-ferrous metals	0.00982	P74	Optical instruments	0.00369
P3	Gold and uranium ore products	0	P27	Paper products	0.00984	ISI	Structural metal products	0.0096	P75	Motor vehicles	0.00518
P4	Other mining products	0.03720	P28	Containers of paper	0.0078	P52	Treated metal products	0.00278	P76	Motor vehicles parts	0.03836
P5	Meat products	0.00095	P29	Other paper products	0.00365	P53	General hardware products	0.00105	P77	Other transport products	0.02982
P6	Fish products	0.00009	P30	Published and printed products	0.01009	P54	Other fabricated metal products	0.00787	P78	Furniture	0.00295
P7	Fruit and vegetables products	0.00009	P31	Recorded media products	0.00044	P55	Engines	0.00161	P79	Jewellery	0.00001
P8	Oils and fats products	0.00047	P32	Petroleum products	0.08437	P56	Pumps	0.00115	P80	Other manufacturing	0.02385
P9	Dairy products	0.00055	P33	Basic chemical products	0.01084	P57	Gears	0.00244	P81	Electricity	0.01713
P10	Grain mill products	0.00036	P34	Fertilizers	0.00163	P58	Lifting equipment	0.00248	P82	Water	0.00293
P11	Animal feeds	0.00085	P35	Primary plastic products	0.01085	P59	General machinery	0.00152	P83	Buildings	0.01813
P12	Bakery	0.00008	P36	Pesticides	0.00064	P60	Agricultural	0.00022	P84	Other	0.01628

Table 1: Production-inducing Effect

	0.02977	0.00816	0.04248	0.06010	0.01096	0.10029	0.03865	0.07764	0.00152	0.00219	0.02526	0.95717
constructions	Trade services	Accommodati on	Transport services	Communicati ons	FSIM	Insurance services	Real estate services	Other business services	General Government services	Health and social work	Other services / activities	Total
	P85	P86	<b>F87</b>	P88	68d	06d	P91	P92	P93	P94	<b>P95</b>	
	0.00057	0.00427	0.00033	0.00331	0.00016	0.00027	0.00330	0.00418	0.00424	0.00258	0.00152	0.00405
machinery	Machine-tools	Mining machinery	Food machinery	Other special machinery	Household appliances	Office machinery	Electric motors	Electricity apparatus	Insulated wire and cable	Accumulators	Lighting equipment	Other electrical products
	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72
	0.00842	0.0017	0.00461	0.00634	0.01241	0.00159	0.01159	0.00139	0.00154	0.00515	0.00654	0.01253
	Paints	Pharmaceutica 1 products	Soap products	Other chemical products	Rubber tires	Other rubber products	Plastic products	Glass products	Ceramic ware	Ceramic products	Cement	Other non- metallic products
	P37	<b>8£</b> d	6£d	P40	P41	P42	P43	P44	P45	P46	P47	P48
	0.00029	0.00003	0.00056	0.00120	0.00279	0.00401	0.00026	0.00033	0.00031	0.00635	0.00055	0.00002
products	Sugar products	Confectiona ry products	Other food products	Beverages and tobacco products	Textile products	Made-up textile products	Carpets	Other textile products	Knitting mill products	Wearing apparel	Leather products	Handbags
	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24

			Produc	tion-inducing	effects by po	rt sector
Rank	Code No.	Products	Production- inducing coefficient	Indirect Impact	Direct Impact	Total (Direct+Indirect)
1	P90	Insurance services	0.10029	403.8	215.6	619.4
2	P32	Petroleum products	0.08437	339.7	260	599.7
3	P92	Other business services	0.07764	312.6	157.5	470.1
4	P88	Communications	0.06010	242	78.5	320.5
5	P87	Transport services	0.04248	171.1	38.5	209.6
6	P91	Real estate services	0.03865	155.6	45.1	200.7
7	P76	Motor vehicles parts	0.03836	154.4	113	267.4
8	P4	Other mining products	0.03720	149.8	17.3	167.1
9	P77	Other transport products	0.02982	120.1	97.2	217.3
10	P85	Trade services	0.02977	119.9	65.2	185.1
			:			
		Total	0.95170	3,854	4,026	7,880

# Table 2: Top 10 production-inducing Effects

(Unit: million Rand)

Table 3: Top 10 Forward Linkage Effect and Backward Linkage Effect

Rank	Code No.	Products	Forward Linkage Effects	Rank	Code No.	Products	Backward Linkage Effects			
1	P92	Other business services	3.71830	1	P85	Trade services	4.22291			
2	P87	Transport services	3.02732	2	P24	Handbags	2.26039			
3	P49	Iron and steel products	3.00927	3	P28	Containers of paper	1.55900			
4	P4	Other mining products	2.98499	4	P83	Buildings	1.39622			
5	P90	Insurance services	2.74251	5	P41	Rubber tyres	1.32985			
6	P1	Agricultural products	2.49316	6	P51	Structural metal products	1.30243			
7	P88	Communications	2.49025	7	P40	Other chemical products	1.29466			
8	P91	Real estate services	2.26539	8	P11	Animal feeds	1.24911			
9	P32	Petroleum products	2.10116	9	P49	Iron and steel products	1.20461			
10 P35		Primary plastic products	2.07158	10	P52	Treated metal products	1.19397			
	Tota	l (95 sectors)	0.97003		Total (95 sectors)					

					(Onu	. munon Rana)
	Cada		Supply	Direct	Indirect	Total
Rank	Coue N.	Product	shortage	Impact	impact	Economy-
	INO.		Coefficient	amount	amount	wide Impact
1	P85	Trade services	0.1310	177.98	194.03	372.02
2	P4	Other mining products	0.1160	283.84	171.87	455.71
3	P49	Iron and steel products	0.0700	81.76	103.65	185.4
4	P83	Buildings	0.0603	84.73	89.34	174.07
5	P92	Other business services	0.0599	79.5	88.67	168.16
6	P87	Transport services	0.0557	45.76	82.58	128.34
7	P88	Communications	0.0520	61.87	76.98	138.85
8	P2	Coal and lignite products	0.0493	117.66	73.04	190.7
9	P32	Petroleum products	0.0487	51.97	72.21	124.18
10	P93	General Government services	0.0457	64.21	67.63	131.84
			:			
			:			
	To	otal group (95 groups)	1.1705	1,481	1,734	3,215

### Table 4: Top 10 Supply Shortage Effects

(Ilmit , million Dand)

Finally, the employment effect induced by port investment was calculated. The results are listed in Table 5. First, this study calculated how many people are employed per unit amount (million Rand) of each product group's economic activity. The employment coefficient could be identified in a similar manner as the 58 product groups based mainly on two sources published by Statistics South Africa (Statistics South Africa, 2003; Statistics South Africa, 2008). Combining these sources, 58 product groups were identified as the most detailed employment coefficient. Based on these 58 product group coefficients, it was important to recalculate the symmetric IO matrix from the original 95 groups to 58 groups to be consistent with the labor product groups that had been identified. From the employee coefficient per unit supply by product group, the productby-product employment-inducing effect  $(\hat{l} \times (I-A)^{-1})$  was calculated, where  $\hat{l}$  refers to the diagonal matrix with the diagonal elements being the 58 product groupwise employment coefficient. Following this process, the employment-inducing effect per port supply of million Rand was calculated, as listed in Table 5. The table shows the direct and indirect employment effect by the 58 product groups both in terms of the absolute number of people per group and per million Rand of port supply in 2002. From the table, it can be seen that 14,209 people were employed directly by the port sector in 2002 and 36,418 people were employed indirectly, making the total of 50,627 people employed by the port sector. The per million rand employment effect was 12.57 in 2002 including the direct and indirect effects.

#### **Table 5: Employment-inducing Effects**

Product	Direct Employee	Indirect Employee	Direct + indirect Employee	Direct + indirect Employee per million Rand
Agriculture, hunting, forestry and fishing	35	1,070	1,104	0.27
Mining and quarrying	169	2,529	2,697	0.40
Manufacturing	2,076	6,928	9,005	2.24
Electricity, gas and water supply	151	395	546	0.14
Construction	1,208	2,356	3,564	0.89
Wholesale-, retail- and motor trade, hotels and restaurants	6,637	11,798	18,435	4.58
Transport, storage and communication	573	2,767	3,340	0.83
Finance, real estate and business services	3,233	9,069	12,302	3.06
Community, social and personal services	163	576	739	0.18
:	1			
Total product groups	14,209	36,418	50,627	12.57

#### 4. Implications and Conclusions

This paper attempted to estimate the macroeconomic impact arising from the port sector using an Input-Output Analysis model. After converting the SUT tables to symmetric IO tables, the port sector was exogenized to estimate the port sector's contribution to the macro-economy of SA. Various types of models, such as demand-driven model, supply-driven model and price model, were used to address a range of issues. From the findings of the models, the following implications can be drawn to assist the policy-formulation in a future port investment for the South African economy.

The overall forward linkage effect of the port sector was 0.97 and the backward one was 0.48, indicating that the port sector does not appear to use other sectors much in producing its activities due to the low backward linkage effect, whereas the port sector is used relatively more by other industries owing to its relatively high forward linkage effect. The overall impact effect of the port sector per unit shortage on all other products was found to be 1.1705. Therefore, one unit shortage in the port sector would have incurred a 17% loss to the entire economy in 2002. Leontief's price model was used for the scenario that what would occur if the price of port sector's cost was increased by various ranges from 5, 10 and 30 to 50 and 100%, respectively. The top ten impacted product groups by the cost change are: Transport services; Other constructions; Trade services; Coal and lignite products; and Sugar; Cement; Other mining products; Buildings; Iron and steel products; Other non-metalic products. In the case of a 5% change in cost, their impacts on the top five product groups would be 38%, 33.1%, 25.5%, 8.1%, and 6.5%, respectively. These estimation results may draw the following implications. First of all, as South Africa plans to develop a new container hub port (the port of Nggura) and logistics distribution centre, policy makers need to develop a short sea shipping network to provide feeder service for East and West Africa and ocean-going routes with Asian and European regions. Current container ports in South Africa do not function as the regional hub, therefore, there seems rather low level of backward and forward linkage effect. To enhance more interaction effect between sectors and also between regions once the hub is developed, the short sea shipping network between the hub and feeder ports is likely to play an important role for the higher linkage effect. Furthermore, to secure integrated inland transportation network and lessen the cargo-handling burden on the seaboard of the country, dry ports in inland areas can be explored. In addition, strategic option of relaying services between South Africa and South America can provide more opportunities to increase international trade between the southern hemisphere continents. Finally, the employment effect induced by port investment was calculated. The results showed that 14,209 and 36,418 people were employed directly and indirectly, respectively, by the port sector in 2002, making a total of 50,627 people employed in the port sector. The per million Rand employment effect was 12.57 in 2002 including the direct and indirect effects. As Acciaro (2008) found that the employment effect generated by the port sector is higher in regional economy than the total national one, a dedicated container port, Nggura in South Africa can contribute more to enhancing the employment effect in the regional level.

Some caveats should be taken when interpreting the results of IO analysis. One of the limitations was to purely distil the port sector's economic activities, which are scattered in a variety of industries and product groups due to the broad level of the Standard Industry Classification System of STAT SA. Despite the research team's endeavours to identify the port sector's economic activities, there are some uncertainties regarding the extent of disaggregating the port sector from the current 95 product groups. The 2002 SUT is the most detailed data source of collecting the National Accounts, amounting to 153 products and 94 industries for the Supply Table and 95 products and 94 industries in the Use Table. Nevertheless, even these details of the classification are not yet sufficient for economists to separate the port sector's data in more details in the future. Another limitation was the inconsistency of the statistical data in general between the different sources. This is particularly true with the labor survey data from different sources. Similar to the IO table data, employment survey data in the port sector should be collected separately as an independent study in the future because the general transport industry's survey data do not show the necessary level of details for the port sector. All these limitations remain an avenue for future research.

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## Nicaragua Canal: A New Corridor to Far East Asia

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#### Abstract

Connections between the Atlantic and Pacific Oceans are important for the international trade. Since 1914, the Panama Canal has provided ships a direct corridor to cross the Atlantic and Pacific Oceans. The geographical advantage of the Panama Canal enables it to enjoy an exclusive position in the international seaborne trade. The vessel tonnage passing through the Panama Canal represents approximately 5% of the world trade and the passage demand grows continuously. However, the Panama Canal's monopoly over interoceanic corridor may soon come to an end. In 2012, a memorandum of understanding was signed to construct the Nicaragua Canal which is close to the Panama Canal. It is expected that the canal should be operational by 2020. The proposed Nicaragua Canal as inter-oceanic corridor not only provides an alternative route for vessels to pass between the Atlantic and Pacific Oceans, but also triggers dynamic changes of seaborne trade pattern. To assess the long-term benefits of the proposed Canal, the scenario planning method will be used in this study to provide a framework for sketching several future scenarios in 2030, 10 years after the proposed Canal is built. The scenario planning enables us to explore novel insights about the future which demonstrate the causal relationships between factors. In this scenario planning, three forces, namely politics, economics and environment, will be taken into consideration. A pair of forces will be combined to generate a dominant scenario in order to foresee the roles of the Nicaragua Canal in the future international trade. The analysis of this study will benefit policy makers and other stakeholders to incorporate alternative mindsets into future strategy formulation and development.

Keywords: Nicaragua Canal; Panama Canal; Scenario planning

#### 1. Introduction

On 8 October 2012, the Nicaraguan Government signed a memorandum of understanding for the construction of a new canal which is known as the Nicaragua Canal. The new canal will be an inter-oceanic waterway to connect the Caribbean and Pacific coasts of Nicaragua (Figure 1). It is expected that the canal should be operational by 2020. In this paper, we study what the proposed Nicaragua Canal will contribute to Far East Asia in 2030, 10 years after the proposed Canal is built. Shipping is a derived demand, and the shipping pattern is affected by many factors. The emergence of a new canal will provide an alternative option to ship navigation. The roles of the new canal depend on many factors as well as competing waterways. Moreover, a new canal will stimulate trade and shipping development. Therefore, we attempt to foresee the shipping pattern by using scenario planning under the uncertain situations of the future, especially in Far East Asia.

In this study, we attempt to develop possible dominant scenarios driven by forces, demonstrate possible interactions of the Nicaragua and Panama Canals (Figure 1), and predict the roles of the Nicaragua Canal. Shipping patterns are a result of route choices of ships. Route choices are determined by many factors, e.g. distance, cost, resources supply and demand, carriers' preference and route constants. This study will focus on analysing how the global factors (politics, environmental and economic) affect the role of new canal, in the presence of a competing canal, and how the two canals jointly affect the trade pattern. As the result, the policy makers and other stakeholders will benefit by incorporating alternative mindsets into future strategy formulation and development.

In Section 2, we review the literature related to canal and scenario planning. In Section 3, we develop scenarios for foreseeing the global development caused by forces. In Section 4, three scenarios will be formed by interacting between each pair of the 3 forces. Moreover, the possible roles of the new corridor will be generated. By demonstrating how the neighbouring canal, i.e. Panama Canal, will be affected by the new canal, the roles of the new canal will also be discussed in Section 4. Afterthat, the implications and corresponding strategies and the direction of future research will be incorporated in the conclusion.

### 2. Literature Review

In existing literature, there are many studies to compare competing canals or trade routes. Canals and trade routes maintain their competitive advantages by providing a shortcut to countries e.g. the Panama Canal, the Suez Canal, or deep channel for resources' accessibility, e.g. the Cape of Good Hope. In the 1970s and 1980s, few studies analysed the competitiveness and complementary nature of canals or trade routes. After the Suez Canal had been closed, Gradus (1977) investigated whether the Negev desert could be an alternative to the Suez Canal. The study compared cargo traffic in the period from the closure to re-opening of the Suez Canal. Gradus (1977) analysed the reasons for failure of this continental bridge.

New routes may be possible as ice melting is being caused by global warming. After the arctic route become more navigable, the distance between the Far Asia and Europe, and Asia and North America will be shortened. Previous studies illustrated cost advantages of new routes by comparing against existing the predominant routes of the Panama Canal or Suez Canal. Somanathan et al. (2009) simulated the shipping route between Asia and the East coast of North America via the Northwest Passage in northern Canada and the Panama Canal, respectively, in order to calculate the required freight rate. They concluded that the viable economic benefit may be achieved when arctic ice is further thinned in the possible future. Liu and Kronbak (2010) investigated the economic potential of the Northern Sea Routes (NSR) to be an alternative of liners to passage between Asia and Europe. The study was done from a users' prospective by conducting a case study, and a 4,000-TEU-containership was assumed. By adjusting main factors, e.g. bunker prices, the NSR navigable time and the ice-breaking fee, the economic feasibility of NSR in different scenarios were tested. It concluded that NSR is not competitive to the Suez Canal. Schøyen and Bråthen (2011) explored if there are potential benefits of energy saving from the shorter distance of Northern Sea Routes attracting the tramp shipping from the present predominant shipping routes of Suez Canal. It is found that the NSR may be profitable for minor bulk trades during the summer time. Many recent studies used a mathematical approach to estimate cost savings in order to determine the competitiveness of new arctic routes. The findings depend very much on the preset hypothesis and assumptions. In a different way from previous studies, we use the scenario planning to formulate the future strategies that enable the Nicaragua Canal to be an important asset of maritime transport.

Scenario planning is widely used to evaluate long term corporate strategies, and the most classic example is done by Shell Oil (Zentner, 1982). The recognition of future uncertainty and adaptive management allowed Shell Oil to outperform and move from being one of the smallest to being the second largest multinational oil companies (Wack, 1985). Moyer (1996) demonstrated the application of scenario planning with a case study of British Airways. The scenario planning study enabled British Airways to broaden the views on how the world would be changed in order to decide the corresponding corporate strategy to strive against the uncertain future. Moreover, scenario planning is applicable for forecasting the future in different scopes, and varies from being related to managing risk under dynamic changes for a new products (Ahn and Skudlark, 2002), industries (Stokke, et al., 1990), regional transport planning (Zegras, Sussman, and Conklin, 2004a), and national policy (Kahane, 1992).

Millett (1988) addressed how organisations are using scenario planning for strategic thinking and management. His paper illustrated the advantages of using scenario planning which offers alternative views of the future. This approach is the best to use for long term planning with complex situations especially when there is little or a lack of data is available for quantitative models. The business environment can be forecasted in order to evaluate and decide the corresponding strategies. Millett (1988) summarised the insights gained from scenario planning and concluded the study by citing the corporate examples that use scenario planning for strategic thinking. The 5th insight illustrates that the scenarios enable planners to deal with competition by considering rival companies with similar products and services and emerging threats in substitute products

and services into the scenario planning. Godet and Roubelat (1996) argued that the future cannot be simply built based on the continuation of the past. They cited the study of Gaston Berger (1964) that prospective attitude of forecast shall be (1) long term, (2) interactive, (3) risking taking (far horizons enable changing), (4) in depth (identify important factors and trend), and (5) interested in human consequences. The result of forecast should be simple enough to communicate between users and customers. Scenario planning can fit these criteria that stimulate imagination and build the offering visions of the normative future. The straightforward scenarios can be used as backgrounds behind strategic alternatives for solving "what-if" questions. Varum and Melo (2010) reviewed the literature that uses the scenario planning approach. They discussed the contributions of scenario planning which is a future analytical method and enables the planners to maintain the competitiveness of organisations by recognising uncertainty and applying adaptive management. While scenario planning creates a description of the future, it does not provide an accurate future.

The proposed Nicaragua Canal as inter-oceanic corridor will not only provide an alternative route for vessels to pass between the Atlantic and Pacific Oceans but also trigger dynamic changes of seaborne trade patterns. The future is highly uncertain, especially when little mathematical data is available for forecasting the accurate situation. Instead of mathematical forecasts, we would like to assess the long-term benefits of the proposed Nicaragua Canal by using the scenario planning method to provide a framework to sketch a few future scenarios. This study will enable us to explore novel insights about the future which demonstrates the causal relationships between factors. The micro and market changes of seaborne trade patterns will be analysed. These analyses will provide guidance for the future mathematical forecasts.

#### 3. Scenario Development

In the literature, there are different approaches to develop scenarios. Ahn and Skudlark (2002) showed the steps for incorporating scenario planning in a new service development process: (1) generating issue, (2) developing scenario, (3) generating strategies, (4) analysing scenario corresponding strategies. To develop scenarios, a scenario delta chart is used. Key uncertainties and key nodes are listed. Distinct scenarios are explored based on effects of the trigger event on uncertain environment and nodes. Zegras (2004) summarised that there are different approaches to build scenarios, two are most commonly used: (1) inductive (bottom-up) - builds based on data available that allows the structure to emerge by itself; and (2) deductive (top-down) - starts with building overview framework and fits data into it. The study used a deductive approach. It first defines scope and identifies strategic options, and then outlines key local factors and driving forces. When combining driving forces, each force has two potential states, i.e. good/ bad binary possibilities. 16 combinations have been generated in a matrix, and the three most representative scenarios are selected. After that, scenario implications and strategic options were analysed. Shell International Limited (2005) constructed a Trilemma Triangle to provide an overview on global trends, emerging challenges and corporate strategies. It first identifies a trigger issue and three driving forces. Instead of generating scenarios at each corner of the triangle, i.e. from one dominant force, the plausible scenarios are developed based on the interaction between two forces and the trade-off of the third force.

Following Shell (2005), our procedure of scenario planning is summarised as follows:

- 1. Decide the key questions What is the role of the Nicaragua Canal?
- 2. Time of analysis -10 years.
- 3. Identify key driving forces
- 4. Determine the dominant (extreme) scenarios
- 5. Assess the scenarios and associated implications.

In the absence of data, a critical step is to identify the key driving forces. We are making reference to previous related studies. Zentner (1982) classified methods for development scenarios into two methods: (1) "hard" method - mathematics models and computers; and (2) "soft" method - *intuitive and descriptive*. The most sophisticated "soft" technology is *cross-impact analysis* which "*identifies reinforcing and inhibiting events and trends, to recover relationships and to indicate the importance of specific events: application of multiple scenarios to corporate strategic planning*". Godet and Roubelat (1996) categorised scenario planning into *two major types: (1) exploratory type - explore the likely future based on past and present* 

trends; and (2) anticipatory or normative type - built different scenarios based on different versions, e.g. desired or feared. There are multiple methods to construct scenarios, a widely held consensus method includes numerous specific steps: systems analysis, retrospective, actors' strategies, and elaboration of scenarios. Stokke et al. (1990) did the scenario planning for the Norwegian Oil and Gas industry. They first established a "conceptual model" of the external environment which are: (1) micro forces - market and industry forces that determine future trends, e.g. product demand, price, market structure; (2) macro drivers - global and national economic, political, technological and social factors. By using an "Impact/ Uncertainty Matrix" and scoring scheme, three alternative outcomes (energy market structure, national economy and technology) are summarised. Four descriptive scenarios are constructed and corresponding strategies are generated.

Due to data limitation, an intuitive and descriptive approach is used for this study. Alternative scenarios will be built based on a cross-impact analysis that reinforces events and trends, to recover relationships by an anticipatory or normative method. Instead of using the approaches of two dimensional matrix or good/ bad binary possibilities, a Trilemma Triangle is constructed. Therefore, three distinctive scenarios are directly developed. Scenario planning is built based on the recognition of future uncertainty and adaptive management. In addition, driving forces are the areas having potential far-reaching changes to the environment responding to specific situations. Trends of economy, social, international, policy, and technology are forces commonly used in Shell's cases (Rene, 1982). Geopolitics, international economics and natural environment are driving forces (Kahane, 1992). Moyer (1996) applied technology, education, world trade and world finance as driving forces for the case study of British Airways. Zegras (2004) used economy, finance, technology and environment for building scenarios for Houston regional transportation planning. As we attempt to foresee the roles of the Nicaragua Canal in the future international trade, as suggested by previous studies, politics, economics, and environmental forces are selected as the three most significant factors affecting global trade pattern. We will discuss the three forces in the following sections.

#### 3.1. First Force – Politics

The emergence of a new canal may create a new situation of seaborne trade. Marine traffic between countries implies political reasons. When the Suez Canal was blocked by the Egyptians from 1967 to 1975, the State of Israel built the Negev, a continental bridge, as an alternative to move freight between the Red Sea and the Mediterranean Sea. Gradus (1977) concluded that political force was one of major reasons for the failure to use the Negev. He showed that political force may deter some countries' preference on route choice. The security of global maritime trade is critical; and the threat to maritime trade route makes countries vulnerable to the threat on scarce natural resources (Nincic, 2002). Rodridue (2004) concluded that the fallout would be political and economic chaos, and a vulnerable and petroleum-dependent global economy could come to an end. In other words, canals and straits may be considered as national chokepoints to secure the supply of scarce resources, e.g. energy and food. They are critical to global economies. As China became a net importer of crude oil, Collins and Murray (2008) mentioned that the United States, India, and Japan are seen as potential blockaders of China. They examined the Chinese potential responses to energy blockade. Energy and scarce materials are mostly dependent on maritime transport, and canals and straits are considered as chokepoints. It is definitely a threat to a country when the energy insecurity is caused by a maritime blockade through canal or straits closures. Political force will alter the role of a canal.

#### *3.2. Second Force – Economics*

Trade pattern is interactive with economic development. Huebner (1915) mentioned there are two main functions of the Panama Canal. The first one is its political value as it enables the United States to transfer naval vessels between the Atlantic and Pacific Oceans, and the second one is its economic value as it offers a shortcut to transport freight between the Oceans. The shortened distance directly reduces travel time, fuel cost and access to profitable cargoes. Huebner (1915) summarised the economic value of the Panama Canal to America as one which stimulates traffic, changes trade flow, domestic and international economies and the growth of industries. In other words, economic development influences demand of trade routes and induces dynamic trade patterns. Mountjoy (1958) analysed the potential development of the Suez Canal, and he highlighted that development of the less-developed areas linked by the canal is speeded up. Fletcher (1958)

showed that the opening of the Suez Canal offered revolutionary changes to the shipping world and this canal shifted the trade pattern of East Asia and Australasia. All these studies showed trade affects the national and global economic development. On the reverse side, seaborne trade is a derived demand of commodity influenced by global economy (Stopford, 1997). In short, trade patterns interact with the national and global wealthy.

### *3.3. Third Force – Environment*

International trade affects environmental sustainability in two folds: these are production and transportation. International trade is generated by demand and supply of a product between two countries, greenhouse gases are emitted during the manufacturing processes. International trade magnifies the products demand when manufacturers supply the product to fulfil global demand. International trade involves transportation, transportation generates greenhouse gases when fuel combust. In short, trade and environment are closely related. Yunfeng and Laike (2010) illustrated how international trade accelerates carbon-dioxide emissions in China. The study found that most of carbon-dioxide emissions in China are embodied in manufacturing goods for exporting to global. The high use of coal and low manufacturing efficiency intensified the situation in They suggested applying a consumption-based carbon-dioxide accounting system to ensure China. responsibility is fairly allocated. Cristea et al. (2013) quantified the emissions of international transport and highlighted the patterns across products and trade partners. Moreover, they further analysed the situation when global trade is affected by liberalisation. They found that full liberalisation encourages trading between distant countries and, as a result, emissions increased by 6% when land transport is replaced by air transport. In summary, international trade and emission of greenhouse gases are closely related in several aspects: energy consumption mix and manufacturing efficiency of export countries, transportation distance and mode, and system for allocating emission responsibility.

#### 4. Discussion: Three Scenarios

It has been shown that politics, economic and environmental forces are significantly related to the international trade. These three driving forces are used to develop scenarios in 2030, so as to foresee the possible roles of the Nicaragua Canal in the future international trade.

After identifying the three driving forces, the Trilemma Triangle is developed by interacting and trading off between the different forces. Driving forces are represented by different colours: red represents economic, blue represents environment, and yellow represents politics. This Trilemma Triangle suggests three possible scenarios based on interaction/trade-off between the three driving forces. Purple represents the interaction between economics and environment and is named **Green Gold Scenario**; green represents the interaction between environment and politics and is named **Gold Spilt Green Scenario**; orange represents the interaction between economics and politics and is named **Gold Spilt Scenario** (Figure 2). Table 1 summarises the characteristics of the three scenarios and the corresponding roles of the two canals.

### 4.1. First Scenario – Green Gold Scenario

In the first scenario, the "*Green Gold Scenario*", countries will emphasise the boosting of national economic development and fight against environment deterioration by global cooperation. The consideration of political security will be lightened. Globalisation will enable countries to magnify their comprehensive advantages by specialisation. Developed countries will maximise their national economic development by stimulating international trade. Developing countries will tend to manufacture at a large scale to enjoy benefits generated from economies of scale. The awareness of low carbon emissions will increase, and the carbon tax will be imposed in order to further share the emission responsibilities embodied in import products. Developed countries will further share responsibilities of carbon emissions by exporting their low carbon technologies to developing countries, both improving manufacturing efficiency and the energy consumption mix, e.g. advanced manufacturing equipment and biofuel technologies.

### *4.1.1. Implications to maritime and international trade*

The emissions intensities of export countries will be reduced when low cost is no longer the sole consideration by import counties, while developing countries will maintain the comparative advantages by minimising carbon emissions of products in both the manufacturing process and transportation. Low carbon emissions will generate and maintain economic development in both developing and developed countries. By considering carbon emissions, distance between trading partners and transportation modes used are essential factors for international trade. Countries will tend to import products from proximate counties and use the most environmental friendly transport modes, e.g. railway and shipping.

Maritime transport will become more dominant in international trade by taking over from the air transport. To further take advantage of the low carbon opportunities, the shipping liners will use larger vessels and enjoy economies of scales for both economic and environmental benefits, while the hub and spoke system will be chosen to maximise the operation efficiency.

### 4.1.2. Possible roles of Nicaragua Canal

To survive, Canals will adapt to the global changes and fulfil the demands of Gold Green Scenario. Possible roles played by canals include:

Green Corridor

To enable supply chain parties to assess energy consumption or supplier evaluation, a canal will implement an energy management system and impose green policies or launch a green program, e.g. Vessel Speed Reduction Program to request / encourage vessel sailing speeds within certain nautical miles of the canal in order to help lower vessel emission levels, and a Clean Fuels Vessel Incentive Program to encourage vessel to use clean fuel when passing through the Canal. The Canal will provide incentives by offering discounts on passage dues. An energy management system applied in the Canal can be considered as a comparative advantage when public awareness on low carbon increases.

• Large Vessel Corridor

As shipping liners will deploy larger vessels to enjoy scale economies and environmental benefits, a canal shall have water depth to accommodate both post-panama and very large vessels. To combine with shortened distance offered by the Canal, the economic and carbon-dioxide emissions will be lowered. The Nicaragua Canal can specialise in servicing very large vessels.

### • Specialisation

Moreover, efficiency implies saving in cost, time and energy. Specialisation improves the operations efficiency of the Canal. The Canal will focus on handling specialised types of product, e.g. bulk specialised canal, tanker specialised canal or containerisation specialised canal. The speeding up of operation efficiency not only comes from equipment specialisation but also minimisation of errors. High operation efficiency further enables the canal to offer an unobstructed free-flow to vessels.

- ~ Containership:
  - Moving high-end electronics products from East Asia to North America
  - Moving agriculture products (e.g. sugarcane and soybean as food or energy supply) from Brazil to East Asia

~ Tanker:

- Moving chemicals as raw materials for producing high-end electronics products from Venezuela to East Asia
- Moving ecological products (e.g. biofuel as end products of biomass) from Brazil to East Asia for energy sources

~ Bulk carrier:

• Moving coal as energy resources from Venezuela to East Asia

### 4.1.3. Reaction of Panama Canal

Instead of being in price competition, the Panama Canal and the Nicaragua Canal will be complementary

routes. The expansion project of the Panama Canal will allow the transit of vessels with 49 m width, 366 m length and 15 m draft which is equivalent to a container ship carrying around 12,000TEU. That means the Panama Canal is very likely to seize the opportunity to be "Large Vessel Canal" to attract liners to pass through the deepened channel with their Post-Panamax rather than passing through the Atlantic and the Pacific Oceans via South America. Therefore, the customer base of the Panama Canal widens to Post-Panamax. The Panama Canal specialises in handling containership. The specialisation and advanced equipment enables the Panama Canal to become the logistics hub of the North America.

#### 4.1.4. Counter-reaction of Nicaragua Canal

The Nicaragua Canal will fulfil the market gap and offer green services to attract shipping liners which emphasise low emission of carbon-dioxide. The Nicaragua Canal will implement energy management system, impose green policies and launch a green program, e.g. Vessel Speed Reduction Program to attract low carbon liners passing through the Canal.

In addition, the Nicaragua Canal specialises in handling bulk vessels for moving coal from Venezuela to East Asia and tanker vessels for moving chemicals as raw materials from Venezuela to East Asia for producing high-end electronics products.

#### 4.2. Second Scenario - Split Green Scenario

In the second scenario "*Split Green Scenario*", environmental issues will rise to the top of the political agenda, and countries will impose conservative environmental policies. Trade barriers will be built based on different opinions of combating global warming. There will be two major groups of judgment on product consumption: pro-green group and anti-green group. The pro-green group will share the emissions responsibility by bearing carbon tax on import products. The anti-green group will shift emissions responsibility to exporting countries, i.e. do nothing embodied on import products. International trade will only occur between the countries that have a similar belief on environmental tendency. In other words, two trade blocs will be formed. European Union, Australia and China will be the leaders of the pro-green group which will actively impose national regulations and support emissions responsibility by imposing a carbon tax and carbon trade. Japan, America, Russia and Canada will be the leaders of the anti-green group which will withdraw from the Kyoto Protocol. Developing countries will maintain their economic development by adapting to the different preferences of the two blocs.

### 4.2.1. Implications to maritime and international trade

Pro-green developing countries, e.g. China, will develop a market niche by manufacturing eco-products when trading with the European Union and Australia. The environmental dialogue will be opened between countries having similar directions to environmental protection. Pro-green developing countries will attract foreign direct investment from the European Union and Australia. The European Union and Australia will share their low carbon technologies with their partners, but they will import eco-products from their partners. Those developing countries will emphasise low carbon emission along the supply chain, e.g. using cleaner fuel and imposing an energy management system. China will switch to cleaner fuel from coal to natural gas and biomass with the supports of advanced technologies of the pro-green group. Furthermore, China will import biomass or biofuel to replace coal. Maritime transport will be boosted within the pro-green bloc. They will develop a green supply chain, especially in the shipping industry.

On the other hand, the anti-green developing countries, such as India, will maintain advantages on cost minimisation when trading with Japan, America, Russia and Canada. They will minimise costs by improving operation efficiency and enjoying economies of scales.

### 4.2.2. Possible roles of Nicaragua Canal

• National Chokepoint, or Energy and Food Corridor

Division of environmental protection approach will induce the political argument. The split of trade blocs with political consideration will induce traffic separation. Traffic separation will imply national chokepoints for communications which access scarce resources, e.g. energy and food.

• Green Corridor

Environmental consideration is one of the trigger points of traffic separation. To attract pro-green bloc to use the canal, it should implement an energy management system and impose green policies or launch a green program, e.g. Vessel Speed Reduction Program to request/ encourage vessel sailing speeds within certain nautical miles of the channel in order to help lower vessel emission levels and a Clean Fuels Vessel Incentive Program to encourage vessels to use clean fuel when passing through the Canal. The Canal provides incentives by offering discounts on passage dues. The Canal develops a market based on enabling countries to transport cargoes by minimising carbon emissions from transportation.

### 4.2.3. Reaction of Panama Canal

Political consideration alters the role of canals. The Panama Canal will continue to have a close relationship with the United States although it became independent in 1995; The Panama Canal will offer the United States a short cut between the Atlantic and Pacific Oceans, as well as being a military strategic point of the United States.

### 4.2.4. Counter-reaction of Nicaragua Canal

The United States, India, and Japan will be seen as potential blockaders of China, especially as they have different tendency on environmental protection. Energy and scarce materials will be mostly dependent on maritime transport, and canals and straits are considered as chokepoints. It is dangerous if a country faces the energy insecurity caused by a maritime blockade via the Panama Canal or Indian Straits closures. China will consider developing an alternative to prevent maritime blockade. China will invest in the construction of the Nicaragua Canal, and the Chinese government will maintain a good relationship with the Nicaragua government. Through the Nicaragua Canal, China will assess and extend its influence to South America via foreign direct investments. Therefore, South America will fight against the maritime blockade and will support the pro-green group by supplying energy and food to China. The Nicaragua Canal will move agriculture products, e.g. sugarcane and soybean, as food or energy supply from Brazil to China by containerships, while biofuel will be moved as an end product of biomass from Brazil to China as energy sources in tankers. In short, the Nicaragua Canal will act as green energy corridor for China.

### 4.3. Third Scenario - Gold Split Scenario

In the third scenario "Gold Split Scenario", countries will impose a conservative policy. The rapid rise of China will upset the peaceful environment. This will be worsened by the South China Sea Crisis. Countries will emphasise national economic development, countries of Far East Asia will be split. This will cause dynamic changes in trade patterns. To boost national economic development, countries will extend their political influence by foreign direct investment to the developing countries. Eco-political blocs will be formed. International trade will be conducted within eco-political blocs. China will strengthen its relationship with the European Union and expand into new markets with South America; the national economic development of China will be likely maintained. Japan will maintain its existing eco-political relationship with the United States to maintain its economic development.

### 4.3.1. Implications to maritime and international trade

Within the eco-political blocs, countries will specialise in manufacturing complementary products to maximise economic benefits. To further minimise the cost, specialised large vessels will be deployed for international trade. Shipping liners will decide the routing that maximise the capacity of vessels in every sailing; the trade routes that link complementary trading favour liners.

### 4.3.2. Roles of Nicaragua Canal

• National Chokepoint/ Energy and Food Corridor

National economic benefits will induce the political argument. The split into trade blocs with political consideration will induce traffic separation. Traffic separation will then imply national chokepoints for communications which access scarce resources, e.g. energy and food.

### • Specialization

As shipping liners will deploy larger vessels to enjoy the economic benefits from economies of scale, the Canal will need to have water depth to accommodate post-panama and very large vessels. Combined with the shortened distance offered by the Canal, the transport cost will be lowered. The Canal will specialise in servicing very large vessels. Specialisation will improve the operations efficiency of the Canal. This efficiency will imply cost and time savings. The Canal will focus on handling specialised types of product, e.g. bulk specialised canal, tanker specialised canal or containerisation specialised canal. The speeding up of the operation efficiency not only comes from equipment specialisation but also minimisation of errors. High operation efficiency further enables the canal to offer an unobstructed free-flow to vessels.

#### 4.3.3. Reaction of Panama Canal

The expansion project of the Panama Canal will allow the transit of containerships carrying around 12,000 TEU. That means the Panama Canal will be very likely able to seize the opportunity to be "Large Vessel Canal" to attract shipping liners to pass through deepened channel with their Post-Panamax rather than passing through the Atlantic and the Pacific Oceans via South America. Therefore, the customer base of Panama Canal will be increased to Post-Panamax. The Panama Canal will specialise in handling large containerships. The Panama Canal has close relationship with the United States although it was independent since 1995 and it is also a military strategic point of the United States. The specialisation and advanced equipment will enable the Panama Canal to become the logistics hub of the United States.

#### 4.3.4. Counter-reaction of Nicaragua Canal

United States, India, and Japan will be seen as potential blockaders of China, especially when they have different tendencies regarding environmental protection. Energy and scarce materials will be mostly dependent on maritime transport, and canals and straits are considered as chokepoints. The maritime blockade via the Panama Canal or Indian Straits closures will pose significant threats to energy insecurity of some countries, e.g. China.

China will develop an alternative to prevent maritime blockades. China will invest in the construction of the Nicaragua Canal, and the Chinese government will maintain a good relationship with the Nicaragua government. Through the Nicaragua Canal, China will assess and extend its influence to South America by foreign direct investment. Therefore, South America will fight against the maritime blockade and support the pro-green group by supplying energy and food to China. This means that the Nicaragua Canal will be used to move agriculture products, e.g. sugarcane and soybean as food or energy supply from Brazil to China by containerships, while coal will be moved as energy resources from Venezuela to China.

Besides energy and food, South America will supply raw materials to China, e.g. agricultural products and energy, while China will export finished products to South America for consumption, e.g. textile and electronics. Therefore, specialised hub ports of containers or tankers will be developed in both South America and China to facilitate trade and maximise operation efficiency.

- ~ Containerships:
  - Moving high-end electronics products from East Asia to South America and Canada
  - Moving agriculture products (e.g. sugarcane and soybean as food or energy supply) from Brazil to East Asia
- ~ Tankers:
- Moving Chemicals as raw materials for producing high-end electronics products from Venezuela to East Asia

 Moving ecological products (e.g. biofuel as end products of biomass) from Brazil to East Asia

#### 5. Conclusion and Future Research

This study represents the first attempt to conceptually investigate the future possible roles of the new Nicaragua Canal in the presence of the competing Panama Canal. Generally speaking, the proposed Nicaragua Canal will make the world more integrated via the maritime transport network.

This paper uses scenario planning as a methodological approach to gain new insights into the roles of Nicaragua Canal in three different dominant scenarios. Scenario planning allows us to understand how driving forces will work and jointly develop different scenarios. From our analysis, the new Nicaragua Canal will complement the Panama Canal in the international maritime transport network. These two canals may separate the traffic of ship types so that the efficiency of canal transits will be enhanced. They may separate the traffic of cargo types so that the safety of canal transits will be improved. Currently, the presence of different ship types and ship sizes imposes navigational and pollution hazards in the Panama Canal that make it essential to reduce the speed for safety. If the Nicaragua Canal and Panama Canal separate the traffic separation could be an effective way of managing the traffic flows in both canals, especially when the traffic becomes very congested.

It is found that the Nicaragua Canal will strengthen particularly the connection between the Far East and the East Coast of South America and will become an energy corridor for the Far East. South American countries export iron ore, crude oil and other resources, while China and other Far East Asian countries are exporting finished and semi-finished products. Although South American and Far East Asian countries have some competitive exports, export differentiation shows a high potential of mutual trade between the two regions. In addition, the new Nicaragua canal will reduce the trade barrier between the two regions.

The driving forces behind these scenarios are assumed to be political, economic, and environmental. For other objectives, a mix of different driving forces may be established for further investigation and analysis, which may enable the Nicaragua Canal to be more contributory to the world. Even under different scenarios, large net benefits are likely to occur from this new canal. This paper provides useful information in shaping policy regarding the canal's development and enhancement.

In this study, the intuitive and descriptive method is used to build up the scenario planning. Three forces, namely politics, economics and environment, are taken into consideration. It recovers micro and market changes of seaborne trade and indicates the importance of the emergency of Nicaragua Canal.

This study attempts to conceptually investigate the future possible roles of the new Nicaragua Canal in the presence of the competing Panama Canal. It enables us to explore novel insights about the future of interoceanic canals, which demonstrates the causal relationships between factors of canal market. The economic conflicts between the Nicaragua Canal and the Panama Canal can be further analysed by the game theory when more information is available. More specific results can then be obtained such as competition, substitution and cooperation among rival canals.

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Scenario	1	2	3
	Green Gold Scenario	Split Green Scenario	Gold Split Scenario
Politics	Political environment will	Political environment will be	Political environment
	be stable and globalised.	unstable.	will be unstable.
Economics	Economics will be focused.	Trade barriers will be set up.	Economics will be
			focused.
Environment	Environment will be	Environment will be at the top	N/A
	focused.	of political agenda.	
Descriptions	Countries will boost national	Countries will be split into	Countries will be split
	economic development and	two trade blocs based on their	into eco-political blocs.
	fight against environment by	environmental tendency, i.e.	Countries will boost
	globalisation.	pro-green group and anti-	national economic
		green group.	development by
			influence vie foreign
			direct investment
Possible	* A green corridor	* National chokepoint.	* National
Roles of	* A large vessel corridor	Energy and food corridor	chokepoint: Energy and
Nicaragua	* A specialised corridor	* A green corridor	food corridor
Canal	r	6	* A specialized
			corridor
Reaction of	* Specialised on handling	* Become an military	<ul> <li>* Specialized on</li> </ul>
Panama	Post-Panamax ships	strategic point of the United	handling Post-Panamax
Canal	* Become a logistics hub of	States	ships
	North America		* a logistics hub of
			North America
			* Military strategic
			point of the United
Counter	* Will fulfil the market	* China abakanaint: Enargy	States * China chokonoint:
reaction of	gap by offering green	and food corridor green	Fnergy and food
Nicaragua	services e g launching	corridor	corridor green corridor
Canal	green programme similar to	contact	* Will specialise in
Cuntur	Vessel Speed Reduction		handling containerships
	Program		and tankers
	* Will specialise in		
	handling bulk vessels, e.g.		
	coal from Venezuela to East		
	Asia and tanker, e.g.		
	chemicals from Venezuela		
	to East Asia.		

# **Table 1: Summary of Scenarios**



Source: Google Map





# Revisiting China's Legislation on Compensation for Marine Ecological Damages: Lesson Learned from 2011 Penglai 19-3 Oil Spill

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#### Abstract

The 2011 oil spill in Bohai Bay caused widespread attention in China. Legislation on the protection of marine environment was therefore challenged by the Chinese society. This article firstly probes the background and the compensation agreement of Penglai 19-3 oil spill accident, and then looks into the current legislation on marine ecological damages in China. Bearing other marine maritime pollution accidents like Gulf of Mexico oil spill in mind, this paper provides detailed comparative study and detailed analysis about the legal problems of Bohai oil spill, i.e., definition of "marine ecological damage", the qualified parties to claim for the damages, the scope of compensation, the compensation limits and the evaluation criteria. After pointing out the legal loopholes which were disclosed during the negotiation about the compensation plan between State Oceanic Administration and the COPC from 2011 to 2012, the last part draws conclusion on the consideration and Inspiration for the legal framework of Compensation for Marine Ecological Damages after the Bohai Oil Spill.

Keywords: Bohai Oil Spill, China' Marine Environmental Protection Law, Compensation Claims on Marine Ecological Damages

#### 1. Introduction

On June 2011, Penglai 19-3 oilfield, the biggest offshore oilfield in China, experienced two unrelated leaks, with initial estimates indicating that about 723 barrels (115 cubic meters) of oil were released into the sea and 2,620 barrels (416.45 cubic meters) of mineral oil mud were released onto the seabed, according to ConocoPhillips China, the operator of the oilfield.<sup>1</sup>

Bohai is a half-closed sea with comparatively low self-clean ability due to limited water exchange with the outside. Penglai 19-3 oilfield was jointly owned by China National Offshore Oil Corporation ("CNOOC"), with 50% stake, and ConocoPhilips China Inc. ("COPC"), with 49% stake and actually run the field. The said oil leaks in Bohai Bay have brought attention to the general public, not only because of the severe marine environmental impact on fishing, breeding and other related industries in the neighboring areas such as Liao Ning, He Bei, Shan Dong and Tian Jin, but also because of the accused concealment of the accident by ConocoPhillips. According to 2012 China's Ocean Development Report released by the State Oceanic Administration ("SOA"), the Bohai oil spill polluted an area of about 6,200 square kilometers (nearly nine times the size of Singapore), including 870 square kilometers that were severely polluted.<sup>2</sup>

On June 21, 2012, based on the Investigation Report on the Oil Spill Accident of Penglai 19-3 Platform (hereinafter referred to as "the Investigation Report") conducted by the Joint Investigation Group led by the SOA, the accident was identified as "a very serious marine pollution accident caused by oil spill", as a result of the loopholes of COPC's regulation and management which were reflected in the violation of the overall development plan during the operation, and due to lack of necessary preventive measures against the foreseeable risks. <sup>3</sup> Penalty and compensation cause by the oil spill in the Investigation Report can be classified into three categories: Firstly, administrative penalty of a fine of 200, 000 RMB. On September 1, 2011, the SOA ordered CPOC to pay administrative penalty of such fine based on Article 85 of the Marine Environmental Law. CPOC accept the order and paid the fine on September 9. Secondly, compensation on marine ecological damages was reach on June 2012 between SOA on one side and CPOC and CNOOC on the

other side. COPC and CNOOC will pay an aggregate amount of RMB 1.683 billion, among which COPC will contribute RMB 1.09 billion to compensate for the marine ecological damage caused by the oil spill accident. In addition, CNOOC and COPC will each fund 0.48 billion RMB and 0.113 billion RMB to resume the social responsibility for the environmental protection in Bohai Bay. The compensation will be used for ecological and environmental protection in Bohai, reduction on oil pollutants discharge at entrance to Bohai, habitat restoration of damaged marine ecological environment, as well as monitoring and researching on oil spill impact on ecological environment. Thirdly, compensation on fishing losses was also reached between CPOC, CNOOC, and the Ministry of Agriculture, local governments of Ministry of Agriculture, Niao Ning and He Bei Province after mediation process. One billion RMB will be paid by CPOC and to be used for the loss of fishery resources. The separate expenditures of 100 million RMB by COPC and another 250 million RMB by CNOOC will be spent from their joint contributed Fund on the Protection of Marine Ecology and Environment and will be used on the restoration and conservation of fishery resources.

In 2012, the consumption of crude oil in China reached 270,000,000 tons, an increase of 1.3 percentage points. <sup>5</sup> Since the consumption of oil products has kept on increasing, China is now facing serious marine environmental problems accompanied by the offshore oil exploitation activities. Although COPC and CNOOC agreed to pay an aggregate amount of 1.683 billion RMB as compensate for marine ecological damages, one year after the disclosure of the accident by Chinese media, the accident itself cast doubt on whether China's laws and regulations concerning compensation on marine ecological damages can cope with the foreseeable oil spills caused by offshore oil exploitation or shipping.

#### 2. Current Legislation on Compensation for Marine Ecological Damages in China

In an interview with the Wall Street Journal, US oil giant ConocoPhillips claimed oil spills in the Bohai Bay from June to November of 2011 caused "minimal lasting impact to the environment". <sup>6</sup> As a matter of fact, CPOC had been ordered to halt all operations by the SOA at Penglai 19-3 oil platform in September 2011 due to its negligence, and the Chief Executive James Mulva expressed deeply regrets and apologized for the impact of the accident.<sup>7</sup> Controversial attitude of ConocoPhillips about the marine environmental pollution caused by the oil spill in Bohai Bay somehow may provide in-depth thoughts on the imperfection and loopholes of the current legislation on the compensation of marine ecological damages.

Chinese environmental legislation began in 1978 with formal recognition in Article 26 of the Constitution of the People's Republic of China, requires that "the state protects and improves the environment in which people live and the ecological environment. It prevents and controls pollution and other public nuisance."<sup>8</sup> Rapid growth over the past 35 years has fostered the formation of a detailed environmental legal system. A comprehensive list of the legislation concerning marine environment is as follows: A. Laws address marine environmental protection. Marine Environmental Protection Law ("MEPL"), Maritime Law, Maritime Procedural Law and Fishery Law are the typical examples of this category. And the Laws are superior to other legislation made by the States Council, ministries or departments inferior to the State Council, and local governments of the provinces which are inferior to the NPC, such as the Measures, the Standards, and the local Regulations etc. B. Administrative Regulations adopted by the State Council. Regulations of this type consist of Regulations on The Administration of Environmental Protection in The Exploration and Development of Offshore Petroleum, Regulations on the Prevention and Treatment of the Pollution and Damage to the Marine Environment by Marine Engineering Construction Projects, Regulations on Control Over-dumping of Wastes in The Ocean, Regulations on The Prevention of Vessel- Induced Sea Pollution, etc. C. Measures, Standards and other legislation enacted by the ministries or departments of the State Council. In this regard, the SOA plays essential rule. Legislation concerning marine environmental protection enacted by the SOA are Measures on the Regulation of the Oil Platform Abandonment, Effluent Standards for Oil-bearing Waste Water from Offshore Petroleum Development Industry, Specifications for Oceanograpic Survey, Specification for Marine Monitoring, Emergency Plan for Oil Spill in the Exploration and Development of Offshore Petroleum, Technical Guidelines for Ecological Damages Assessment on Marine Oil Spill, Specifications for the Identification System of Oil Spill at Sea etc. Legislation relates to marine environmental protection can also be found in the form of national "Standards" made by the Ministry of Environmental Protection ("MEP") such as Sea Water Quality Standard, Water Quality Standard for Fisheries and Effluent Standard for Pollutants from Ships etc. D. Local Regulations promulgated by provinces. Shang Dong Province
is the first province to legislate on the compensation for marine ecological damages, i.e., Interim Measures on the Management of Marine Ecological Damages and Loss Compensation (2010) and Measures on the Assessment Method of Marine Ecological Damage and Loss Compensation (2010). Similarly, Article 8 of the Regulations on the Protection of Marine Environment of Jiang Su Province (implemented from 2007) also allows regional ecological reparation.

Except for the legislation above, Supreme Court of the People's Republic of China published a series of judicial interpretations and documents, amongst are Summary of the Second National Working Conference on Foreign-related Commercial and Maritime Trails (2005) and Regulation on the Trails of the Compensation on Oil Pollution Caused by Vessels (implemented from July 2011) which are especially important as guidance for the inferior courts to deal with the compensation claims for marine ecological damages.

Meanwhile, as to the involvement of international legislation on marine environmental protection, China already ratified 1969 Civil Liability Convention ("CLC Convention 1969") and 1992 International Convention on Civil Liability for Bunker Oil Pollution Damage.<sup>9</sup> For the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage ("1992 Fund"), it only applied to Hong Kong but not to mainland China yet.

One may clearly see that a systemized legal framework regarding the compensation on marine ecological damages has not been established, although ideas and notions can be found dispersed in the laws and regulations for marine environmental protection. China's involvement of international legislation on marine environmental protection has not achieved ideal improvement of its domestic legislation. In practice, Tasman Sea accident<sup>10</sup> was the first case related to the compensation for marine ecological damages in China. On December 30, 2004, Tianjin Maritime Court ordered the two defendants jointly to pay 99,581,000 yuan in compensation to Tianjin Oceanic Bureau for loss of marine environmental capacity and the costs of investigation, monitoring, evaluation and research into biological restoration, which were less than Tianjin Oceanic Bureau hoped for, since it also claimed for other six items of compensation for marine ecological damages. <sup>11</sup> Seven years later, following an appeal and a hearing at the Supreme People's Court, Tianjin Oceanic Bureau received a settlement of just 3 million yuan (US\$466,000). What the compensation was for was not specified, and even costs incurred were not recovered. <sup>12</sup> As marine ecological damage differs from traditional personal injury and property damage, there are no international conventions which are directly applicable to liability for compensation. However, if this gap is not filled and marine ecosystem damage is simply ignored, there would be no one to compensate for damage done to the marine ecosystem. Such a gap would certainly make the marine environmental situation in China even worse and seriously trample the maritime rights and interests of China.<sup>13</sup>

Therefore, even before the 2011 Bohai oil spill accident, China's legislation on marine environmental protection already faced challenges by the practical problems in the previous cases concerning oil spill, which may more or less reflect on the compensation settlement for marine ecological damages after Bohai oil spill accident.

# 3. Legal Issues Regarding 2011 Bohai Oil Spill

# 3.1 Definition for "Marine Ecological Damages"

"Ecological damage" is frequently used by European scholars, while the term "natural resource damage" is often used in U.S. law and by American scholars. Lahnstein Christian defines "ecological damage" as "material damage to nature, specifically to earth, water, air, climate, landscape, flora and the fauna living in them, and to the interaction between them. It is also conspicuous man-made damage to the ecosystem and its component parts." <sup>14</sup> The 1990 OPA of the United States naturally addresses natural resource damages as "damages for injury to, destruction of, loss of, or loss of use of, natural resources, including the reasonable costs of assessing the damage, which shall be recoverable by a United States trustee, a State trustee, an Indian tribe trustee, or a foreign trustee."<sup>15</sup>

The definition for "marine ecological damages" normally influences the scope of the compensation in practice.

There is room for notional costs of damage to marine ecological damages such as the case of the Patmos, the Antonoi Gramsci, or the Haven.<sup>16</sup> The term of "ecological damages" refers to the damages or passive impact on ecosystem caused by human activities instead of damages to individual interest, <sup>17</sup> therefore may not be the types of damages under environmental tort liability in China. As a result, claimants of the oil spill cases normally tend to claim for compensation for fishery losses other than marine ecological damages in practice.

The Chinese Constitution prohibits "appropriation or damaging natural resource by any organization or individual by whatever means." <sup>18</sup> The Environmental Protection Law states that "all units and individuals shall have the right to report or file charges against units or individual that cause pollution or damage to the environment."<sup>19</sup> Article 95, Section 1 of the Marine Environmental Protection Law ("MEPL") of the People's Republic of China<sup>20</sup> defines "pollution damage to the marine environment" as "any direct or indirect introduction of substances or energy into the marine environment which results in deleterious effects such as harm to marine living resources, hazards to human health, hindrance to fishing and other legitimate operations at sea, impairment of the useful quality of sea water and degradation of environment quality." Article 90 of MEPL, on the other side, simply explicit the liability for "damages to marine ecosystems, marine fishery resources and marine protected areas", providing no precise definition as to what constitute "damages to marine ecosystems." As for the terms "pollution damage to the marine environment" and "damages to marine ecosystems" adopt by MEPL, some authors tend to believe that the usage without significant differentiation are often used both in China and elsewhere; <sup>21</sup> others, on the contrary, argue that the existence of the differences does conflict with the current Chinese tort law which provides inadequate remedies for environmental damages.<sup>22</sup> This author shares the view with the latter one and believes that lack of clear definition for "marine ecological damages" in MEPL has become a hard nut to crack in judicial practice. Even if the MEPL made an innovative step for the compensation on marine ecological damages, there are still few successful precedents, such as the collision near the mouth of Zhu Jiang River,<sup>23</sup> Tasman Sea case, and Bohai oil spill accident. In this regard, the U.S Oil Pollution Act of 1990 provides useful reference. For example, in Section 1001 (20), "natural resources" is defined as "includes land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources"; Section 1002 (b)(2)(A) further defines "natural resource damage" as "damages for injury to, destruction of, loss of, or loss of use of, natural resources, including the reasonable costs of assessing the damage." <sup>24</sup> Precise and practical definition of "marine ecosystem" and "marine ecological damages" therefore needs to be perfected in the future reversion of the MEPL, by taking account of the losses of public interests such as Royalties for using sea areas and state taxation, impairment or losses of the use value for marine environment, losses of natural resources, etc.<sup>25</sup>

# 3.2 Qualified Claimants

The MEPL 1999 provides different provisions about who may claim for compensation for marine environmental damages and for marine ecological damages. Section 1, Article 90 of the MEPL states that "whoever causes pollution damage to the marine environment shall remove the pollution and compensate the losses." Meanwhile, according to Section 2, Article 90, "for damages to marine ecosystems...which cause heavy losses to the State," "the department invested with power by the provisions of this law to conduct marine environmental supervision and administration shall, on behalf of the State, put forward compensation demand to those held responsible for the damages." On one side, any individual or unites suffered from pollution damage to marine environment has qualification to bring the claim; while on the other side, the department invested with power to conduct marine environmental supervision and administration may, on behalf of the State, to ask for compensation for damages to marine ecosystems. Therefore, Article 90 of The MEPL 1999 was appreciated for being an important breakthrough in the compensation for marine ecological damages. <sup>26</sup> What's noteworthy is that Article 5 of the MEPL further stipulates that "department invested with power to conduct marine environmental supervision and administration" shall include: i. The competent administrative department in charge of environment protection; ii. State oceanic administrative department in charge of marine affairs; iii. The competent state administrative department in charge of maritime affairs; iv. The competent state administrative department in charge of fisheries, and, v. The environmental protection department of the armed forces.

Theoretically, any "supervision and administration departments" may claim for marine ecological damages, unnecessary problems usually arise. Firstly, on behalf of the State, usually more than one department has

qualification to ask for the compensation for marine ecological damage. It's not easy for the court to identify which one may represent the State, or to distinguish the supervision and administration competence among these departments. For example, on behalf of the State, Qingdao Environmental Protection Bureau and Qingdao Bureau of aquatic products brought the claims for ecological damages in 1983 Eastern Ambassador oil spill case. <sup>27</sup> Similar claims were also brought by Zhanjiang Detachment of Guangdong Fishery and Maritime Inspection Corps in 1997 Haicheng case<sup>28</sup>, and by Tianjin Oceanic Bureau and Tianjin Fishery Bureau in 2002 Tashman Sea case<sup>29</sup>. Furthermore, overlapping compensation claims by various claimants were usually challenged by the respondent, and that was the case in Tashman Sea accident. <sup>30</sup> Thirdly, the competence issue may lead to chaos during the negotiation process and further result in mismanagement of the compensation. Current Chinese legislation does not make it clear as for whether the said "supervision and administration departments" has competence to reach conciliation with the respondent who responsible for the pollution, or whether the conciliation agreement needs to be approved by the superiors. It is therefore usually up to the "supervision and administration departments" to negotiate and reach conciliation agreement with the respondent who are responsible for the pollution.

After the Bohai oil spill was disclosed, from August 2011, on behalf of the State, State Oceanic Administration formally claimed for marine ecological damages,<sup>31</sup> since the oil leaks already became a serious cross-regime issue. Taking 2012 compensation agreement into account, at least two phenomena can be observed, firstly, instead of local supervision or administration departments, the SOA is a qualified claimants for marine ecological damage which shows its cross-regime characteristic; secondly, it's still unclear about the detailed arrangement or management for the aggregate amount of RMB 1.683 billion. One still has reason to concern about the following compensation arrangement, especially whether it would repeat the disposal of 2010 oil spill accident in Xingang, Dalian,<sup>32</sup> which in the end turned out to be investment for oil refinery and ethylene plant by the CNOOC as alternative plan instead of compensation for marine ecological damages.<sup>33</sup>

#### 3.3 Scope of the Compensation

Scope of the compensation was one of the difficult issues for the compensation claims not only for the accident of Bohai oil spill, but also for similar marine pollution accidents.

Under the U.S OPA, natural resource damages are quantifiable and the measure of natural resource damages is: (1) the cost of restoring, rehabilitating, replacing, or acquiring the equivalent of, the damaged natural resources; (2) the diminution in value of those natural resources pending restoration; plus (3) the reasonable cost of assessing those damages. <sup>34</sup> The Exxon settlement is an example of a best-case scenario--a success story in the world of natural resource damages.<sup>35</sup> Exxon agreed to pay \$900 million with annual payments stretched over a 10-year period to reimburse the Governments' costs and to restore, replace, or acquire the equivalent of the natural resources affected by the Spill.<sup>36</sup> However, in China, Environmental Protection Law or Marine Environmental Protection Law provide little guidance for the scope of the compensation for marine ecological damage. Courts tend to rely on the Specification or Guidelines issued by the inferior departments of the State Council, or judicial documents released by the Supreme Court. In Chinese judicial practice, compensation for marine ecological damages usually proceeds with the claims for fishery resources, courts usually resort to three typical legal documents to determine scope of the compensation for fishery losses or marine ecological damages, i.e., Specification Method for the Calculation of Fishery Loss in Water Area (Ministry of Agriculture, "Calculation Method 1996"), Specification Method for the Calculation of Fishery Loss 2008 (Standardization Administration, "Calculation Method 2008"), and Technical Guidelines for Ecological damage assessment on marine oil spill (SOA, "Technical Guidelines 2007").

Article 2 of the "Calculation Method 1996" simply states that "calculation for natural fishery resources shall be no less than 3 times of the direct economic loss of water product loss." <sup>37</sup> "Calculation Method 2008" refines on this provision by stipulating that "fishery losses caused by marine pollution" shall include "direct economic losses and restoration fees for natural fishery resources." <sup>38</sup> Moreover, in Article 8.2 of the "Technical Guidelines 2007" issued by the SOA states that, "direct damage to marine ecosystem shall be calculated respectively based on various types of marine ecosystems, mainly including two types of damage, namely, the loss of marine ecosystem service function, and the loss of marine environmental capacity." <sup>39</sup> Nevertheless, legal forces of the document issued by the departments of the State Council, namely, Ministry of

Agriculture, the SOA or Standardization Administration, are inferior to the laws adopted by National People's Congress, as well as the regulations adopted by the State Council. Furthermore, it's discretion instead of mandatory obligation for the courts to apply the said legal documents to determine the scope of the compensation. According to Notice of Supreme People's Court on Circulating the "Summary of the Second National Working Conference on Foreign-related Commercial and Maritime Trials" (hereinafter referred to as "the Summary of Supreme People's Court"), scope of indemnification for oil pollution damage includes: oil pollution by ships cause loss of property to citizens, legal persons or other organizations; cleanup costs incurred to prevent or mitigate oil pollution, and damage to fishery resources and marine resources resulting from the oil pollution by ships. <sup>40</sup> although "the Summary of Supreme People's Court" provides guideline for local maritime courts, loopholes of Article 150 of "the Summary of Supreme People's Court" can be observed and summarized as follows: First, the terms of "marine ecological damages" or "marine environmental damages" were replaced by "damage to fishery resources and marine resources"<sup>41</sup>, as result leads to a separation between the types of damages and the subject of claimants; Second, actual compensation may be limited by the scope of indemnification for oil pollution damage, because claims for damages to marine ecological resources other than "fishery resources and marine resources" would be difficult to be supported by local courts in judicial practice. <sup>42</sup> Third, the estimation for the damage was restricted to "the expenses incurred for the reasonable recovery measures that have actually taken or will be taken", <sup>43</sup> namely actual damage can be compensated while losses for the use right of natural resources or unrecoverable natural losses are excluded from the actual compensations. More importantly, "the Summary of Supreme People's Court" makes no specific indication as for whether the Specification or Guidelines issued by the inferior departments of the State Council shall be applied in judicial practice, although those documents provide guidance for wider scope of damage, even marine ecological damage.

In a word, Marine-related laws in China usually provide broad definition for marine ecological damages instead of practical scope of the compensation for marine ecological damages. Legal forces of the said Calculation Method and the Technical Guidelines from departments of the State Council or judicial documents of the Supreme Court are inferior to the marine-related laws in China, so that application of the documents by maritime courts is still discretionary and the outcome for the compensation will be unforeseeable by the victim of the marine pollution.

#### *3.4 Valuation Criteria for Marine Ecological Damages*

Another important factor to influence the outcome of the compensation is the valuation criteria for marine ecological damages. During or after the oil spill, evidence collection or investigation for the influence on fishery resources are not the easy tasks, so does the valuation for marine ecological damages, no wonder marine ecological expert made comment after Bohai oil spill, "evaluation on marine resources damages focuses on fishery resources including Aquatic animals and plants is the general practice. This type of resource is valuable and can be supported by judicial practice. However, evaluation on the polluted sea waters or natural landscape may not be easy." <sup>44</sup> When it comes to the case of Exxon Valdez, although Sanne Knudsen praised the case as "a success story in the world of natural resource damages," she still acknowledged that "natural resource damage assessments, however, are costly propositions. In fact, the prospect of undertaking the cost of an assessment puts pursuit of natural resource damages out of reach for some state and federal trustees." <sup>45</sup> Unlike damages to normal property which can be valued based on market price, marine ecological damages have to be evaluated by technical measures; while such evaluation measures may not be acknowledged by traditional evaluation system of compensatory damages. As result, even if the scope of the compensation has been well solved by the current legal framework of marine environmental protection law, compensation for marine ecological damages still can not be guaranteed without sound evaluation process and method.

As for evaluation criteria for marine ecological damages in China, although "State Council and local People's Governments at the Provincial level" are entitled to "adopt effective measures to protect typical and representative marine ecosystems" <sup>46</sup>by the MEPL, However, the MEPL does not indicate the quantification of the expenses for reparation and restoration. In another word, it will be difficult for those who bring the compensation claim concerning marine ecological damages to prove the connection between their losses and the pollution caused by oil spill. In this regard, the 2007 Technical Guidelines for Ecological Damages

Assessment on Marine Oil Spill (The "Technical Guidelines") announced by the SOA serves the needs as technical support. Learned from the experience of the U.S OPA, The "Technical Guidelines" clearly stipulates that "subjects of the damage" include "Damage to Seawater Quality, Environmental Damage to Marine Sediment, Environmental Damage to Tidal Flats, Damage to Marine Organisms, and Damage to Marine Ecosystems;" <sup>47</sup> and "ecological damage assessment costs" are divided into four sections, namely, "the cost of assessing the direct damage to the marine ecosystem, habitat restoration cost, organism population recovery cost, and investigation and assessment cost." <sup>48</sup> Nevertheless, courts tend to compensate "direct, actual and quantizing" economic losses spend on methods which have be taken or will be taken to restore natural resources; compensatory damages to environmental derogation which measured by "abstract theoretical calculation or mathematical model" will usually not be supported by judicial practice. <sup>49</sup> For example, in Tashman Sea case, Tianiin Oceanic Bureau asked for compensation based on damages to marine environmental capacity, beach restoration cost, recovery cost for phytoplankton, recovery cost for nekton, research cost for ecological management, and cost for monitoring and evaluation.<sup>50</sup> As first instance, Tianjin Maritime Court only supported two items of costs, namely, damages to marine environmental capacity and cost for monitoring and evaluation. <sup>51</sup> On the contrary, compensation settlement for marine ecological damages in 2012 after Bohai oil spill covered costs for ecological and environmental protection in Bohai, reduction on oil pollutants discharge at entrance to Bohai, habitat restoration of damaged marine ecological environment, as well as monitoring and researching on oil spill impact on ecological environment. This author is holding the view that the "Technical Standards" is simply a type of Marine Industry Standard and it's usually subject to the courts to decide whether they would apply or not; even if the "Technical Standards" issued by the SOA was recognized as evaluation criteria for the compensation claim brought by the SOA in Bohai Oil Spill case, the compensation settlement might not be recognized as general practice. After all, the SOA is not only the claimant on behalf of the State for damages to marine ecology, resources and protected areas, but also the body organizing evaluation of these damages. <sup>52</sup>

## 3.5 Ceiling for administration penalty

On September 1, 2011, the SOA ordered CPOC to pay administrative penalty of RMB 200,000 thousand, as provided in Article 38 of the Environmental Protection Law: "An enterprise or institution which violates this Law, thereby causing an environmental pollution accident, shall be fined by the competent department of environmental protection administration or another department invested by law with power to conduct environmental supervision and management in accordance with the consequent damage..." and further provided in Article 85 of Marine Environment Protection Law: "In violation of the provisions of this law, undertakes to conduct offshore oil exploration and exploitation causing pollution damage to the marine environment, shall be warned by the competent State administrative department in charge of marine affairs and be fined not less than RMB 20,000 and no more than RMB 200,000." The "ceiling" of administrative penalty for marine pollution under current Chinese law is an important reason for COPC to conceal the real situation several times after the accident and was insincere in making an apology.

In the United States, on the contrary, although the 1990 OPA requires that "the responsible party with respect to an offshore facility" shall not exceed "the total of all removal costs plus \$75,000,000", <sup>53</sup> OPA's \$75 million cap on liability for spills from offshore facilities would be eliminated by the Consolidated Land, Energy, and Aquatic Resources (CLEAR) Act<sup>54</sup> passed by the House Committee on Energy and Commerce after the Gulf of Mexico accident. Section 702(a) would not only eliminate OPA 90's \$75 million cap on liability for spills from offshore facilities, but also would permit the President to increase other liability caps based on specific findings. <sup>55</sup>

The "ceiling" of administrative penalty under the current MEPL is comparable mild and would not deter oil drilling companies from offshore oil spills. In this sense, the MEPL needs to be implemented as soon as possible.

#### 4. Concluding Remark

The 2011 Bohai oil spill is the first marine ecological accident caused by offshore drilling activity in China and has already challenged the legal framework of the compensation for marine ecological damages. In this

regard, this author summaries consideration and inspiration to perfect the legislation and other corresponding measures as follows:

# 4.1 Revising Marine Environment Protection Law

The MEPL needs to be revised and the corresponding detailed implementation in the form of Regulation need to be promulgated. During the process of the revision, first, the "ceiling" of administrative penalty (RMB20, 000) for marine pollution has to be either increased or eliminated. Second, the definition and the compensation scope of the marine ecological damages need to be specified in the provisions. Third, a long term mechanism for marine ecological compensatory claim also needs to be established, in order to supervise and encourage departments in charge of "marine environmental supervision and administration" to act actively.

## 4.2 Fasten the process to establish marine ecological reparation system

Suggestions the Establishment of Ecological Compensation Mechanism Improvement initiated by Development and Reform Commission of the State Council was an innovative step for China to development a national ecological reparation system. The SOA has worked on the promulgation of more legal documents in relation to marine ecological protection, in order to coordinate with other departments of the State Council, aiming at achieve systematic policies for ecological reparation system. The 2007 Technical Guidelines for Ecological Damages Assessment on Marine Oil Spill of the SOA is simply a Marine Industry Standard and only provides guide for maritime courts. Realizing the shortcoming of the said Guidelines, The SOA accomplished the Draft on Suggestions on the Regulation of Marine Ecological Damage National Claims in the end of 2010. It's necessary for the government to fasten the process of the legislation on marine ecological damages, compensation criteria and the evaluation process, etc., so as to solve the practical problems in judicial practice.

# 4.3 *Perfection of the environmental public interest litigation*

Represented by the Environmental Protection Law and the MEPL, when it comes to environmental disputes, laws and regulations in China tend to provide administrative solution other than litigation as "first choice" for the parties, although "administrative processing priority" may not be followed by such laws and regulations. Anyone who brings claims based on tort liability caused by marine ecological damages may possibly face with the dilemma under the Chinese procedural law. For example, Article 108 of the Civil Procedure Law provides: "the plaintiff must be an individual, legal person or any other organization that has a direct interest in the case," public interest litigation against marine ecological damages therefore barred by the current legal framework. On August 31, 2012, "Draft on Implementation of the Civil Procedure law" was passed by the National People's Congress, in which public interest litigation was provided by Article 55 of the amended Civil Procedural Law (entered into force on Jan 1, 2013): "relevant organs and organizations prescribed by law may initiate lawsuit at competent courts against conducts jeopardizing the public interests, such as causing environment pollution or damaging the interests of a large number of consumers." Hopefully, the amended Civil Procedural Law may create possibility for the perfection of the legal atmosphere of public interest litigation against marine pollution, but the details such as burden of proof, evidence evaluation and causality assertion which are in relation to the claims for marine ecological damages still need to be further perfected by subsequent laws and regulations.

# 4.4 Establishment and perfection of the Oil Pollution Fund System

Oil Fund established by BP shortly after the Gulf of Mexico accident was to compensate the victims suffered from oil spill as soon as possible, so as to avoid time consuming and money consuming litigation. However, similar scenario may not always repeat in China, because it has been usually for the government to "pay the bills for the trouble makers" in order to maintain social stability, as result spoiled the polluters and would not be deter those who broke environmental law. The Fund Convention is a supplement tool for mandatory insurance for oil pollution from ships. China may either figure out possible timing to be a party of the Fund Convention, or to establish its own Fund System in order to tackle marine ecological damages caused by oil

spills in the future. Fund for compensation for oil pollution damage from ships was already examined and approved by the State Council, and it was reported that the permanent administrative organ of the Fund would locate in Shanghai<sup>56</sup>. In addition, Management Regulations of Collection and Use of the Ships Pollution Damage Compensation Fund has been implemented in China since July 1, 2012. Further implemented laws and regulations in relation to the Fund system in China will be promulgated, in return to improve the legislation concerning compensation for marine ecological damages.

<sup>1</sup> See "The oil spill accident in China's biggest oil and gas field", http://www.infzm.com/content/60932, Nan Fang Zhou Mo [Southern weekend ] June 20, 2011; "3-year plan to heal wounds of Bohai Bay oil spill", China Daily, June 23, 2012.

<sup>2</sup> State Oceanic Administration, Zhong Guo Hai Yang Fa Zhan Bao Gao 2012 [China Ocean Development Report 2012], Beijing: Ocean Publishing House, 2012, pp. 231-232.

<sup>3</sup> See "Investigation Report on the Oil Spill Accident of Penglai 19-3 Platform conducted by the Joint Investig ation Group," available at http://www.soa.gov.cn/soa/news/importantnews/webinfo/2012/06/13399805591037 21.htm, access date: June 21, 2012.

<sup>4</sup> See "Investigation Report on the Oil Spill Accident of Penglai 19-3 Platform conducted by the Joint Investig ation Group," available at http://www.soa.gov.cn/soa/news/importantnews/webinfo/2012/06/13399805591037 21.htm, access date: June 21, 2012.

<sup>5</sup> See "Regulating offshore oil exploitation by New Policies of Environmental Protection," available at http://news.cnpc.com.cn/system/2012/11/27/001402326.shtml, access date: March 7, 2013.

<sup>6</sup> See "ConocoPhillips: Minimal damage from Bohai spill", available at http://www.china.org.cn/environment/ 2011-12/20/content\_24198418.htm, access date: March 7, 2013.

<sup>7</sup> See Judy Hua and Don Durfee, "China eyes controls as ConocoPhillips apologizes for spill," available at http://www.reuters.com/article/2011/09/07/us-conocophillips-idUSTRE7860P020110907, access date: Sep 7, 2011.

<sup>8</sup> Wang Canfa, Chinese Environmental Law Enforcement: Current Deficiencies and Suggested Reforms, 8 Vt. J. Envtl. L. 159, 2007.

<sup>9</sup> China ratified the International Convention on Civil Liability for Bunker Oil Pollution Damage in December 2008. The Convention entered into force On March 2009 in China.

<sup>10</sup> Tashman Sea accident: on November 23, 2002, the Maltese-registered Tasman Sea, laden with crude oil, collided with Shunkai No. 1, a Chinese vessel, 23 nautical miles east of the Tianjin Dagu Anchorage, north China, triggering an oil spill. Tianjin Oceanic Bureau brought the lawsuit in Tianjin Maritime Court against the owners of the Tasman Sea, Infinity Shipping, and its insurers, the London Protection and Indemnity Club, seeking compensation for damage to the marine environment caused by the spill.

<sup>11</sup> See Jin Haifa First Trial No. 183 Civil Verdict, Tianjin Maritime Court (2003).

<sup>12</sup> See "Losses at Sea", available at http://www.chinadialogue.net/article/show/single/en/4433-Losses-at-sea, a ccess date: March 1, 2013.

<sup>13</sup> Xiaoqin Zhu and Lin Dong, Maritime Environmental Protection under International Law: Legal Remedies for Marine Ecological Damage in China: As Illustrated by the Tasman Sea Oil Spills Case, 2 JEAIL 391, 2009. <sup>14</sup> Lahnstein Christian, *A Market-Based Analysis of Financial Insurance Issues of Environmental Liability Taking Special Account of Germany, Austria, Italy and Spain, in* Faure Michael, Deterrence, Insurability, and Compensation in Environmental Liability: Future Developments in The European Union, Springer Wien, 2003, p. 307.

<sup>15</sup> OPA 1990, 33 U.S.C § 2701, Section 1002(b)(2).

<sup>16</sup> See Patricia Birnie, Alan Boyle, and Catherine Redgwell. (2009), International Law and the Environment, New York: Oxford University Press, p. 437.

<sup>17</sup> Xiao Zhu. (2007), Rethinking the Dilemma Reflected from the Administrative Penalty for Song Hua Jiang Water Pollution: An Angle of the Responsibility to Compensation on Ecological Damages, Law Science [Fa Xue] 3.

<sup>18</sup> Article 9, Constitution of the People's Republic of China (adopted on December 1982, as amended in 1993.

<sup>19</sup> Article 6, Environmental Protection Law of the People's Republic of China (adopted in December 26, 1989).

<sup>20</sup> Adopted at the 24th Meeting of the Standing Committee of the 5th National People's Congress on August 23, 1982; revised at the 13th Meeting of the Standing Committee of the 9th National People's Congress on

December 25, 1999 and promulgated by Order No. 26 of the President of the People's Republic of China on December 25, 1999.

<sup>21</sup> Xiaoqin Zhu and Lin Dong. (2009), Maritime Environmental Protection under International Law: Legal Remedies for Marine Ecological Damage in China: As Illustrated by the Tasman Sea Oil Spills Case, Journal of East Asia & International Law 2: 391-407.

<sup>22</sup> Xiao Zhu. (2007), Legislation Modes for the Definition of Ecological Damages in China, Zhe Jiang Academic Journal [Zhe Jiang Xue Kan] 3; Xiao Zhu. (2007), Rethinking the Dilemma Reflected from the Administrative Penalty for Song Hua Jiang Water Pollution: An Angle of the Responsibility to Compensation on Ecological Damages, Law Science [Fa Xue] 3.

<sup>23</sup> Collision near the mouth of Zhu Jiang River: On December 7, 2004, a Panama registered vessel collided with a German registered vessel at the sea near the mouth of Zhu Jiang River. Oil leaked from the German vessel after the collision and resulted in the most serious marine pollution in that region. Compensation claims soon brought by six claimants, including Guang Dong Maritime Safety Administration, Administration of Ocean and Fisheries of Guang Dong Province, Administration of Ocean and Fisheries of Hai Nan Province, and class action brought by 96 fishermen from Hainan Province. Hai Nan fishermen asked for 83,038,700 yuan as compensation for the polluted marine ecology, marine protected areas, and marine living resources, clean-up fees for the beach and coastal lines, fishery losses and so on. On August 11, 2006, with the mediation arranged by Guang Dong Maritime Court, two respondents reached agreement with the claimants and agreed to pay around \$8.5 million, among which \$850,000 would be allocated to Hai Nan claimants with the assistance of local departments of Guang Dong Claimants. See "Successful Mediation Settlement for 12.7 Collision Accident near to Zhu Jiang River Mouth by Guang Zhou Maritime Court", available at http://www.gzhsfy.org/showccmtnews.php?id=6939, last access date: March 7, 2013.

<sup>24</sup> OPA 1990, 33 U.S.C 2702, 1002 (b) (2) (A).

<sup>25</sup> Jiayi Liu. (2011), Public Interest Claims on Marine Ecological Damages Caused by Oil Pollution Under the Legal Framework of Marine Environmental Protection, China Soft Science Magazine [Zhong Guo Ruan Ke Xue]5.

<sup>26</sup> Jiayi Liu. (2010), Study of International Oil Spill Cases and Legal Mechanism of State Claim on Marine Ecological Damage, Ocean Press: Beijing, pp. 90-91.

<sup>27</sup> Shanshan Zhang. (2002), Claimant Qualification for the Administrative Departments to Claim for Marine Environmental Damages, in Tianjin Maritime Court (2002), Proceedings for the 11<sup>th</sup> National Conference on Trials of Maritime Courts, p. 52.

<sup>28</sup> Yue Gaofa Final Trial No. 327 Economic Verdict, Guang Dong Supreme Court (1999).

<sup>29</sup> Jin Haifa First Trial No. 183 Civil Verdict, Tianjin Maritime Court (2003).

<sup>30</sup> See Jin Haifa First Trial No. 183 Civil Verdict, Tianjin Maritime Court (2003).

<sup>31</sup> See "State Oceanic Administration Began to Claim for Marine Ecological Damages Caused by Penglai No. 19-3 Oil Platform," available at http://www.soa.gov.cn/soa/news/specialtopic/yiyou/webinfo/2011/08/1314515 388756755.htm, access date: Oct. 18, 2011.

<sup>32</sup> See Tonghui Zhu. (2010), Recollection and Inspiration on the Disposal of Oil Spill Accident in Xin'gang, Dalian, Ocean Development and Management 27 (8).

<sup>33</sup> See "Contractors were asked to be responsible for Dalian Xingang oil spill accident the CNOOC put investment as alternate for compensation," Economy & National Weekly, Jan. 1, 2011.

<sup>34</sup> OPA 1990, 33 U.S.C § 2701, Sec. 1006 (d) (1).

<sup>35</sup> Sanne Knudsen. (2009), A Precautionary Tale: Assessing Ecological Damages After The Exxon Valdez Oil Spill, 7 U. St. Thomas L.J. 95.

<sup>36</sup> Governments' Memorandum in Support of Agreement and Consent Decree (October 8, 1991), available at http://www.evostc.state.ak.us/pdf/settlement/gov\_memo100891.PDF, access date: April 8, 2013.

<sup>37</sup> Article 2, Specification Method for the Calculation of Fishery Loss in Water Area, promulgated by Ministry of Agriculture on Oct 8, 1996.

<sup>38</sup> Article 6.1, Specification Method for the Calculation of Fishery Loss, promulgated by Standardization Administration on June 1, 2008.

<sup>39</sup> Article 8.2, Technical Guidelines for Ecological Damages Assessment on Marine Oil Spill, Issues by the State Oceanic Administration on April 9, 2007.

<sup>40</sup> Article 150, Notice of Supreme People's Court on Circulating the "Summary of the Second National Working Conference on Foreign–related Commercial and Maritime Trails," Document of the People's Supreme Court, Fa Fa [2005] No.26.

<sup>41</sup> Article 150 (3), Notice of Supreme People's Court on Circulating the "Summary of the Second National Working Conference on Foreign–related Commercial and Maritime Trails".

<sup>42</sup> Guoping Xu. (2007), Legal Problems Need to Be Solved in the Legislation on Natural Resource Damages Caused by Oil Pollution from Ships, in Proceedings on International Conference on Maritime Law 2007.

<sup>43</sup> Article 150 (3), Notice of Supreme People's Court on Circulating the "Summary of the Second National Working Conference on Foreign–related Commercial and Maritime Trails."

<sup>44</sup> See "Dilemma for the Compensation after Oil Spill Accident", Xinmin Weekly, June 21, 2011.

<sup>45</sup> Sanne Knudsen. (2009), A Precautionary Tale: Assessing Ecological Damages After the Exxon Valdez Oil Spill, 7. U. St. Thomas L.J. 95.

<sup>46</sup> Article 20, Marine Environmental Protection Law.

<sup>47</sup> Article 7, Technical Guidelines for Ecological Damages Assessment on Marine Oil Spill (Marine Industry Standards of the PRC, HY/T 095-2007), issued on April 9, 2007, State Oceanic Administration (implemented on May 1, 2007).

<sup>48</sup> Article 8.1, Technical Guidelines for Ecological Damages Assessment on Marine Oil Spill.

<sup>49</sup> Jiayi Liu. (2011), Public Interest Claims on Marine Ecological Damages Caused by Oil Pollution Under the Legal Framework of Marine Environmental Protection, China Soft Science Magazine [Zhong Guo Ruan Ke Xue]5.

<sup>50</sup> Jin Haifa First Trial No. 183 Civil Verdict, Tianjin Maritime Court (2003).

<sup>51</sup> Jin Haifa First Trial No. 183 Civil Verdict, Tianjin Maritime Court (2003).

<sup>52</sup> Zhang liying and Liu Jia. (2011), The Accountability of the Offshore Drilling Platform's Oil Pollution Damages in the COPC Incident: In Comparison with the United States Gulf of Mexico Oil Spill Incident, China Oceans Law Review, Issue 14, No. 2, p. 158.

<sup>53</sup> Section 1004(a) (3), Oil Pollution Act 1990, 33 U.S.C. § 2701.

<sup>54</sup> H.R. 3534, 111th Cong. (2010).

<sup>55</sup> John Wyeth Griggs. (2011), BP Gulf of Mexico Oil Spill, Energy Law Journal, Vol.32, No. 1, p. 57.

<sup>56</sup> See "Fund for compensation for oil pollution damage from ships will locate in Shanghai," Oriental Morning Post [Dong Fang Zao Bao], Sep 16, 2011.

# **Measurement of Container Security at Dry Ports**

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#### Abstract

In recent years, container security at nodes in the international supply chains such as inland dry ports has become a major concern on the international maritime agenda. If security measures and initiatives are not carefully designed and effectively implemented, they can negatively impact the entire maritime transport chain. Yet, there are limited studies conducted on this subject. In this paper, we aim to address this gap by devising a framework for measuring the quality of container security at dry ports by conducting an empirical study to verify the quality of container security at 26 Indian dry ports. The study was conducted by using the triangulation of both mail survey and in-depth interview techniques. It was evident from this study that the standards of container security at the said dry ports left much to be desired. The paper also analyses the reasons for such abysmal level of container security at the dry ports.

Statistical analysis employed in this paper reveal that there is a clear consensus amongst all the respondents that quality of container security at dry ports is a construct consisting of five dimensions, namely, equipment, personnel, policy and planning, drills and training, and security audit. In the context of Indian dry ports, the quality gaps of container security service are currently related to policy and planning, as well as security equipment. The paper also argues that the positive outcomes of container security at dry ports could be realized only if the dry ports employ effective container security management strategies. Finally, academic and managerial implications are explained and future research directions along this research area will be outlined.

Keywords: Dry Port, Container Security, Service Quality and India.

#### 1. Introduction

Maritime transport is one of the most ancient modes of transportation since the inception of the human civilisation. In recent years, the issue of maritime security has become a major concern in the international maritime agenda. Maritime security dates back to the early maritime history under the themes of piracy and cargo theft and now includes also stowaways, people and drug trafficking, information security and, of course, maritime terrorism after the September 11th event. When it comes to transportation of containers, there have been various scenarios in which this special type of cargo in maritime transportation can be used as weapons of terror. Containerisation has revolutionised the maritime industry and nowadays it is of critical importance especially in the context of multi-modal transport. More than 90% of world trade travels in containers aboard ocean-going ships whilst about 151 million TEUs move through world ports in 2011 (UNCTAD 2012). In the United States, nearly 50% of the value of all US imports arrives via sea containers (Stasinopoulos 2003). Although containers provide shippers and maritime service providers with advantages in terms of safety of handling and cargo security from threats such as theft and pilferage, they also pose some other security threats. It is argued that containers can also be misused by drugs dealers, crime syndicates and contraband

dealers for these activities, or high-value cargoes in containers can also be targets of thieves with internal conspiracy (OECD 2003).

However, the most concerned terrorist threat involving container transport system is that it can be exploited by terrorists groups for their purposes, for instance, using containers to transport and deliver weapons of mass destruction (WMD). In a worst case scenario, it is hypothesised that terrorists can load weapons of mass destruction, for example, nuclear, radioactive or bio-chemical weapons, into a shipping container and introduce it into the international transport system using legitimate shippers, intermediaries and carriers, and remotely detonate the weapon upon its arrival in the heart of a major population centre. The success probability of such operations would be heightened by the fact that only a small number of containers are physically examined (In the United States, for instance, roughly 17,000 containers arrive U.S. ports each day and about 2% of them were examined before the September 11<sup>th</sup> attack) (OECD 2003, Stanford Study Group 2003, RAND 2003). The terrorist attack with WMD, if materialised, can result in significant loss of human lives, destruction of infrastructures, and erosion of public and business confidence; and ultimately, global trade and prosperity are threatened (Lee and Whang 2003). Another terrorist threat involving containers is that while they safely carry legitimate dangerous cargoes such as explosive compounds, munitions, fireworks and dangerous chemical, terrorists can mask the true identity of these hazardous cargoes so as to use these as weapons for achieving their purposes (OECD 2003).

Because of the critical importance of container transport system in maritime transport industry and potential security threats that they pose, the security of containers is thus extremely vital. There has also been a paradigm shift of focus regarding the perception on security of containers. Before the security threat of terrorism in maritime transportation is recognised, the traditional approach to container security is keeping the goods that were supposed to be in the box, in the box. Given the terrorist threats, especially the scenario that terrorists can use container to conceal and deliver WMD, there is added responsibility to ensure that things that are not supposed to be in the box are actually kept out of the box (Eyefortransport 2002). To ensure the integrity of containers is thus critical as a matter of security, since the integrity of container will affect the security of cargo inside containers, and therefore, the security of maritime transport services (RAND 2003). However, characteristics of the container transport system also create some difficulties for security efforts. For example, the movement of each container is part of a transaction that can involve up to 25 different parties: buyers, sellers, inland freighters and shipping lines, middlemen (customs and cargo brokers), financiers and governments. A single trade can generate 30-40 documents, and each container can carry cargo for several customers, thus multiplying the number of documents further (Economist 2002). Such a complexity of the container transport system triggers the need to address the security of this system with a comprehensive intermodal framework integrating measures across the entire container transport chain. While such a framework may exist covering ports and maritime transport, there is not yet an analogous framework for inland transport (RAND 2003, OECD 2004). This implies the fact that while there has not been any such a framework, it is critical to promote a self-regulation culture involving security as similar as what the ISM Code is aiming for safety in maritime transport.

As can be seen from the earlier argument, the issue of container security cannot be tackled purely by the container shipping lines and ports since it involves the whole supply chain, including inland ports. Therefore, in this paper, we aim to address the aforementioned issue from the inland port perspective by critically examining the important security components that inland ports must possess in order to manage security effectively, i.e. ensuring security while not jeopardizing business efficiency.

The reliability, safety, time and cost of transportation, both on land as well as over sea have morphed the global trade and have almost uniformly enhanced the standard of living. Furthermore technological advances particularly in information and communication have resulted in lower transportation costs and shrinking of *economic* distances and consequently more trade. Dry ports have been playing an increasingly important role in the trading system. Economic reforms, trade liberalization and the development of land infrastructure have abolished captive hinterlands, thus obliging different dry ports to compete for customers. Greater choice in routing cargo and parallel advances in supply chain management has altered the nature of competition from ports and dry ports to one between supply chains. This is precisely what makes *container security* a most critical, relevant and timely issue for the present era.

Usually located near or along gateway seaports, industrial regions and/or transportation axes, dry ports perform several important functions (Nozick & 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 in gateway seaports; (vi) assistance in inventory management; and (vii) deference of duty payment for imports stored in bonded warehouse (Paul 2005). Dry ports also play a key role in the supply chain of a country's international trade and inland cargo transportation, acting as nodal points of cargo consolidation and distribution, while providing connectivity to the gateway seaports. In India in particular, over 70% of container throughput originates in the dry ports.

Presently, the ownership and operations of the dry ports in India can broadly be divided under two heads namely private and public. The permission for construction of dry ports is granted by the ministry of finance of the government of India. While granting the permission, the government implicitly permits individual dry ports to develop their own security plans without explicitly expounding on the liability and responsibility issues in cases of security breaches.

Conflicts of interest between different authorities and stakeholders have resulted in lack of adequate cooperation 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.

The remainder of this paper is organized as follows. First, a literature review will be conducted followed by the conceptual foundation for this research. Empirical validation is presented next with research methodology described and findings discussed. The paper concludes with the discussion of implications and recommendations for future extension of this research.

# 2. Literature Review

Measurement is a fundamental activity of science and is usually associated with other scientific questions (DeVellis 1991). Specifically, performance measurement is the process of measuring actual outcomes or the end goal of performance, as well as the means of achieving those outcomes as represented by in-process measures (Harbour 2009). Therefore, an absence of measurement scales for evaluating the development and managerial policies of the dry port sector and their role in enhancing port productivity and efficiencies is a potential barrier to the effective implementation of appropriate policies adopted by them.

The dry port industry in India as anywhere else embraces all the activities concerning the movement of cargoes among different parties within a transportation chain, whereby the activities involve the integration of upstream shippers and downstream consignees (Lun, Lai, & Cheng 2010). Therefore, implementation of effective policies needs coordination of internal functions within the dry port and the external operations of partner firms, e.g., shippers, consignees, logistics services providers, intermodal transport operators, and other trade related firms, along the transportation chain. However, stakeholders, such as shippers, consignees, and carriers, tend to emphasize the performance areas that serve their best interest. For instance, carriers may focus on operational efficiency, while shippers are more concerned with service effective policies would thus lead to inconsistency in the performance measures valued by different stakeholders.

The implementation of container security quality enhancement policy will have a strong impact on several aspects of service quality of a dry port. This could be done by adopting several container security initiatives and regulations which have been introduced by the IMO and US. In respect of some initiatives, IT plays a critical role in its success while other would require radical changes in operating practices in order to comply with security requirements. Such procedures serve two main purposes: better control of visibility of the shipment during transport, to and from ports, and better management of information regarding the shipment. Aichlmayr (2003) argued that about 6%–10% of money spent on transporting goods is wasted as a result of inaccurate, inadequate or insufficient information.

One of the most important thought behind the concept of measuring quality is expressed by Gronroos (1984)

who stated that the perceived quality of a given service is an outcome of the comparison between the customer's expectations about the service and the perception about the actual service received by him. Thus the quality of the service is dependent on two variables, viz; the expected and perceived service and when both these aspects are compared, they give birth to the concept of service quality. Taking this fundamental concept into consideration, Parsuraman *et al.* (1991) developed the GAP model which has been extensively used in several service industries such as Banking, Hospitality, Transportation, Retail etc. but is used for the first time to measure the quality of container security at Indian dry ports in this study.

Gronroos (1984) has also stated that a service provider must have an understanding of the concept of service quality and the way the quality is influenced by different factors, both external and internal. Hence, in order to improve service quality, the service provider has to necessarily align both the aspects of expected and perceived service with each other. This is only possible if the gaps between the expected and perceived qualities are identified, analyzed and bridged over by the service provider. With regards to dry ports, service quality indicates several aspects such as on time delivery, accuracy of order fulfillment, frequency of service, compensation for loss or damage, promptness in attending to customer complaints, commitment to continuous improvement, etc. (Millen & Maggard, 1997). However, container security does not receive its due importance from the dry port operator as he does not consider container security as an integral part of the service offered by him.

The literature about service quality is extensive in terms of definitions, dimensions, models and measurement issues related to service quality (Asubongteng *et al.*, 1996; Dabholkar *et al.*, 2000). It is also well supported by a large number of empirical studies from a variety of service related application areas (Badri *et al.*, 2005; Seth *et al.*, 2006; Yeh & Kuo, 2003). In the original model developed by Parsuraman *et al.* (1988), 10 dimensions of service quality covering 97 service items were identified. Subsequently, after conducting Exploratory Factor Analysis (EFA) the ten dimensions were collapsed into five dimensions. These five dimensions along with 22 service items yielded the scale of the SERVQUAL model which has been revised, refined and reformed over the years. A detailed survey of the literature on the applications of the SERVQUAL model has been conducted by Badri *et al.* (2005). In this paper, we too follow the footstep of Parasuraman *et al.* and have divided the container security concept in five dimensions covering 24 service items.

Several researches on service quality have been developed around this model (Davis & Mentzer, 2006; Piero *et al.*, 2005; Chen *et al.*, 2009). However, the conceptualization and measurement of service quality by using this model has not been bereft of its share of controversy and criticism. Gronroos (1984) argued that the model was more suitable for measurement of performance rather than service quality while Cronin & Taylor (1992) proposed a modification of the model and called it SERVPERF. Teas (1993) also addressed the aspect of measurement of expectations and developed the Normed Quality and Evaluated Performance model. Durvasula et al., (1999) contended that the SERVPERF model has better prediction ability as compared to the gap model. In spite of such adverse critical comments, Parsuraman *et al.* (1993) maintained that their model has much wider perspective when it comes to measurement of service quality. In the context of maritime transport, the SERVQUAL instrument has not been applied popularly. There has also been an attempt to construct a separate scale of measuring service quality of maritime transport services, the ROPMIS model, incorporating new dimensions such as management, image and social responsibility (Thai, 2008).

Unlike physical goods, quality of which can be measured unambiguously for durability or defects, service quality is abstract and elusive because of three factors viz; intangibility, heterogeneity and inseparability of production and consumption (Parsuraman et al.,1993). Thus in the absence of objective measures, the quality of security service in a facility such as dry port can only be assessed by measuring the stakeholders expectations/perceptions. However, there is no quantitative yardstick available for gauging these perceptions precisely. It goes without saying that without a clear and unambiguous definition of service quality the dry port operator would issue vague instructions for improving service quality which would further complicate matters (Lehtinen & Lehtinen, 1982). In such circumstances the focus shifts to the service process from service outcomes (Asubonteng *et al.*, 1996). In other words process quality assumes greater importance rather than final outcomes. This is particularly applicable in case of dry ports as the stakeholders compare their expectations against their experiences than eventual outcomes and develop impressions of service levels.

The concept of service quality from the perspective of the different stake holders varies sharply. The number of service quality dimensions depends upon the complexity of the service offered by the service provider. By attempting to examine the quality of container security at a dry port in conjunction with sustainable competitive advantage derived by the user and aligning it with the stated objectives/visions of the dry port, we expect to highlight hitherto unknown facets of service quality concept. By attempting to analyze the gaps in service quality of container security provided by the dry port operator, this paper will assist in closing them and improving service quality.

#### 3. Research Design and Data Collection

The measurement and analysis of port security policy needs to be the starting point of our analysis. While there have been multitudinous efforts in the study of port security policy, to date there has been no consensus on the adoption of the appropriate measurement tools. In developing a measurement instrument for evaluating the quality of container security service, we followed the standard guidelines to ensure the key components of validity with respect to content, discriminant, convergent, and nomological validity (Bagozzi, Li, & Phillips, 1991). Using the inputs from an earlier study (Haralambides & Gujar, 2012), together with the insights from ten professionals in an international port economists forum we developed an appropriate questionnaire consisting of 26 service items.

The measurement instrument so constructed was further validated with the help of Exploratory Factor Analysis (EFA) and, following this, the service items are reduced to 24. These items were measured on a seven-point Likert scale, where 1 = strongly disagree and 7 = strongly agree, to measure the extent to which the policy were implemented in the port sector. We also conducted a content validation test by inviting experts in the port industry to review the measuring items, so as to ensure that they are representative of our conceptualization of a suitable container security policy implementation. We then invited five shipping and seven logistics experts from academia and five industry practitioners to review the questionnaire to ensure the relevance and clarity (i.e., face validity) of the descriptions for each item in the measurement scale. We explained to the experts the purpose of our study and asked them to comment on the items for completeness, understandability, terminology used, and ambiguity. We made several changes to improve the wording after the expert review and refined the questionnaire items in a pilot test.

We initially pilot tested the measurement scale for evaluating container security policy implementation with 30 managers attending a postgraduate master's program in international shipping and transport logistics. The pilot test sought their feedback with a view to improving the wording and seminal meanings of individual measurement items for content validity. Subsequently, we organized the refined measurement items collectively as a measurement scale in the form of survey questionnaire for administering to a sample of shipping, port and intermodal operator companies to capture the status of container security policy implementation in the port industry. To evaluate the construct of policy implementation, we then carried out the Confirmatory Factor Analysis (CFA) tests to examine the measurement properties, followed by a comparison of the test results of two alternative measurement models to evaluate the policy implementation construct.

Subsequently data was collected through personal semi-structured interviews followed by a written questionnaire survey. In order to get a balanced opinion we selected respondents not only from various firms and organizations but also representing different hierarchy. However all of them had adequate field experience of at least 2 years. Though we used a questionnaire to solicit their views the interviews were semi structured in nature. All the respondents were also answered confidently.

The first questionnaire was administered to 300 specifically selected addressees who could be considered as port stakeholders. Each target respondent received an initial mailing, which consisted of a covering letter explaining the purposes of the study and a copy of the questionnaire. Approximately one month later, we sent a second mailing identical in content to the initial one to the non-respondents, followed by a reminder letter two weeks after the second mailing. We received a total of 247 usable questionnaires, yielding a valid response rate of 82.3%. We have broadly divided the respondents into nine major groups, depending on the role they played in port operations. They are summarized in Table 1 below.

	Categories of Respondents		
1	Shipping Lines	32	
2	Freight Forwarders	43	
3	Railway officials	21	
4	Port Officials	20	
5	Custom Officials	21	
6	Shippers	37	
7	Consignees	47	
8	Logistic service Providers	47	
9	Port Labor	32	
	Total	300	

**Table 1: Details of Respondents** 

The questionnaire was built in a manner by which the respondent could express what he expected of a specific aspect of a specific facility which he patronized and how he perceived the facility in reality to be. We also asked the respondent to assign a weight for each of the five dimensions. This helped us to quantify the weighted average gap score which is shown in table 3. 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. 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
- 5. Qualifications of Personnel employed are suitable for the job

# **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

#### **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

# 4. Data Analysis

## 4.1 Reliability Test

Before proceeding to conduct various multivariate tests, we first examined the skewness and kurtosis scores of each item to ensure there is no serious deviation from the normality assumption (Hair, Black, Babin, & Anderson, 2010). All of these scores fall within the range of -2 to +2 (skewness: -0.90 to 1.10; kurtosis -0.94 to 1.18), suggesting no violation of the normality assumption and the data quality is assured. To assess the measurement properties of container security policy implementation, we first conducted the reliability test and corrected item-to-total correlation (CITC) analysis, followed by CFA. Though the CITC analysis assesses how well all the items are highly correlated if they belong to the same domain of concept in order to improve model reliability we also used CFA to assess how well the observed variables reflect unobserved or latent variables. Table 2 summarizes the Cronbach's alphas for the five dimensions and the CITC results. All the seven factors of BPP implementation have a Cronbach's alpha and composite reliability greater than the recommended threshold value of 0.70 (Fornell & Larcker, 1981; Nunnally & Berstein, 1994) and all the CITC results are greater than 0.50 (Churchill, 1979).

# 4.2 Convergent and Discriminant Validity

We next performed a CFA using the maximum likelihood estimation with AMOS 18.0. We used a multiple of goodness-of-fit indices to evaluate the fit of the factor structure of the CFA. The criteria of these indices for evaluating fitness are: comparative fit index (CFI) > 0.9, incremental fit index (IFI) > 0.9, root mean square residual (RMR) < 0.1, and normal fit index (NFI) > 0.9 (Hu & Bentler, 1999).

To test the convergent validity of the measurement scale, we followed Fornell and Larcker (1981) and calculated the AVE values. The AVE of each construct exceeds the recommended minimum value of 0.5, which indicates convergent validity. The significant loading of the measurement items on their latent factors (> 0.4 and t > 2) provides further support for convergent validity. We also followed Fornell and Larcker (1981) to test discriminant validity. The square root of AVE of each construct is greater than the correlation between any pair of them. This suggests that the relationship between the measurement items of their respective construct is greater than the relationship of the measurement items across constructs. This result provides evidence of discriminant validity.

We conducted a series of  $\chi^2$  difference tests between nested CFA models for all pairs of constructs to assess the discriminant validity of the constructs to examine the degree to which each construct and its measurement items are different from another construct and its measurement items (Churchill, 1979). We compared the  $\chi^2$ between the constrained model, where the correlations between two constructs are constrained to 1.0, and the unconstrained model, where the two constructs vary freely (Bagozzi, Yi, & Phillips, 1991). Table 2 provides a summary of the  $\chi^2$  values of the unconstrained and constrained models. Significant  $\chi^2$  differences between all pairs of constructs indicate discriminant validity.

	Table 2: Results of Reliability and Cfa								
BPP	Cronbach's	Range	of	CFI	IFI	RMR	NFI	χ2 (df)	AVE
	alpha	CITC						(all with $p < 0.001$ )	
EQUIP	.92	.6186		.96	.96	.03	.95	33.16(8)	.62
PERS	.93	.7189		.98	.98	.04	.97	13.23(5)	.74
POLY	.96	.7692		.94	.94	.07	.93	62.95(8)	.69
TRNG	.94	.7790		.92	.91	.05	.91	41.54 (6)	.85
ADT	.90	.5976		.98	.98	.04	.97	12.91(4)	.63

# 5. Perception-Expectation Gaps of Container Security Dimensions

Table 3 indicates the weighted mean gap scores of all five dimensions of container security. It can be noticed that all the scores are negative, i.e. there exist gaps between the stakeholders' perception and their expectation of all container security dimensions at dry ports. The largest gap is seen in the policy dimension particularly 5<sup>th</sup> and 6<sup>th</sup> service items concerning employee guidelines and benchmarking of security standards. The main reasons for such a scenario are the inadequate awareness about the importance of container security in the minds of all stakeholders and secondly the ambiguities in the government policy relating to the responsibility of dry ports with respect to container security. The current policy does not saddle the dry ports with liability for container security failures, nor do they specify limits of liability. The responsibility of the carrier to exercise due diligence in making the ship seaworthy is a well established principle in maritime law. In a similar situation, the International Port and Ship Security Code (ISPS) saddles the sea ports with the responsibility to ensure security. The absence of a similar code applicable to dry ports is starkly conspicuous. This elicits a non standardized response from the dry ports.

The second largest gap in the mean scores between perception and expectation of the stakeholders is towards the container security equipment dimension. Indeed, gaps exist in all service items within this dimension, i.e. there is a difference between stakeholders' perception of these service items at JNPT dry ports and those expected of an excellent dry port in terms of container security equipment. These differences are also evident in all other dimensions of container security at dry ports. From the quality management viewpoint, such gaps between stakeholders' perception and their expectation of various container security dimensions signify the lack of quality in providing container security service at dry ports.

#### Table 3: Weighted Mean Gap Scores

					-	
	1	2	3	4	5	Mean
Equipment	-2.90	-3.00	-3.00	-3.00	-3.10	-3.02
Personnel	-3.10	-2.90	-3.00	-3.00	0.00	-2.00
Policy	-3.10	-3.00	-3.10	-2.90	-3.10	-3.05
Training	-3.40	-3.20	-3.30	-2.80	0.00	-2.12
Audit	-3.50	-3.60	-3.20	-3.40	-3.50	-2.87

It can be noticed from the expected mean score that the largest score pertains to the policy dimension followed by equipment, audit, training and personnel. The policy on container security is essentially formulated by the government; as such the blame for this must also lie at the doors of the government. The government has failed to unambiguously enunciate its policy on container security particularly in the context of affixing liability and responsibility. In such circumstances every dry port develops and implements its own security policy which serves no specific purpose.

#### 6. Inferences and Discussions

While seeking to interpret the results and findings of this study especially while attempting to draw some general inferences, caution needs to be exercised. This is because cross extrapolation is neither correct nor possible as it is practically impossible to replicate all the circumstantial inputs. Furthermore, certain outputs are a result of several intangible inputs combined together in different ratios of permutations and combinations.

However, some broad inferences can certainly be drawn from this paper. The first inference is that a quantum of minimum capital investment is essential for implementing container security strategy which naturally will adversely impact operational efficiency. There is also an unintended consequence of such capital investments which is creation of excess capacity to cater to future demand and growth.

Cargo safety and security in the inland container transportation is a complex issue that involves numerous key actors such as customs, railways and police, in addition to other enforcement and inspection agencies, but the onus of providing security in the dry ports has been placed on the *custodian*. However, the custodian is not saddled with the responsibility of exercising *due diligence* in his operations so as to eliminate the possibility of contraband in containers. *Due diligence* in this context would mean the steps, equipment, personnel and the

procedures which ought to have been allotted or prescribed for cargo handling, or the precautionary steps taken by the custodian to ensure security and integrity of cargo in the dry ports.

Container security improvements resulting from improved policy and procedures implementation will definitely have a positive impact on service quality of dry port operations especially due to enhanced shipment tracing capability. Moreover, in dry port operations, the reliability of service is critically important, since logistics costs increase and service levels decline as reliability of service – for example delivery time reliability – decreases. Thus, the relationship between security improvements and shipment safety and security is the most direct and comprehensible. The importance of security improvements in this respect has long been acknowledged as a contributing factor to increase profits for organizations. Sennewald (1978) even argues that security contributes to company or corporate profit by reducing or eliminating preventable losses.

Security improvements also have an impact on the reliability of documentation, so that documentation processes conducted by dry port service providers can be potentially free from errors. Improved systems and procedures will also help to reduce the intervention of human input and possible errors in the processes of documentation preparation and issuance.

Another potential impact of security improvements is on the competitive price of service. The infrastructure and facilities of a dry port are essentially designed and built for efficiency and competitiveness, not security. In dry port operations, specifically, the competitive price of service is critically important as the profit margin in this sector is very slim. However security improvements and other security-related processes and procedures required by security initiatives would also affect the operating and capital budgets of many firms, and hence increase the cost of providing the service which would lead to an increased price of service and therefore affect the competitiveness of the service provided. As such small and medium-sized dry ports would find bearing the costs associated with these requirements more difficult than dry ports with greater resources.

In the long run, however, benefits should outweigh the initial costs of security investment. Secondly, the costs of ineffective security management may in fact be larger than the potential benefits realized from security improvements. An 'examine everything' inspection approach or bad management of shipment information, for instance, can potentially lead to delays and congestion, and thus reduce the speed and reliability of service.

Security improvements also have an impact on the efficiency of operations. A review of the literature in this respect identified several discussions on the impact of heightened security on the efficiency gains of the supply chain. More specifically, security measures superficially appear to jeopardize the long established efficient business operating practices, which have brought massive efficiency gains to the global supply chain in the first place. But, if security is not effectively managed and an 'inspect everything' practice is utilized, the efficiency of operations and management of supply chain players may actually deteriorate. This problem could be neutralized by using mathematical modeling and Automatic Targeting System (ATS) to minimize the number of inspection and transshipment container moves, it was found that the number of container inspections could be minimized.

To summarize, in dry ports, the enhanced capability of the dry port operator in shipment visibility control, increased speed of service performance, reliability of service performance and documentation processes can enhance the efficiency of their operations and management. They also help to enhance efficient information exchange at the ship/port interface, as well as among partners in the integrated supply chain. However from the standpoint of dry port operators, excess security efforts for the perceived level of security threat, or ineffective management of security improvements, may lead to waste for organizations and negative impact on the supply chain as a whole. Container security does not simply start at the main seaport, and therefore it must be put in the context of supply chain security and is subject to principles of good supply chain so as to achieve the two main objectives of supply chain management, namely, global optimization and managing uncertainties (Simchi-Levi et al., 2003).

In the general supply chain context, supply chain integration is not easily attained as players in the chain normally focus on sequential, rather than global optimization, and the sharing of information for integration

requires some level of trust. In practice, a 'focal' firm in the chain will normally take the lead and initiative to make a business case and bring all key players together for supply chain integration. For container security, since dry ports are considered as 'extended commercial arms' of main seaports, the latter should play the role of the 'focal firm' in the supply chain in coordinating and imposing the security policy, i.e. awareness and accountability on dry ports. Since there exists a close commercial link between dry ports and main seaports as the former functions at the satellite in canvassing and distributing cargoes for the latter, seaports hold the major responsibility in ensuring security requirements to be complied with due diligent not only at their premises but also at their suppliers' venues, such as dry ports. This will help complete the loop of control and management of quality of container security service from the perspective of 'group-wide quality control' (Ishikawa, 1990).

## 6. Conclusion

It is relevant to note that service quality measurement tools adopted are often inadequate as the respondents are confused at times and are not sure about their priorities. In order to eliminate bias and prejudice, research regarding measurement of service quality, has usually focused on the process of actual service delivery in addition to precisely quantifiable facts such as actual time taken to provide service, quantum of customers to whom service was provided in a given time period etc. The Gap model does manage to ascertain the demands and priorities of the stakeholders. It would be more helpful if such surveys were repeatedly undertaken at regular intervals. Furthermore, the selection process of respondent targets and construction of questionnaire should be paid more attention to achieve wider acceptability.

In order to improve quality of container security, it is critically important to understand the environment and the circumstances in which the demanded service was delivered. It will only then be possible to objectively judge and measure the performance of the dry ports and remedial steps could be undertaken to improve quality of security. The dry port operator also needs to differentiate the varying needs of different stakeholders. It is inappropriate on their part to implement standardized security policy when the objectives of different stakeholders are not only non - standardized but also vary from one transaction to another. In conclusion, it could be said that the dry ports, to a certain extent does manage to satisfy, most if not all the demands of the stakeholders. The inability of the dry port operator to completely satisfy the demands of all the stakeholders is mainly due to reasons beyond his control. But it would definitely be of assistance in improvement of security environment if the dry port operator and their employees endeavor to communicate more often with the stakeholders and explain the reasons for occasional security failures and the remedial steps undertaken to prevent re-occurrences of such failures. To summarize, understanding of different stakeholder's perceptions of container security and ability to measure it can be beneficial for the dry port industry as a whole.

It is fairly obvious that *container security* at the dry ports is a non issue at present. Furthermore, it becomes more complicated due to the involvement of numerous key actors such as customs, railways and police, in addition to other enforcement and inspection agencies, but the onus of providing security in the dry ports has been placed on the *custodian* i.e the dry port operator. However, the custodian is not saddled with the responsibility of exercising *due diligence* in his operations so as to eliminate the possibility of contraband in containers. *Due diligence* in this context would mean the steps, equipment, personnel and the procedures which ought to have been allotted or prescribed for cargo handling, or the precautionary steps taken by the custodian to ensure security and integrity of cargo in the dry port.

The Railways Act of 1989 which presently governs dry port operations in India was drafted in an era when the Indian Railways (IR) were not transporting containers. Indian Railways, have yet to develop a system of container cargo inspections. IR still continues to rely on the expressly stated threat in the Railways Act that makes the consignor (carrier) liable for any damage or loss suffered by it by reason of incorrect particulars furnished by the consignor in regard to the cargo, in the forwarding note submitted by him to the dry port operator. It is interesting to note that under the present conditions, all the agencies involved in stuffing, loading and transportation of containers hold the consignor liable for the particulars and do not consider checking the correctness as part of their responsibilities, even when they are expected to carry out "due diligence" in such matters.

Currently the dry port operators issue their own Inland Way Bills (IWBs) for the goods received by them for transportation but there is no standardized format for the IWBs. The IWBs implicitly state that "*This Inland Way Bill is issued subject to the conditions and liabilities as specified in the Railways Act 1989.*" However it is also mentioned in the IWB that the claims for loss suffered while transporting containers by road are actually settled as per Carriage by Road Act 2007. Thus the provisions of the Railways Act are invoked only for the railway portion of the transportation which only further complicates the issue of responsibility from the perspective of the shipper.

Thus there is an inherent contradiction between the stated legal status on the IWB and the legal obligations arising out of the Act under which road transportation is undertaken. In addition, there is also the issue of implementation that invariably demands larger allocation of resources.

Although India enacted the Multi Modal Transportation of Goods Act (MMTG) in 1993 to provide a seamless legal environment for the entire inland transportation of international containerized cargo, it failed to achieve the stated objective for several reasons. One of the most important of them was the non-recognition of the MMTG Act by foreign nations. Another reason for the failure to gain wider acceptability was its inability to appropriately integrate the different legal provisions mentioned in the different Acts which governed the inland transportation process, especially with regard to the liabilities and responsibilities of the various performing parties, including dry ports. The ratification of the dry port operator especially in exercising *due diligence* while conducting stuffing operations at the dry port. It would also go a long way in improving the security environment at the dry ports.

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# Hub-Port Choice in West Africa

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#### Abstract

Many West African countries are facing the challenge of expensive port charge due to several reasons. One of them is the lack of a hub port in the whole region. The carriers have to use Western Europe or Middle East hub ports, which seriously affects the cost. The purpose of this paper is to determine the right location of the hub-port for West Africa. Firstly we analyze the advantages of having a hub port in West Africa since a hub port will bring a considerable cost benefit. The study considers the main aspects that influence the hub port location choice. Secondly the qualitative and quantitative analyses of the ports in some coastal countries are done to evaluate their competitiveness and efficiency through multitude criteria. Thirdly we use an AHP method to find the most suitable hub Port.

Keywords: maritime transport, hinterland, competitiveness, hub-port, West Africa

## 1. Introduction

The maritime transport in West Africa is developing fast and the region strongly contributes to the African shipping market and offers a multitude choice for shipping companies due to its multitude ports. On the costal part there are eleven ports for about 320 million people. The port charge in these countries is relatively high comparing to other regions especially Asian and European countries.

The West African region is one of the few in the world without a dominant hub port. A 1990 World Bank study found that a combination of factors has dissuaded the creation of a West African transshipment facility. The same study also found that any cost savings resulting from containerization were not significant enough to warrant a transition from the existing multiple-ports of call to a transshipment facility. However, this paradigm appears to have changed and a market now exists for a regional transshipment hub port. In recent years, the area GDP kept growing what increased the port demand. This has developed a competition between ports that expect to attract more shipping companies.

Many West African countries have adopted different reforms to improve competitiveness; some like Nigeria change the port administration mode and improve the port equipment. More effort has been made in Tema and in Ivory cost where the different policies adopted have improved the port capacity. In Benin and in Senegal the procedure is in progress though the ports are no longer capable to face the port demand.

Nevertheless, all these ports are small and aren't able to receive big ships. All the major shipping lines have expanded their service networks and size of fleet in order to increase their carrying capacity to meet the growing demand of container transportation. The drafts in most ports of the West African countries are between 10m and 15m, which are not deep enough for the big ships. Therefore, port charge in West Africa is among the highest in the world due to the lack of a hub port in the region. This paper describes the global ports situation and makes a comparative choice analysis for a future hub port location. There are many factors

that determine a hub port choice such as port facilities, port location, port security, port service. All these factors that are considered by companies are taken into consideration by shippers in order to choose the port.

# 2. Overall Analysis of West African Shipping Market

For many years, West African ports have been blight by inefficiency, corruption and congestion. The infrastructure is not well maintained, the hinterland access infrastructures, such as highways, railways and waterways, are not well developed, and the bureaucracy plays an important role in such a way that in some ports it became an obstacle for all port users (Shipping Lines & Customers). The immediate consequences are that the vessels are wasting a lot of time due to the waiting, and cargo operation increases the costs of the shipping lines. In the end of the day, the end user in Africa is paying the price for it. The small ports that seriously lack infrastructures cannot face the port demand and the fierce international competitiveness. So far the area doesn't have a hub port and it has a big impact on the port's price as well. This entire situation and the lack of a direct and appropriate connection put West African landlocked countries in an even worse situation. Transport integration between African countries is very low. The landlocked countries in West Africa have to pay a high price because of the bad condition of the different mode of connection between the ports and their countries.

## 3. Hub-Port Choice Determinant Factors

There is an extensive literature as to what factors impact the choice of the port, defined here as the door-to-door shipment of imports and exports including land transport, maritime transport and transfer in ports. These factors include transport costs, transit time, frequency and reliability of service. User surveys dating back to the 1980's show that quality of service aspects are important (Peters, 1989; Collison, 1984). This research is refined by the use of the Analytical Hierarchy Process method to analyze the survey data.

The port choice elasticity is derived with respect to ports in West Europe (Veldman and Buckmann, 2003; Veldman *et al.*, 2005), in the US (Malchow and Kanafani, 2001 and 2004; Blonigen and Wilson, 2006; Anderson, 2009), in the Mediterranean (Veldman and Rachman; 2008), and in China (Tiwari *et al.*, 2003). The main explanatory variables used in these studies include: inland transport costs: sometimes distinguished by mode of transport or just approximated by over land distances between port and hinterland regions; Ocean transport costs: distinguished by port pair and/or approximated by overseas distances, or aggregated over all trades and averaged; Port costs in the combination with port efficiency: find a clear impact of port related costs on port choice; Quality of service aspects: in the studies concerning port choice in West Europe, hub port effects are approximated by port throughput level indicators.

# 4. Methodology

For this study to determine the hub port in West Africa we considered only four main criteria because of data constraints in the AHP (figure2). The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned according to data by summing of the products for all criteria. All the criteria do not have the same importance, thus the priorities will be derived from a series of measurements. We have compared the ports with respect to their strengths in meeting each of the criterions. Then we have compared the Criteria with respect to their importance to being the hub port. By processing a matrix mathematically, the AHP derives priorities for the port with respect to the criteria. The priorities are measurements of their relative advantages, derived from the judgments or data as entered into the matrix. These values have been calculated by using specialized AHP software. The priorities have then been combined throughout the hierarchy to give an overall priority for each port. The port with the highest priority will be the most suitable alternative.

## Figure 1: AHP Hierarchy for Choosing the Hub Port



- 1) Construct a pair-wise comparison matrix for criteria with respect to objective by using Saaty's 1-9 scale of pair wise comparisons
- 2) For each comparison, we will decide which of the two criteria is most important, and then assign a score to show how much more important it is.
- 3) Compute each element of the comparison matrix by its column total and calculate the priority vector by finding the row averages.
- 4) Weighted sum matrix is found by multiplying the pair wise comparison matrix and priority vector.
- 5) Dividing all the elements of the weighted sum matrix by their respective priority vector element.
- 6) Calculus to find the average of this value to obtain:

 $\lambda_{
m max}$ 

7) Calculate the Consistency Index, CI and the consistency ratio, CR and normalized values for each criteria/alternative.

## 5. General Conditions of West African Major Ports

For this study, we have considered three major ports: the port of Tema in Ghana the port of Dakar in Senegal and the port of Abidjan in Ivory Coast (Figure 2).



#### Figure 2: Map of the West African Countries

#### 5.1 The Port of Tema

The port of Tema is one of the two main seaports in Ghana and it handles about 80% of the nation's

import and export cargos. The port has 12 berths whose depths range from 8 meters to 13 meters.

A complete operational performance review of a port includes the five main port facilities or services: the berth, the storage yard, intermodal transfer, customs, and the gate. Tema port does not have an intermodal transfer facility, and the WA Trade Hub draft report addresses the operations at the storage yard and gate, as well as Customs procedures.

Tema port handled approximately 865,000 tons of transit cargo in 2008; on average, 48% was Burkinabe (413,000 tons). The majority of the Burkinabe transit traffic volume, 64% was handled at Tema port in containers as transit cargo. The highway from Tema to Ouagadougou is about 1,000 km and is generally in fair condition, with some segments in poor to very poor condition. All the transit cargo that is transported by the surface in the Tema-Ouagadougou corridor uses the highway for transportation along the route.

# 5.2 The Port of Abidjan

The Autonomous Port of Abidjan is a state owned enterprise. It has a depth of between 10 and 15 m. The PAA (the port of Abidjan) is a "landlord port". The PAA operates three quays. The North Quay has 5 mooring posts (with a total length of 775 m) and 5 storage facilities with an area of 28,800 m<sup>2</sup>. The West Quay has 10 landing posts (with a total length of 1525 m) and 10 storage buildings with an area of 55,200 m<sup>2</sup>. The South Quay has 5 landing posts (with a total length of 800 m) and 4 storage buildings with an area of 26,400 m<sup>2</sup>. The PAA also operates several specialized terminals: A modern container terminal covering 27 ha, with 5 mooring posts, a total quay length of 960 m and 4 container winches.

# 5.3 The Port of Dakar

Dakar has one of the largest deep-water seaports along the West African coast. It has an advantage over other West African ports because of its deep-draft structure and 640 foot-wide access channel (dredged to 36 feet) which allows round-the clock access to the port. Its strategic location at the extreme western point of Africa and at the crossroad of the major sea lanes linking Europe to South America and North America to South Africa makes it a natural port of call for shipping companies. Dakar ranks fifth in cargo volume in Africa after Richards-Bay, Durban, Lagos and Abidjan. The Port of Dakar has adequate depth and size to handle large vessels and has a number of berths to accommodate specialized cargo handling equipments. Its current infrastructure includes tanker vessel loading and unloading terminals, a container terminal with a storage capacity of 3000 TEU. The port of Dakar serves Senegal, Mali by highway and railway, Mauritania, Gambia, Guinea and Bissau-Guinea by highway. The market also includes the container traffic from and towards the hinterland, countries, such as Burkina Faso and Niger.

# 5.4 Transit and Connecting Corridors

In West Africa, the freight distribution system is entrenched in these sub regions. The three landlocked countries import their cargo mainly from Dakar in Senegal, Cotonou in Benin, Abidjan in Ivory Coast, Tema in Ghana, and Lome in Togo (Figure 3). This generates a big competitiveness between the ports.

The lack of other modes of transport in connection with the hinterland contributes to the price increasing. The whole western African railway system is very poor, only trucks transport the goods from the ports except from Abidjan to Ouagadougou (Burkina Faso) where there is railways connection. Cartels create a large gap between costs and prices and provide low quality. Operators in such markets achieve high profits despite low yearly utilization of their vehicle fleets and many nontariff barriers. Under such conditions, it would be expected that new operators would enter the market aggressively, but this does not happen. In fact, there is an oversupply of trucking capacity because outsiders find it hard to break into a market dominated by the cartels and market access rules. In West Africa the trucking environment is not competitive and the market not matures. Major corridors are the least advanced in terms of prices and efficiency of services, mainly because of a deregulated transport market.

The volume of cargo transit to the landlocked countries kept growing and according to the statistics this

will continue.



Figure 3: Maritime Transit Traffic (TEU) for Burkina Faso Mali Niger

Source: West African Road Transport and Transit Facilitation Strategy, by Zerelli et al, ECOWAS

#### 6. The Ports Competitiveness Evaluation

#### 6.1 Evaluation of the Ports Location

This criteria is important in order to serve as a hub port, the future hub port must be located at a reasonable distance for all the regional port users including the other ports in the world. The port should provide a good transshipment service for the hinterland countries. This criterion has been put at the first place.

Dakar strategic location at the extreme western point of Africa and at the crossroad of the major sea lanes linking Europe to South America and North America to South Africa makes it a natural port of call for shipping companies, but considering the hinterland countries, and other ports in the region it is in a disadvantaging position. Abidjan port with regard to the hinterland and the international geographic shipping map has the best location. (Table 1)

Tuble 1011110111105 101 the 1 of the ment respect to the Location								
		Abidjan	Dakar	Priority				
Tema	1	1/4	4	0.217				
Abidjan	4	1	9	0.717				
Dakar	1/4	1/9	1	0.066				

(1)

<b>Fable</b>	1:1	Priorities	for th	ne P	orts	with	resp	ect to	o the	Locati	on
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Calculus Method:

Sum of first column of the Judgment Matrix

$$\sum_{k=1}^{3} a_{k1} = 1 + 4 + 1/4 = 5.25$$
$$\overline{a_{11}} = 1/5.25 = 0.19$$
$$\overline{a_{21}} = 4/5.25 = 0.76$$
$$\overline{a_{31}} = 0.25/5.25 = 0.05$$

Sum of second column of the Judgment Matrix

$$\sum_{k=1}^{3} a_{k2} = 1/4 + 1 + 1/9 = 1.36$$

$$\overline{a_{12}} = 0.25/1.36 = 0.18$$

$$\overline{a_{22}} = 1/1.36 = 0.74$$

$$\overline{a_{32}} = 0.11/1.36 = 0.08$$
(2)

Sum of third column of the Judgment Matrix

$$\sum_{k=1}^{3} a_{k3} = 4 + 9 + 1 = 14$$

$$\overline{a_{13}} = 4/14 = 0.29$$

$$\overline{a_{23}} = 9/14 = 0.64$$

$$\overline{a_{33}} = 1/14 = 0.07$$
(3)

Sum of the elements of each row of the matrix, and after normalization, we get the priority vector:

$$\bar{W} = \begin{pmatrix} 0.217\\ 0.717\\ 0.066 \end{pmatrix}$$
(4)

Calculate of the largest (maximum) Eigen value

Dividing all the elements of the weighted sum matrix by their respective priority vector element and find the average of this value to obtain  $\lambda_{max}$ :

$$A\overline{W} = \begin{pmatrix} 1 & 1/4 & 4 \\ 4 & 1 & 9 \\ 1/4 & 1/9 & 1 \end{pmatrix} \begin{pmatrix} 0.217 \\ 0.717 \\ 0.066 \end{pmatrix} = \begin{pmatrix} 0.66 \\ 2.18 \\ 0.20 \end{pmatrix}$$

$$\lambda_{\text{max}} = 3.03$$
(5)

Find the Consistency Index, CI, as follows:

 $CI = \frac{\lambda_{\max} - n}{n - 1}$ 

Where n is the matrix size CI = 0.015

Finding the consistency ratio, CR as Follow:

$$CR = \frac{CI}{RI}$$

 $CR = 0.015 / 0.58 {=}\; 0.025 < 0.1$ 

Therefore, CI, and CR are satisfactory. So decision can be taken based on the normalized values.

## 6.2 Evaluation of the Operating Cost (Charge)

Like other criterion, this criterion is important as well. The main reason why this study has been made is to reduce the cost of the imported and exported goods for the region. So port cost has been place at the second rank. The ports that perform best are often those that charge the most. Container handling costs are well above \$200 per TEU in Abidjan, (Table2) or about twice the global benchmark. General cargo handling is around \$15 per tone in Abidjan, again about twice the global benchmark. After analysis we give a score to the ports (Table 3).

	Abidjan Côte d'Ivoire	Dakar Senegal	Tema Ghana
Container handling (US\$/TEU)	260	160	168
General cargo handling (US\$/tone)	14	10	10

Table 2: Ports charge in the three selected countries

Charge	Tema	Dakar	Abidjan	Priority
Tema	1	1/3	5	0.265
Dakar	3	1	9	0.672
Abidjan	1/5	1/9	1	0.063

<b>Table 3: Priorities</b>	for the Ports	with respect to	Port Charge

# 6.3 Evaluation of the Port Efficiency

According to a survey we made in order to evaluate the port efficiency, we found out that the port efficiency is very important as well. Shippers cannot afford wasting time due to ports inefficiency regarding all the negative aspects it involves. The port efficiency has been put at the third rank. To evaluate the ports efficiency, we have selected four performances (Table 4) to attribute the scores (Table 5).

	Abidjan Côte d'Ivoire	Dakar Senegal	Tema Ghana
Container dwell time (days)	12	7	25
Truck processing time (hours)	3	5	8
Crane productivity (containers/hour)	18	12	13
Crane productivity (tones/hour)	16	16	14

#### **Table 4: Port Performance and Efficiency**

Tema Port in Ghana seems to perform significantly worse than others in terms of efficiency. Container dwell times are particularly high, exceeding one month in a number of cases. Abidjan (Côte d'Ivoire), Dakar (Senegal), all present significantly better performance on efficiency. Container dwell time is as low as seven days in Dakar, putting it close to global best practice. Crane productivity is substantially better than elsewhere, although still short of the international benchmark.

Table 5: Friorities for the Forts with respect to Efficiency									
Efficiency	Abidjan	Tema	Dakar	Priority					
Abidjan	1	3	1/5	0.188					
Tema	1/3	1	1/7	0.081					
Dakar	5	7	1	0.731					

# Table 5: Priorities for the Ports with respect to Efficiency

#### 6.4 Evaluation of the Port Capacity

Compare to other big ports all over the world, these three ports are relatively small. The port capacity is an important factor to meet the vessel requirements. For a port that tends to be a hub port, there is a minimum requirement to meet. With the rapid expansion of traffic, many of the region's ports are beginning to experience capacity constraints .This is most notable in the case of Dakar (Senegal), where both container and general cargo traffic significantly exceed designed capacity. The port of Tema (Ghana) is also experiencing capacity constraints with respect to container traffic. There is some scope for easing those constraints by improving the efficiency of port performance. Among these major ports selected, the port of Abidjan (Ivory Coast) seems to be the one with the port largest capacity (Figure 4).Based on this figure we gave the score to port in respect with port capacity (Table 6).

#### Figure.4: Ports Containerisation Volume (TEU) (Port Authorities Sources)



	Tema	Abidjan	Dakar	Priority
Tema	1	1/4	4	0.217
Abidjan	4	1	9	0.717
Dakar	1/4	1/9	1	0.066

Table 6: Priorities for the Ports with respect to Capacity

# 6.5 The Criteria Compared With Respect to Reaching the Goal

As all criteria don't have the same importance so we made a table comparison (Table 7)

	Table 7. I fibilities for the Criteria with respect to Reaching the Goal							
		Location	efficiency	Cost	Capacity	Priority		
	Location	1	4	3	7	0.547		
	Efficiency	1/4	1	1/3	3	0.127		
	Charge	1/3	3	1	5	0.270		
	capacity	1/7	1/3	1/5	1	0.056		

Table 7: Priorities for the Criteria with respect to Reaching the Goal

When we multiplied the alternatives value in respect with each criterion by the criterion Value we get the result as in (table 8) and concluded from the three Ports total priority (Table 9) the eventual hub port in the region

Criterion	Priority vs. Goal	Alternative	A		В	С	
		Dakar	0.066	х	0.547	=0.036	
Location	0.547	Abidjan	0.717	х	0.547	=0.392	
		Tema	0.217	х	0.547	=0.119	
Efficiency		Dakar	0.731	х	0.127	=0.093	
	0.127	Abidjan	0.188	х	0.127	=0.024	
		Tema	0.081	х	0.127	=0.010	
Charge	0.270	Dakar	0.672	х	0.270	=0.181	
		Abidjan	0.063	х	0.270	=0.017	
		Tema	0.265	х	0.270	=0.071	
Capacity	0.056	Dakar	0.066	х	0.056	=0.003	
		Abidjan	0.717	х	0.056	=0.040	
		Tema	0.217	х	0.056	=0.012	

Table 8: Priorities for the Ports according to Criteria Value

Factor Ports	Location	Efficiency	Charge	Capacity	Goal
Dakar	0.036	0.093	0.181	0.003	0.313
Abidjan	0.392	0.024	0.017	0.040	0.473
Tema	0.119	0.010	0.071	0.012	0.212

 Table 9: Ports Total Priority for Reaching the Goal

# 7. Conclusion and Remarks

From the AHP result, we see that the port of Abidjan should be more operational and could serve as a regional hub. It has a score of 0.473. Abidjan port is the best emplacement for the hub-port serving the needs of Ivory Coast, other West African ports and the landlocked countries. But still a lot have to be taken in consideration. The port should be able to better serve the regional needs including the hinterland of West Africa so it has to improve it connection roads. The port should of course be an international port; able to attract the overflow of other ports in the region. On the maritime side, the port is expected to have a transshipment function for the West African coast. As containers will most likely be feeder to other small ports. And the port should provide good nautical access to relatively large vessels.

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# **Productivity Changes in Chinese Container Terminals 2006-2011**

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#### Abstract

In the past decades, nearly all the Chinese coastal provinces and municipalities invested heavily in the construction of seaports and tried to improve the ports' operations by all means. How effectively have these efforts worked? This paper uses Malmquist productivity index to determine and analyse the productivity changes and its decomposition in Chinese coastal container terminals during 2006-2011. We find that the average growth in sample terminals' productivity is 4.6% within the period. By the decomposition of the Malmquist index, we identify the major source of productivity growth to be technological progress, rather than an improvement in technical efficiency and the major source of technical efficiency growth to be scale efficiency. We also find that the productivity of terminals in the Yangtze Delta is the highest while the one of terminals in the southeast coastal area is the lowest.

Keywords: container terminals; Malmquist productivity index; technical change; technical efficiency change

#### 1. Introduction

With the development of international trade, container terminals play a more and more important role within the global supply chains in general and the worldwide sea cargo transportation system in particular. Besides, China's container terminals have performed spectacularly well, with the annual throughput of 163 million TEUs in 2011. The container handling performance of Chinese seaports probably scores the best all over the world. For the container terminal operators, it becomes increasingly urgent and interesting to evaluate the internal compositions of container terminals and therefore to find the effective solution to promote their sustainable development.

The repeated big jumps of the Chinese ports' container throughputs have been mainly caused by massive investment in the terminal infrastructures and significant improvement in their operation and management as well. As the land and water resources become increasingly scarce today, it's unlikely and unwise for Chinese coastal ports to continually expand their existing handling facilities on a large scale. Only based on the real performances of different container terminals can the operators and administrative institutions optimize their resource allocation and strategy/policy amendments concerning port investment and governance. Therefore, this paper compares the performances among Chinese container terminals by measuring and analysing their productivity changes during 2006-2011 and probes the causes of increasing productivity.

The structure of this paper is organized as follows: Section 2 provides a brief review of previous studies on the Malmquist productivity of ports and container terminals. Section 3 explains the methodology of Malquist productivity index we used in this study to measure productivity change and its decomposition. Section 4 describes the variables and data statistics. Section 5 presents and discusses the empirical results regarding the change of productivity level and its characteristics. Finally, section 6 draws some concluding remarks.

#### 2. Reviews of Literature

# 2.1 Productivity and Malmquist index

Productivity can be simply defined by the ratio of 'outputs' to 'inputs'. Sumanth (1998, p.5) presents three

different definitions of productivity as relevant to companies/ enterprises: Partial Productivity, the ratio of output to one class of input; Total factor productivity, the ratio of net output to the sum of associated labor and capital (factor) inputs, and Total productivity, the ratio of total output to the sum of all input factors. This paper adopts the TFP concept.

Previous studies on TFP can be classified into two groups (Fung et al., 2008) according to the estimation method that was used, with one group using a parametric method (econometric analysis) and the other a non-parametric method (data envelopment analysis). We adopt the latter because it does not require the imposition of a possibly unwarranted functional form on the structure of production technology as required by the econometric approach (Rebelo et al., 2000).

Three different non-parametric methods are frequently used to evaluate productivity changes: the Fischer (1922), Tornqvist (1936), and Malmquist (1953) indices. According to Grifell-Tatjé et al. (1996), the Malmquist index has three main advantages relative to the Fischer and Tornqvist indices. First, it does not require the profit maximization, or cost minimization assumption. Second, it does not require information on the input and output prices. Finally, if the researcher has panel data, it allows the decomposition of productivity changes into two components (technical efficiency change, or catching up, and technical change, or changes in the best practice). Its main disadvantage is the necessity to compute distance functions. However, the data envelopment analysis (DEA) technique can be used to solve this problem. Therefore, we adopt the Malmquist index to measure the productivity changes in Chinese container terminals.

Malmquist (1953) first adopted Malmquist index to analyze consumers' behaviors, and then Caves et al. (1982) first presented Malmquist productivity index and defined it as the ratio between productivity changes between any two periods. Fare et al. (1994) applied the output-based Malmquist productivity index to analyze the productivity growth for a sample of OECD countries. They decompose productivity growth into two mutually exclusive and exhaustive components: changes in technical efficiency (EC) over time and shifts in technology (TC) over time, and Malmquist productivity changes = EC×TC. Then technical efficiency change (EC) can be further decomposed into scale change (SEC) and pure efficiency change (PEC), and EC = SEC × PEC. According to Sun (2004), the decomposition of TFP is important for indicating the status of technical progress inherent in industries or firms. In other words, the decomposition analysis reveals whether technological progress is stagnant or vigorous over time and whether the given production technology has been utilized in an efficient manner to fully realize its potential. So we would like to adapt this method to decompose productivity changes.

As to Nishimizu et al. (1982), technological progress, which we call technical change, is the consequence of innovation or adoption of new technology by best practice firms. Technical efficiency change refer to all other productivity change, such as learning by doing, diffusion of new technological knowledge, improved managerial practice, short run adjustment to shocks external to the enterprise. And high rates of technological progress can coexist with deteriorating technical efficiency performance and low rates of technological progress can coexist with high improvement in technical efficiency (Kalirajan et al., 1996). Furthermore, technical efficiency is determined by the managerial capacity to (1) maximize outputs given input levels, or timely adjust input factors given output levels (PEC), and (2) respond to demand by flexibly adjusting production scales (SEC) (Cheon et al., 2010).

#### 2.2 *Studies on productivity/efficiency of container terminals*

There are several reasons for the mass studies on the container ports: (1) The pressure to boost port competitiveness has triggered an increasing number of port benchmarking studies, especially for leading container ports (Yip et al., 2013); (2) The complex of ports activities make the study of ports as a homogenous entity more difficult, therefore, it's not advisable to study ports as a whole (González et al., 2009). Tongzon (2001) argues that to restrict the scope of analysis to a limited number of ports and a specific type of cargo is necessary for the multiplicity of ports and cargo handled. So the research on ports tends to focus more on container ports for their standard operations, and (3) It's not easy to select ideal sample terminals and periods due to lack of each terminal's data. As González et al. (2009) find, some scholars analyzed the terminals of each port as a whole for the data used aggregated the individual terminals within each port, even though their

interest was initially targeted at the study of container port terminals considered individually, such as Cullinane et al. (2004).

Table 1 summarizes the recent studies using DEA-Malmquist methodology on port or container terminal productivity, from which it can be discerned that seaport productivity has not been estimated using a unified framework.

There are still issues yet to be addressed in previous study about seaport container terminals. On the one hand, most of the published studies were focusing on container ports, rather than container terminals. Container terminal operation is quite different from ports' other activities (eg. bulk cargo stevedoring and passenger transport), and a port is generally formed by more than one container terminals, e.g. Shanghai port has 9 container terminals. Each container terminal varies with its operator's ownership structure and corporate governance. Therefore, it seems not appropriate to use ports' whole input and output variables to measure the productivity of container terminals.

Paper	Unites	Inputs	Outputs	Productivity change
Estache et al. 2004	11 Mexico's ports 1996-1999	<ul><li>(1) length of docks</li><li>(2) number of workers</li></ul>	volume of merchandise handled	TFP: 1.041; TC: 1.024; EC: 1.017; PEC:1.001; SEC: 1.016
Liu et al. 2008	45 Chinese mainland container terminals 2003-2005	<ul><li>(1) quay length</li><li>(2) quayside gantry crane</li><li>(3) rubber-tyred gantry crane</li></ul>	throughput	TFP: 1.125; TC: 0.937; EC: 1.200; PEC: 1.031; SEC: 1.164
Alejandro et al. 2009	7 Mexican ports 2000-2007	<ul><li>(1)storage area</li><li>(2)length of docks</li><li>(3)gantry cranes</li></ul>	container cargo handled	TFP: 1.013; TC: 1.049; EC: — PEC: 0.966; SEC: 0.994
Cheon et al. 2010	98 world ports 1991and 2004	<ul><li>(1) berth length</li><li>(2) terminal area</li><li>(3) container crane</li></ul>	container throughput	TFP: 2.418 TC: 1.285; EC: — PEC:1.470; SEC:1.787
Yuen et al. 2013	21 container terminals in China, S. Korea and Singapore 2003-2007	<ul> <li>(1) number of berths</li> <li>(2) total berth length</li> <li>(3) port land area</li> <li>(4) number of quay cranes</li> <li>(5) number of yard gantries</li> </ul>	container throughput	TFP: 1.132 TC: 1.072; EC: 1.024 PEC:—; SEC:—

Table 1: Research Studies on Port or Terminal Productivity using DEA-Malmquist Methodology

On the other hand, the selection for research variables is not reasonable enough. It is necessary to select variables as the representatives of three basic inputs to measure the productivity of a container port/terminal, namely land, labor and capital (Alejandro et al., 2009; Dowd et al., 1990). In fact, except for the land, labor and capital inputs are not unified. There is widespread consensus among authors regarding how to approach the labor input, with a greater diversity in estimating the capital input (González et al., 2009). Cheon et al. (2010) selected three variables of total container berth length (meters), container terminal area (square meters) and capacity of container cranes (tonnage) as proxies for input factors of container production. Alejandro et al. (2009) represented land and capital inputs by storage area and length of docks, respectively. Among various inputs, none of them selected labor variable due to lack of reliable database. Cullinane et al. (2002), Notteboom et al. (2000) and Tongzon (1995) argued that labor variable could be proxied by certain physical characteristics of the terminals. Marconsult (1994) considered a fixed relation between the number of quay cranes and the number of dock workers at a container terminal. After a couple of years' study, Cullinane et al. (2004) drew the conclusion that a predetermined relationship observed in the past between port labor and container cranes, will not necessarily remain static and continuously linear in the future, or the relationship is further complicated by the rapid development of manufacturing and transportation technology, and new equipment such as automated guided vehicles and automatic stacking cranes deployed at the container terminal yard.

Theoretically, terminals' outputs consist of container throughputs measured in either TEUs or metric tons, and ships served in terms of either the number of callings or their tonnages. In order to avoid some irrelevancies, this paper aims to focus on Chinese coastal container terminals, combine the inputs of land, equipment and

labor with the output as container throughput measured in TEUs, and estimate the productivity changes from 2006 to 2011 with the help of Malmquist index.

#### 3. Methodology

Let  $X = (x_1, x_2, ..., x_k)$  denote a vector of K inputs and  $Y = (y_1, y_2, ..., y_m)$  be a vector of M outputs in a firm. Since not all inputs can be equally important to outputs, and not all outputs can be equally important to the firm,  $a_m$  and  $b_k$  are respectively the weights of inputs and outputs. Where the total factor productivity can be expressed by:

$$TFP = \frac{\sum_{m=1}^{M} a_m Y_m}{\sum_{k=1}^{K} b_k X_k}$$
(1)

The change in total productivity can be estimated as the ratio of the change in TFP over a period of analysis. Particularly, the productivity of a firm that produces one output and employs one input can be shown as TFP=Y/X. Whence, the productivity change of this firm from time "s" to time "t" is as follows:

$$\frac{y_t / x_t}{\frac{y_s}{x_s}}$$
(2)

Expression (2) can only be used for production processes involving one output and one input with comparing productivity levels observed in two periods, assuming that the technology has remained constant. To solve this, the Malmquist index proposed by Caves et al. (1982) is required. This index employs the distance functions introduced by Shephard (1953) to determine the distance between the entities compared and the most efficient ones.

Owing to two approaches (input-oriented and output oriented) to qualify distance functions, there is a choice of using an input-oriented analysis (which focuses on the movement toward an efficiency frontier by the proportional reduction of production inputs) or an output-oriented analysis (which focuses on the movement toward the frontier by the proportional expansion of production outputs) to measure changes in TFP. We chose to use the output-oriented Malmquist productivity index model, because the container terminals aim to maximize the throughput and obtain the greatest benefits by using its existing infrastructure and equipment more efficiently.

The Malmquist productivity index can be represented by the following function:

$$M_{oc}^{t}(x^{t}, y^{t}, x^{t+1}, y^{t+1}) = \frac{D_{oc}^{t}(x^{t+1}, y^{t+1})}{D_{oc}^{t}(x^{t}, y^{t})}$$
(3)

Where  $M_{oc}^{t}(x^{t}, y^{t}, x^{t+1}, y^{t+1})$  compares  $(x_{t+1}, y_{t+1})$  with  $x_{t}$ ,  $y_{t}$ , obtaining the distance between them and the best possible benchmark given the technology of period "t". Thus, a value greater than 1 in expression (3) would indicate that the value of TFP has increased, whereas the opposite is true of values below 1.

Similarly, the corresponding ratio can be determined by taking the technology of period t+1 as the base, which gives the expression:

$$M_{OC}^{t+1}(x^{t}, y^{t}, x^{t+1}, y^{t+1}) = \frac{\frac{D_{OC(x^{t+1}, y^{t+1})}^{t+1}}{D_{OC(x^{t}, y^{t})}^{t+1}}$$
(4)

Expression (3) and (4) assumes that the technology remains the same at times t and t+1. Caves et al. (1982) argued that changes in technology could be determined by calculating the geometric mean of the expressions above, the output-based Malmquist productivity change index can be shown as follows:

$$M_{OC}(x^{t}, y^{t}, x^{t+1}, y^{t+1}) = \left[\frac{D_{oc(x^{t+1}, y^{t+1})}^{t}}{D_{oc(x^{t}, y^{t})}^{t}} \times \frac{D_{oc(x^{t+1}, y^{t+1})}^{t+1}}{D_{oc(x^{t}, y^{t})}^{t+1}}\right]^{1/2}$$
(5)

According to T.J. Coelli et al. (1998), an equivalent way of writing the Malmquist index is as follows:

$$M_{OC}(x^{t}, y^{t}, x^{t+1}, y^{t+1}) = \frac{D_{\mathcal{OC}(x^{t+1}, y^{t+1})}^{t}}{D_{\mathcal{OC}(x^{t}, y^{t})}^{t}} \left[ \frac{D_{\mathcal{OC}(x^{t+1}, y^{t+1})}^{t}}{D_{\mathcal{OC}(x^{t}, y^{t})}^{t}} \times \frac{D_{\mathcal{OC}(x^{t}, y^{t})}^{t}}{D_{\mathcal{OC}(x^{t}, y^{t})}^{t}} \right]^{1/2}$$
(6)

In this way the index is expressed as the product of two components: the efficiency change component (EC), which measures the change in relative efficiency of a terminal between period t and t+1, and the technical change component (TC), which captures the shift in the frontier technology between the two periods. We can calculate and decompose the Malmquist productivity index with the aid of software DEAP 2.1.

#### 4. Description of the Data

Our data comprise a balanced panel dataset of the inputs and outputs of 21 Chinese container terminals selected from a dozen of Chinese seaports, such as Shanghai, Shenzhen, Ningbo-Zhoushan, Guangzhou, Qingdao, Tianjin, Xiamen, Dalian, Lianyungang, Yingkou, Yantai, and Fuzhou, which are cited from China's Port Yearbook.

Four inputs are identified in the analysis as the number of workers, capital invested, quay length and the number of the gantry cranes, which represents the labor input, the capital input, the terminal infrastructure input and the mechanical equipment input respectively. In this study, we assume that the main function of a container terminal is to move cargo from quay to ship or visa verse, so that the output (throughput) is defined as the amount of containers handled by the terminal. On this basis, the ports with a continuous record of container handling were chosen.

	Indicator		Output				
Year		Staff and	Capital Invested	quay	Bridge	Throughput	
		Workers (No.)	(million RMB)	Length (m)	Cranes (No.)	(million TEU)	
	Average	560	1764	1244	13.24	1.93	
	Std. Dev	336	1921	804	8.32	1.46	
2006	CV	60%	109%	65%	63%	76%	
	Max	1499	7344	3400	34	6.77	
	Min	147	11.4	240	4	0.20	
	Average	579	1844	1364	13.81	2.43	
	Std. Dev	350	1897	755	8.32	1.93	
2007	CV	60%	103%	55%	60%	79%	
	Max	1531	7344	3400	34	8.24	
	Min	133	11.4	519	4	0.29	
2008	Average	596	1907	1395	15.14	2.49	
	Std. Dev	376	1766	798	9.5	2.03	
	CV	63%	93%	57%	63%	82%	
	Max	1741	6701	3413	38	8.72	
	Min	188	11.4	519	4	0.36	
	Average	575	2000	1407	15.10	2.32	
	Std. Dev	386	1781	845	9.7	1.98	
2009	CV	67%	89%	60%	64%	85%	
	Max	1832	6701	3400	40	8.96	
	Min	179	11.4	519	4	0.33	
	Average	562	1921	1398	15.10	2.58	
	Std. Dev	362	1825	846	9.9	2.32	
2010	CV	64%	95%	61%	65%	90%	
	Max	1685	6701	3400	41	10.57	
	Min	172	11.4	519	4	0.40	

 Table 2: Summary Statistics of Input and Output Variables (Average Value)

2011	Average	572	2159	1400	14.86	2.87
	Std. Dev	367	2463	847	9.8	2.78
	CV	64%	114%	60%	66%	97%
	Max	1714	10010	3400	40	12.43
	Min	168	11.4	519	4	0.50

Data Sources: China's port yearbooks 2007 ~ 2012

For the sample period of 2006-2011, the summary of the annual observations for the variables is shown in Table 2. The average data of four input variables and one output variable are all increasing at different paces during the sample periods. Specifically, the mean number of staff and workers, capital invested, quay length, number of bridge cranes and containers handled increased by 2%, 22%, 13%, 12% and 49% from 2006 to 2011, respectively. Similarly to Yuen et al. (2013), these figures suggest that the throughput growth significantly exceeds the increase of the resource utilized by container terminals. It seems that Chinese container terminals are still undergoing the stage of enjoying scale efficiency.

# 5. Results

# 5.1 Container terminal productivity changes: the Malmquist index and its decomposition

As is mentioned above, the Malmquist productivity change index can be decomposed into two components: technical efficiency change (EC) and technical change (TC). Technical efficiency change (EC) can be further decomposed into scale change (SEC) and pure efficiency change (PEC), and EC=SEC×PEC. We use the software of DEAP 2.1 to calculate the Malmquist indices in each year and the cumulative change in productivity for each container terminal in the sample period 2006-2011. The chained Malmquist indices and these components are shown in Table 3.

Port	Terminal	Productivity change	TC	EC	PEC	SEC	Overseas share *
Dalian	Dalian Container Terminal	1.045	1.061	0.985	0.985	1	0.49
Yingkou	Yingkou Container Terminal	1.068	1.068	1	1	1	0
	Sea-Land Orient (Tianjin) Container Terminal	1.001	1.063	0.941	0.943	0.998	0.49
Tianjin	Tianjin Five Continents Int'l Container Terminal	1.037	1.052	0.986	0.989	0.997	0.32
	Tianjin Port Container Terminal	0.986	1.041	0.947	0.933	1.014	1
Yantai	DP World Yantai Co.	1.06	1.033	1.026	1	1.026	0.325
Qingdao	Qingdao Qianwan Container Terminal	1.099	1.083	1.014	1	1.014	0.49
Lianyun- gang	Lianyungang New Oriental Container Terminal	1.273	1.141	1.116	1.092	1.022	0
Shanghai	Shanghai Pudong Int'l Container Terminal	1.033	1.038	0.995	0.998	0.998	0.3
	Shanghai Hudong Container Terminal	1.018	1.041	0.978	0.979	0.999	0.49
	Shanghai Shengdong Int'l Container Terminal	1.152	1.054	1.093	1.052	1.039	0
	Shanghai Mingdong Container Terminal	0.96	1.05	0.915	0.936	0.978	0.5
Ningbo- Zhoushan	Ningbo Daxie China Merchants Int'l Terminal	1.087	1.076	1.01	0.866	1.167	0.45
Zhoushan	Ningbo Port Beilun Container Terminal	1.013	1.077	0.94	0.968	0.971	0.49
	Fuzhou Qingzhou Container Terminals	0.941	1.062	0.886	1	0.886	0
Fuzhou	Fuzhou International Container Terminal	1.158	1.059	1.093	0.828	1.321	0.09
Xiamen	Xiamen International Container	0.926	1.048	0.883	0.856	1.032	0.49

#### Table 3: Chinese Container Terminal Productivity Change and Components (Chained Indices) 2006-2011
	Terminal						
	Xiamen New World Xiangyu Terminal	1.036	1.048	0.989	0.995	0.994	0.5
Cuerta	Guangzhou Container Terminal	0.973	1.025	0.949	0.978	0.97	0.49
Guang-	Guangzhou Port Nansha Stevedoring						0
znou	Co.	1.082	1.041	1.039	1.019	1.02	0
Shenzhen	Shekou Container Terminal	1.069	1.077	0.993	0.987	1.006	1
	Geometric mean	1.046	1.059	0.988	0.97	1.019	
	Maximum	1.273	1.141	1.116	1.092	1.321	
	Minimum	0.926	1.025	0.883	0.828	0.886	
	No. of terminals with productivity						
	raised	16	21	7	3	10	
	No. of terminals with productivity						
	unchanged.	0	0	1	4	2	
	No. of terminals with productivity						
	decreased	5	0	13	14	9	

*Note:* \* Overseas share means the ownership shares held by overseas investors ranging from 0 to 1 during 2008-2011. The data are quoted from China's Port Yearbooks 2009-2012

The average value of the chained Malmquist productivity indices is 1.046, which means that the average container terminal productivity level in 2011 was 104.6% of that in 2006, with a 4.6% increase over the sample period. At the end of 2011, 16 container terminals enjoyed a higher productivity level than in 2006, and the remaining 5 terminals won a lower productivity score than in 2006.

In terms of individual terminal performance, Lianyungang New Oriental Container Terminal Co. Ltd., Fuzhou International Container Terminal Co., Ltd. and Shanghai Shengdong International Container Terminal Ltd. had achieved the best records in their productivities between 2006 and 2011, with an increasing rate of 27.3%, 15.8% and 15.2% over the period respectively. Contrarily, Xiamen International Container Terminal Ltd. experienced the worst decline, with a chained Malmquist productivity index of 0.926, which means its productivity in 2011 was 92.6% what it was in 2006.

#### 5.1.1 Components of the Malmquist index (2): efficiency change

The chained EC index represents the cumulative change in efficiency for the individual container terminals and for all of the terminals as a group between 2006 and 2011. The geometric average of the chained EC indices is 0.988, which means the average efficiency level was raised very slightly over the sample period. At the end of 2011, 7 container terminals had reached a higher efficiency level with other 13 terminals' productivity level lower than in 2006. Lianyungang New Oriental Container Terminal Co. Ltd experienced a fastest increase in efficiency by 11.6%, whereas Xiamen International Container Terminal Ltd declined most in its efficiency, which was found in 2011 to be as low as 72.2% of that in 2006.

As mentioned above, technical efficiency change (EC) can be further decomposed into scale-change (SEC) and pure efficiency- change (PEC), and EC=SEC×PEC. In this analysis, the geometric mean of the chained PEC and SEC indices is respectively 0.97 and 1.019. It means that the major source of technical efficiency growth is scale efficiency, while the pure efficiency change is decreased.

Three container terminals increased their pure efficiency indices while 14 container terminals decreased their indices over the sample period. The unchanged efficiency change indices are found in 4 terminals: Yingkou Container Terminal Co., Ltd., DP World Yantai Co. Ltd, Qingdao Qianwan Terminal and Fuzhou Qingzhou Container Terminals Co. Ltd. Lianyungang New Oriental Container Terminal Co. Ltd showed a fastest increase by 9.2% in pure efficiency while Fuzhou International Container Terminal Ltd is the worst performer with 17.2% decrease in pure efficiency at the end of the period.

Ten container terminals increased their scale efficiency indices over the period. Fuzhou International Container Terminal grew in scale efficiency with 32.1% rise at the end of 2011. Nine container terminals decreased their scale efficiency indices over the period. Fuzhou Qingzhou Container Terminals Co. Ltd

experienced the worst decline, its scale efficiency in 2011 was just 88.6% what it was in 2006. Dalian Container Terminal Co. Ltd and Yingkou Container Terminal Co. Ltd had no change in scale efficiency.

### 5.1.2 Components of the Malmquist index (2): technical change

The other component of the Malmquist productivity change index is technical change. This component captures the effect of the shift in frontier of the productivity change of individual container terminals for an exposition of the effect of technical change on productivity change using production functions.

The chained TC indices indicate a change in frontier between 2006 and 2011, the sample period. The geometric average of the chained TC indices is 1.059, which indicates that the 2011 frontier was about 5.9% 'higher' than the 2006 frontier on average. In another word, the major source of productivity growth is technical progress, rather than an improvement in efficiency. The figures show that all container terminals benefited from the technical changes over the sample period. Individually, the technical progress in Lianyungang New Oriental Container Terminal Co. Ltd was increased by 14.1%.

#### 5.2 Productivity changes with location and ownership characteristics

We evaluate the effects of location characteristics on container terminal productivity by categorizing the terminals into four regions: Bohai Rim (7 terminals in Dalian port, Yingkou port, Tianjin port, Yantai port and Qingdao port), Yangtze Delta (7 terminals in Lianyungang port, Shanghai port and Ningbo-Zhoushan port), southeast coastal area (4 terminals in Fuzhou port and Xiamen port) and Pearl River Delta (3 terminals in Guangzhou port and Shenzhen port). The mean productivity levels and the decomposition of the terminals by region are given in Table 4.

Location (region)	Descriptive statistic	Productivity change	TC	EC	PEC	SEC
Dahai Dim	Mean	1.042	1.057	0.986	0.979	1.007
(7 torminals)	Standard deviation	0.039	0.017	0.032	0.028	0.011
(7 terminais)	Geometric mean	1.042	1.057	0.985	0.978	1.007
Vangtza Dalta	Mean	1.077	1.068	1.007	0.984	1.025
(7 terminals)	Standard deviation	0.106	0.036	0.074	0.074	0.067
	Geometric mean	1.072	1.068	1.004	0.982	1.023
Southeast coast (4 terminals)	Mean	1.015	1.054	0.963	0.920	1.058
	Standard deviation	0.107	0.007	0.100	0.091	0.186
	Geometric mean	1.011	1.054	0.959	0.916	1.047
Doord Divor Dolto	Mean	1.041	1.048	0.994	0.995	0.999
(3 terminals)	Standard deviation	0.060	0.027	0.045	0.022	0.026
(3 terminals)	Geometric mean	1.040	1.047	0.993	0.995	0.998

Table 4: Chinese Container Terminal Productivity and Components (Chained Indices) by Location

The productivity and its sub-sector of TC in the four regions were all improved. The average levels of productivity, TC and EC indices of the sample terminals in the Yangtze Delta region reached the highest rank in sample period. Another observation indicates that the average level of productivity, EC and PEC indices of container terminals in the southeast coastal area fell into the lowest position, while its SEC index still scored the best, and its technical change narrowly beat the one for the Pearl River Delta over the sample period. The EC index went up only in Yangtze Delta region while the SEC index dropped only in Pearl River Delta region over the sample period.

Furthermore, as argued by several scholars before, there might be some possible connections between the productivity changes and ownership characteristics for the sample terminals. Unexpectedly, the results found from Table 5 show that the productivity changes of Chinese coastal container terminals are not necessarily positively correlated with the ownership shares held by the overseas (either foreign or Hong Kong based) investors.

Overseas Ownership	Descriptive statistic	Productivity change	TC	EC	PEC	SEC
Dominant Ownership with	Mean	1.013	1.054	0.961	0.963	0.998
share of 50%~100%	Standard deviation	0.049	0.016	0.037	0.033	0.016
(4 terminals)	Geometric mean	1.012	1.054	0.960	0.962	0.998
Heavily Involved with share of 49% (7 terminals)	Mean	1.011	1.057	0.956	0.958	0.998
	Standard deviation	0.054	0.020	0.042	0.048	0.022
	Geometric mean	1.009	1.057	0.955	0.957	0.998
Less Involved with share of 21%~48% (4 terminals)	Mean	1.054	1.050	1.004	0.963	1.047
	Standard deviation	0.025	0.019	0.018	0.065	0.081
	Geometric mean	1.054	1.050	1.004	0.962	1.045
Least Participation with	Mean	1.112	1.071	1.038	0.999	1.048
share of 0~20%	Standard deviation	0.111	0.036	0.086	0.091	0.145
(6 terminals)	Geometric mean	1.108	1.070	1.035	0.995	1.040

 Table 5: Chinese Container Terminal Productivity and Components (Chained Indices) by

 Overseas Ownership

The container terminals with the least overseas shares  $(0\sim20\%)$  are ranked as the best group measured by all the indices, not only productivity change in general but efficiency change in particular as well. Unfortunately, the container terminals with the overseas share of 49% score the worst in the most indices. Since the beginning of the economic reform and opening-up policy, Chinese coastal ports have remained the main attraction for the overseas capital investment for three decades. For the first 20 years, the Chinese seaports were in urgent need for the overseas capital and managerial expertise concerned. As the history witnessed, all the early overseas involvement in the operation and management of Chinese coastal container terminals achieved a lot in their productivities. For the latest decade, the situation has been reversed somehow. One of the explanations is derived from the basic principle of economics, i.e. the marginal returns of overseas investment are diminishing eventually. Besides, the terminals wholly or almost owned by the local investors might gain sufficient technical know-how and managerial skills, and even respond to the changing commercial environment in China much more efficiently. One hypothesis for the bad performance of the terminals with its overseas share of 49% might be a critical conflict between considerably overseas ownership and narrowly domestic control, which needs further testing.

## 6. Conclusions

The Malmquist index is a tool that allows changes in total productivity to be determined and decomposed into each of their components. This is important for the implementation of sound strategic planning policies. This paper adopted the Malmquist index approach to trace the temporal dynamics in China's container terminal productivity change. To conclude this paper, several remarks are addressed as the follows.

Firstly, there are significant differences in productivity among China's container terminals. The average productivity of container terminals was increased by 4.6% from 2006 to 2011. Lianyungang New Oriental Container Terminal Co. Ltd., Fuzhou International Container Terminal Co., Ltd. and Shanghai Shengdong International Container Terminal Ltd. had achieved the biggest increase in productivity between 2006 and 2011, with an increasing rate of 27.3%, 15.8% and 15.2% respectively over the period. Meanwhile, it is noted that at the end of 2011, five terminals had performed so badly with a lower productivity level than in 2006. Of the terminals, Xiamen International Container Terminal Ltd. experienced the worst decline with its productivity in 2011 as 92.6% what it was in 2006.

Secondly, we identify the major source of productivity growth to be technical progress, rather than an improvement in technical efficiency and the major source of technical efficiency growth to be scale efficiency. However, in the perspective of sustainable development, technical efficiency is deemed to be more important to productivity than technological progress and pure efficiency more valuable to technical efficiency than scale efficiency as well. The overall pure technical efficiency level declined more or less, no matter how many ups and downs appeared within the time framework.

Thirdly, the average productivity level for the seaports in the Yangtze Delta was the highest, followed by Bohai Rim region. Our findings also imply that the container terminals in the Pearl River Delta and the southeast coast area lag behind in terms of efficiency though the host regions still enjoy their stronger exportoriented economy and earlier-initiated institutional reform.

Finally, contrary to our initial expectation, overseas investment or involvement is no longer one of the main engines for Chinese seaports' productivity improvement. A certain degree of overseas ownership might exert a negative influence upon the productivity change, due to some possible inconsistence within the terminal companies.

Thus, Chinese container terminals should try their best to improve technical efficiency by more effectively optimizing their corporative governance, utilizing capital and allocating both human and natural resources. In addition, the terminals should choose their appropriate scale of development and sustain their intensive growth. For further research, it would be worth conducting a study on the influences of inland accessibility and educational background of the manpower concerned upon container terminals' efficiency changes.

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## Sustainable Supply Chain and Sustainability Performance in Container Terminal Operators in the Port of Kaohsiung

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#### Abstract

The purpose of this study is to examine the effect of sustainable supply chain on sustainability performance for container terminal operators in the Port of Kaohsiung. Sustainable supply chain consists of internal collaboration and external collaboration. Based on a factor analysis, three internal collaboration are identified, namely, communication and participation, employee training, and green ship. External collaboration can be divided into three factors, including supplier collaboration, partner collaboration, and customer collaboration, whereas sustainability performance can be categorized into environmental, social performance and economic performance. A structural equation modeling (SEM) approach was employed to examine the relationships between the variables. Results indicated that internal collaboration and external collaboration had a positive influence on external collaboration. Practical and theoretical implications from the research findings in improving sustainable development for container terminal operators are discussed in this research.

*Keywords: Sustainability Performance; Structural Equation Modeling; Container Terminal Operators; Sustainable Supply Chain.* 

#### 1. Introduction

Supply chain management is the integration of key business processes from the end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders (Lambert and Cooper, 2000). Vachon et al. (2006) examined green supply chain practice by evaluating partnership among upstream and downstream firms in the supply chain. Linton et al. (2007) indicated that sustainability should be implemented by integrating all production functions through the manufacturing flow. Ports, as key nodes in the supply chains, are critical to trade and transportation networks. Like other economic sectors, the port sector is facing challenge in relation to climate change and needs to reduce its contribution to global warming. Specifically, the major sources of emissions are ocean-going vessels, harbor craft, cargo handling equipment, railroad locomotives, and heavy-duty vehicles. Recently, a growing number of reports and articles have discussed environmental and sustainable management on the port sector (Hallegate 2008).

The largest port in Taiwan, Kaohsiung Harbor Bureau, has also issued a white book to address the importance of sustainable development in port operations. While the techniques and measures described in the literature or reports focus on developing environmental or sustainable management for an organization (i.e. port authority) they do not capture in total the key concerns of the supply chain on how each organization affects

overall sustainability performance. Moreover, while several researchers and port authorities recognize the need to measure environmental or sustainable management across the supply chain, they do not provide a framework for developing sustainable supply chain management (SSCM) to drive environmental or sustainability performance (Peris-Mora et al., 2005). Ports play a crucial role in sea and land transportation networks and provide significant employment and economic benefits to local areas. They also act as the bug for the majority of incoming and outgoing ocean commerce (UNCSD, 2011). Accordingly, the sustainable development of ports needs to take into account internal and external members, including terminal operations, stevedoring companies, trucking and warehousing operations (Lu et al., 2010).

This paper examined the effect of sustainable supply chain management (i.e. internal sustainable development and external sustainable collaboration) on sustainable performance for container terminal operators in Kaohsiung by using structural equation modeling. There are few sections in this paper. After this introduction to the study, a review of the literature on sustainable supply chain management and sustainable performance is predicted in section 2. Section 3 describes the research methodology, including the questionnaire survey, sampling technique, and data analysis methods. Section 4 presents the factor analysis and structural equation modeling findings. Conclusion drawn from the research findings and their implication for port decision-makers, authorities' managers and sustainable development are discussed in the final section.

## 2. Literature Review and Hypotheses

Sustainable supply chain is an innovation of environmental protection, which mitigates the pollution in the whole production process from upstream suppliers, focal company, and downstream customers. Lambert et al. (2006) defined sustainable supply chain as one that integrates the business flow from initial suppliers to end customers, and provides stakeholders with valued-added products and services by employing sustainable operating concept. A number of previous studies have revealed the importance of suppliers, focal company, customer, government and stakeholders when exploring the impact of sustainable supplier chain management on firm performance (Seuring et al., 2008). Zhu et al. (2007) investigated green supply chain practices in the car manufacturing industry containing internal and external collaborations. Shang et al. (2010) examined the effects of six dimensions, namely, green production ability, environmental policy, green marketing, green suppliers, green inventory and green ecologic design on firm performance.

Previous studies on sustainable supply chain management usually defined as green supply chain management, hence mostly focused on the performance of financial and environmental protection (Marlow, 2008; Seuring and Muller, 2008). Firms purchase environmentally superior products and develop comprehensive programs to build environmental practices across the entire supply chain to improve both financial and environmental performance (Rao and Holt, 2005). However, environmental, economic, and social dimensions all need to be considered when evaluating sustainable performance (Seuring and Muller, 2008). Moreover, according to the United Nation General Assembly (2005), the evaluation of sustainable performance should be based on internationally recognized sustainability standards and certification systems.

In this study, sustainable supply chain management and sustainable performance in container terminal operators is reviewed. In previous researches, some viewpoints have been indicated that firms can increase their financial and economic performance by executing effective environmental management (Klassen et al., 1996). De Burgos and Lorente (2001) contended that firms need to consider environmental performance in the evaluation of operational performance. It may therefore be assumed that port authorities that implement internal sustainable management activities such as sustainability participation, practice, policy setting, and personnel sustainability training will be positively associated with sustainable performance. Accordingly, this study hypothesized the following:

Hypothesis 1 : Internal sustainable management will be positively related to sustainable performance for the container terminal operators in Kaohsiung

From green supply chain management literatures that revealed that green partner relationships among supply chain system members can increase environmental protection performance (Handfield et al., 1997; Sarkis, 2001). Collaboration is the process of decision-making among supply chain members. It involves joint

ownership of decisions and collective responsibility for sustainable development. A port that seeks to attain effective sustainable supply chain management through external collaboration with service suppliers and customers must also become more focused internally, so that it may better respond to environmental management requirements and achieve the objective of sustainable development. Effectiveness emerges when port partners are willing to work together, understand other points of view, share information and resources, and achieve collective goals (Stank et al., 2001). Research has indicated that collaboration should lead to improved environmental performance (Lee and Klassen, 2008). For example, a port authority can develop a collaboration program with carriers to reduce air pollution through vessel speed reduction. Also, a port authority can encourage carriers or trucking companies to establish meaningful programs to reduce the impacts of shipping goods by using cleaner fuels and more efficient routes, operations and technologies. Higher levels of supplier collaboration and customer collaboration are therefore expected to result in enhanced sustainable development performance. Accordingly, this study hypothesized the following:

Hypothesis 2: External sustainable collaboration will be positively related to sustainable performance for the container terminal operators in Kaohsiung

To implement sustainability in practice, the relationship between internal sustainable management and external sustainable collaboration should be considered. Walton et al. (1998) pointed out that firms need to consider the importance of the role of their suppliers in the supply chain system when facing a competitive environment. Successful sustainable development has been found to require collaboration and integration among members in the supply chain (Handfield et al., 1997; Mentzer et al., 2001; Kleindorfer et al., 2005; Seruing et al., 2008). Accordingly, this study hypothesized the following:

Hypothesis 3 : External sustainable collaboration will be positively related to internal sustainable management for the container terminal operators in Kaohsiung

## 3. Methodology

#### 3.1. Sample

This study used a questionnaire survey to collect information from container terminal operators in Kaohsiung port. The questionnaire was sent to 9 container operators, LIEN JAI, WAN HAI, OOCL, APL, YML, EMC, HMM, HANJIN, and NYK, in Kaohsiung. These firms targeted because they were considered appropriate respondents to provide useful information. According to the size of operators, 178 questionnaires were sent to container terminal operators on 21<sup>st</sup> February 2011. The total number of usable responses was 141and the overall response rate for this study was approximately 68 %.

#### 3.2. Measures

The questionnaire sought to obtain a profile of respondents by seeking information relating to their job title, work department, age and years of working experience. The importance the accorded 19 internal sustainable items and 12 external sustainable collaboration items was elicited by asking them to indicated their level of agreement/disagreement with the items using a five-point Likert scale ranging from "1 = strongly disagree" to "5 = strongly agree".

#### 3.3. Analysis method

Several research methods were used in this study, including descriptive statistics and exploratory factor analysis. The later was conducted in order to identify and summarize a large number of internal sustainable management and external sustainable collaboration attributes into a smaller, manageable set of underlying factors or dimensions (Hair et al., 2006). A reliability test was conducted to assess whether these dimensions were adequate. Confirmatory factor analysis was then conducted to verify measurement models. This involved the use of structural equation modeling software AMOS 6.0 to analyzed the measurement models, assess psychometric proprieties, and to specify relationship among the latent variables and the proposed measures.

### 4. Result of Analysis

#### 4.1. Profile of respondents

The data of this study was based on the information gathered from a questionnaire survey. Results revealed that 51.8% of respondents were clerks. Other respondents were either vice president or above or manager/assistant manager. Almost 80% of the respondents have been in operation for more than 5 years, 65% have been operating more than 10 years. Regarding the gender, 85% of respondents were male. As regards respondents' ages, more than half (51.8%) were more than 40 years. Regarding the respondents' work departments, 27% worked in the operations department, 8.5% worked in the warehousing department. In addition, the respondent's firm more than half (54.4%) operated more than 1 million TEUs in 2010 and half of them (48.2%) were foreign firms. Regarding the employees of respondent's firm, more than half (61.3%) hired less than 100 employees in terminal area.

### 4.2. Factor analysis result

### 4.2.1. Internal sustainable management items

Exploratory factor analysis with VARIMAX rotation was employed to identify 19 internal sustainable management items and 12 external sustainable collaboration items to smaller sets of underlying factors. To aid interpretation, variables with loadings of 0.5 or greater on only one factor were extracted, which is a conservative criterion suggested by Hair et al. (2006).

- (1) Factor 1 consisted of 7 items related to communication and participation. This factor was therefore labeled an internal sustainability participation dimension. It accounted for 26.73% of the total variance. Communicating sustainable development issues with staff effectively had the highest factor loading on this factor.
- (2) Factor 2 comprised 7 items which were practice related activities. This factor was therefore labeled an employee training dimension. Convening sustainable development conferences periodically had the highest factor loading on this factor. Factor 2 accounted for 23.88% of the total variance.
- (3) Factor 3 was consisted of 4 items which were associated with environmental activities. This factor was therefore designated a green shipping dimension. Asking ship to sail on economy mode to reduce fuel cost had the highest factor loading on this factor. Factor 3 accounted for 18.63% of the total variance.

A reliability test based on a Cronbach Alpha statistic was used to test whether these factors were consistent and reliable. In Table 1 revealed that the reliability value of each dimension was well a value of 0.70, which is considered adequate for a satisfactory level of reliability (Iacobucci and Churchill, 2010). Therefore, no indictors need to be deleted.

Itama		Factor	
Items	1	2	3
My company communicates sustainable development issues with staff effectively	0.804	0.332	0.183
My company allows employees to involve in ssustainable development policy	0.794	0.223	0.117
My company provides sustainable development information to staff	0.757	0.139	0.291
My company convenes sustainable development conferences periodically	0.754	0.336	0.288
My company improves sustainable development through cross section coordination	0.718	0.267	0.347
My company encourages employees to join the goal setting of sustainable development	0.691	0.320	0.277
My company implements the sustainable development procedures actually	0.628	0.314	0.397
My company provides enough sustainable development training courses	0.278	0.834	0.190
My company provides sustainable development programs in excellent course design	0.349	0.787	0.223

#### Table 1: Factor Analysis of Internal Sustainable Management Items

My company establishes evaluation indicators for recycling, greenhouse gas mitigation, and resources saving.	0.078	0.742	0.345
My company applies sustainable development courses in staff's work effectively	0.372	0.731	0.214
My company publishes written sustainable development policy	0.370	0.591	0.222
My company efforts to achieve sustainable development are more than legal requirement	0.295	0.566	0.463
My company sets sustainable development codes of practice	0.311	0.502	0.376
My company requests ships to sail on economy mode to reduce fuel cost	0.216	0.267	0.792
My company mitigates emission of Co2 and noise from berthing ships	0.304	0.301	0.744
My company uses green material in design and building of port construction	0.326	0.213	0.743
My company collects most recent information about sustainable development regulation	0.310	0.453	0.627
Eigenvalues	9.998	1.429	1.034
Percentage variance %	26.73	23.87	18.63
Accumulated Percentage variance%	26.73	50.60	69.23
Cronbach a	0.927	0.905	0.868

## 4.2.2. External sustainable management items

Further, Table 2 shows the results of employing factor analysis to review the external sustainable collaboration in three aspects, supplier, customers, and partner. Three factors were found to underline the eternal sustainable collaboration items for these three aspects in the external collaboration. They were labeled and are described below.

- (1) A supplier collaboration aspect comprised 4 items. This factor accounted for 81.65% of the total variance. Establishing a set of reliable sustainability indicators with supplier had the highest factor loadings on this factor. A reliability test based on a Cronbach Alpha statistic was used to test whether these factors were consistent and reliable. The Cronbach Alpha value for this dimension was above 0.9, considered to represent a satisfactory level of reliability. In addition, due to the factors were all related to supplier, therefore this factor is labeled a supplier collaboration dimension.
- (2) A customer collaboration aspect comprised 4 items. This factor accounted for 79.90% of the total variance. The Cronbach Alpha value for this dimension was above 0.9, considered to represent a satisfactory level of reliability. In addition, due to the factors were all related to customer, therefore this factor is labeled a customer collaboration dimension.
- (3) A partner collaboration aspect comprised 4 items. This factor accounted for 84.99% of the total variance. The Cronbach Alpha value for this dimension was above 0.9, considered to represent a satisfactory level of reliability. This factor was therefore labeled a partner collaboration dimension.

Supplier collaboration	
Items	Factor
Establishing a set of reliable sustainability indicators with supplier	0.924
Discussing with supplier to solve the issues of sustainable development	0.903
Collaborating with suppliers to achieve the goal of sustainable development	0.896
Working together with supplier to reduce the impacts on port area	0.891
Eigenvalues	3.266
Accumulated Percentage variance%	81.649
Cronbach a	0.925
Customer collaboration	
Items	Factor
Establishing a set of reliable sustainability indicators with customer	0.915
Discussing with customer to solve the issues of sustainable development	0.899

#### Table 2: Factor Analysis of External Sustainable Collaboration

Collaborating with customers to achieve the goal of sustainable development	0.884
Working together with customer to reduce the impacts on port area	0.877
Eigenvalues	3.196
Accumulated Percentage variance%	79.895
Cronbach α	0.916
Partner collaboration	
Items	Factor
Establishing a set of reliable sustainability indicators with partner	0.945
Discussing with partners to solve the issues of sustainable development	0.932
Collaborating with partners to achieve the goal of sustainable development	0.916
My firm will work together with partners to reduce the impacts on port area	0.893
Eigenvalues	3.400
Accumulated Percentage variance%	84.992
Cronbach α	0.941

### 4.2.3. Self-reported sustainability performance items

Factor analysis was also used to detect the presence of meaningful patterns self-reported sustainable performance in the last three years from16 items of container terminal operators (see Table 3). Results showed that sustainable performance dimensions were decreased from three categories and 14 items were included. These two dimensions (factors) accounted for 43.20% and 20.35% of the total variance. They were labeled and are described below.

- (1) Factor 1 was called the environmental and social performance dimension since it consisted of five items (in Table 6). This factor accounted for 43.20% of the total variance. I perceive that traffic accidents in port areas have significantly reduced had the highest factor loading on this factor.
- (2) Factor 2 consisted of four items. Since these items were economic related activities, this factor was therefore called an economic performance dimension. I perceive that the energy costs have reduced significantly had the highest factor loading in this factor. Factor 2 accounted for 20.35% of the total variance.

#### Table 3: Factor Analysis of Self-reported Sustainability Performance

Items		tor
items	1	2
I perceive that noise in container yard ha significantly reduced	0.832	0.259
I perceive that the waste in container yard have reduced significantly	0.816	0.300
I perceive that the exhaust emission of each ship has reduced significantly	0.795	0.320
I perceive that the fuel consumption of each ship has reduced significantly	0.785	0.332
I perceive that the usage of environmentally friendly materials for containers ship have significantly increased	0.779	0.317
I perceive that the ability to deal with scrap containers and ships has increased significantly	0.776	0.251
I perceive that the fuel consumption of each ship has reduced significantly	0.746	0.361
I perceive that the caring of the disadvantaged groups have significantly increased	0.691	0.083
I perceive that the employees' working benefit have significantly increased	0.663	0.070
I perceive that industrial accidents in container yards have significantly reduced	0.502	0.436
I perceive that the energy costs have reduced significantly	0.471	0.732
I perceive that profitability have significantly increased	0.327	0.725
I perceive that the costs of dealing with scraps have reduced significantly	0.419	0.714
I perceive that procurement costs in material have significantly reduced	-0.050	0.643
Eigenvalues	7.72	1.17
Percentage variance %	43.20	20.35
Accumulated Percentage variance%	43.20	63.55
Cronbach a	0.933	0.771

#### 4.3. Confirmatory Factor Analysis

Before testing the hypotheses, confirmatory factor analysis, CFA, using AMOS, was performed to ensure the validity of the measurement scales (Anderson and Gerbing, 1988). A number of goodness-of-fit indices recommended by many researchers were used to assess the fit and unidimensionality of the measurement model (Hu and Bentler, 1995). The results, as shown in Table 4, revealed an adequate model fit, indicating that the proposed model was purified and credible (Bollen 1989).

Table 4: Goodness of Fit Indicators					
SEM indicators	Criteria	Results			
$\chi^2$ (Chi-square)	-	17.674			
$\chi^2/df$	< 3	1.401			
P value	> 0.05	0.408			
GFI	> 0.9	0.970			
AGFI	> 0.9	0.936			
TLI	> 0.9	0.998			
NFI	> 0.9	0.976			
RMR	< 0.05	0.010			
RMSEA	< 0.08	0.017			

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.

As shown in Table 5, 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 estimate divided by its standard error. As a rule of thumb, the C.R. value needs to be greater than 0.7 for the estimate to be acceptable (Hair et al., 2010). Results showed that all C.R. values were larger than 0.7, confirming that all indicators measured the same construct and providing satisfactory evidence of the convergent validity and unidimensionality of each construct (Anderson and Gerbing, 1988). 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 (Hair et al., 2010).

Discriminate validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs. As shown in Table 6, results indicated that the highest squared correlation was 0.570, which was observed between External collaboration and Sustainability performance. This value was significantly lower than their individual AVE value of 0.674 and 0.717, respectively. The results therefore demonstrated evidence of discriminate validity for the study variables.

	Table 5: Convergent Validity					
Dimensions	Factors	Loading Factor	AVE	CR	$\mathbf{R}^2$	
	EX 1 Supplier collaboration	0.77			0.595	
External collaboration	EX 2 Customer collaboration	0.82	0.674	0.806	0.674	
	EX 3 Partner collaboration	0.87			0.765	
Internal	IN 1 Internal sustainability participation	0.82			0.675	
collaboration	IN 2 Employee training	0.86	0.717	0.883	0.740	
	IN 3 Green shipping	0.86			0.746	
Sustainability	SP 1 Environmental and social performance	0.89	0 709	0 0 20	0.802	
performance	SP 2 Economic performance	0.79	0.708	0.828	0.634	

Table 6: Discriminate Validity					
	External collaboration	Internal collaboration	Sustainability performance		
External collaboration	$0.674^{a}$	-	-		
Internal collaboration	0.373 <sup>b</sup>	0.717 <sup>a</sup>	-		
Sustainability performance	0.399 <sup>b</sup>	$0.570^{b}$	0.708 <sup>a</sup>		

a: AVE; b: Squared correlation

#### 4.4 Results of hypotheses testing

After confirming the fit of the measurement model, the study proceeded to assess the proposed structural model and examine the hypothesized relationships. Figure 1 shows that the data adequately supported the estimated model. The Chi-Square statistic ( $\chi 2$  =17.694, df =17) at 0.408 was above the 0.05 level of significance. In addition, the goodness of fit index (GFI) was calculated to be 0.970 and the adjusted goodness-of-fit index yielded 0.936 after adjustment was made for degrees of freedom relative to the number of variables. Moreover, the results of fitting the structural model to the data revealed that the model had a good fit as indicated by the normed fit index (NFI= 0.976), comparative fit index (CFI=0.999), root mean square residual (RMR= 0.010) and root-mean-square error of approximation (RMSEA =0.0017).



#### **Figure 1: Structural Equation Modeling Results**

Table 7: Structural Equation Modeling Result	Table 7:	Structural	Equation	Modeling	Results
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	D (1	Estimates					
	Paths	Standardized β	S.E. <sup>a</sup>	C.R. <sup>b</sup>	Р		
H1	(Internal sustainable management) → (Sustainable performance)	0.709	0.101	7.010	с **		
H2	(External sustainable collaboration) $\rightarrow$ (Sustainable performance)	0.244	0.108	2.548	0.011 *		
H3	(External sustainable collaboration) $\rightarrow$ (Internal sustainable management)	0.698	0.085	7.278	**		

Note: a. S.E. is an estimate of the standard error of the covariance.

b. C.R. is critical ratio which obtained by dividing the covariance estimate by its standard error.

c. \*\* P value is significant at the 0.05 level.

Table 7 summarizes the hypotheses testing results which indicated that all hypothesized relationships were significant and in the expected direction. As shown in Figure 1, internal collaboration was found to have a significant relationship with sustainability performance (estimate = 0.709, C.R. = 7.010), internal collaboration was significantly associated with external collaboration (estimate = 0.698, C.R. = 7.278) and external collaboration was found to have a significant relationship with sustainability performance (estimate = 0.244, C.R. = 2.548). As regards the relationship between internal sustainable collaboration and sustainable performance, there is a direct impact of internal sustainable collaboration on sustainable performance. The

results also revealed that external sustainable collaboration also had an influence on sustainable performance. Regarding the relationship between internal collaboration and external collaboration, there is a direct impact between them. Thus, three hypotheses were supported.

### 5. Discussion and Conclusion

Several implications can be drawn from the findings of this study for decision-makers of container terminal operators, authorities, managers and sustainable development. First container operators in sustainable management need to integrate external customers (i.e. carriers) and supply chain partners (i.e. truck companies, and stevedoring companies) and internal sustainable management to improve their sustainable performance. Second, with respect to internal sustainable management policy had the highest mean scores. This suggests that terminal operators should pay attention to setting sustainable development goals, regulations, clear organization of responsibility, and employee participation in training programs for implementing sustainable development in practice. Third, the study results indicated that internal sustainable management was positively associated with sustainable performance, including environmental, social and economic performance. These findings are consistent with those reported in prior studies (Mentzer et al., 2001). Finally, this study found external sustainable collaboration to be positively associated. This implies that the establishment of effective sustainable management to improve sustainable performance requires a combination of these two dimensions (Wolf, 2011).

This study provided empirical evidence for the influence of sustainable supply chain management on sustainable performance in the container terminal operators. However, a number of limitations of the study have to be noted, which also suggest directions for future research. First, this study specifically focused on terminal operators in Taiwan. Different supply chain members may have different levels of sustainability concerns. This may affect the generation of the conceptual model. Future research would profit from more diverse viewpoints, such as the perspective of carriers, bulk stevedoring companies, truck companies, and other groups (Bell et al., 2012). Third, this study was based only on a cross-sectional survey. Future research could conduct a longitudinal study to assess sustainable supply chain management and sustainable performance at different time points and therefore more accurately determine their efficacy within an organization. Finally, the collected data obtained from respondents' perceptions of sustainable performance may have been subject to bias due to respondents' reluctance to report actual performance. Therefore, further research might measure sustainable performance by actual observation or quantitative.

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## Port State Control Perception of the Safe Management of Bulk Carriers

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## Abstract

The development of port state control (PSC) has come a long way since its first appearance in January 1982. Maritime experts focus on the safe management of ships, which allows a better understanding of the factors that influence the safe management of ships. This paper presents a BOCR model, based on the modified Delphi method and AHP approach, to establish a hierarchy structure that is a useful ship safety management system for the control of bulk carriers. The structure validates the relative priorities of each hierarchy for different PSC regimes and compares the view of different PSC regimes with the perceptions of crews, ship managers for shipping companies, or governments, using absolute measurement by paired comparison performance, using the hierarchy for each bulk carrier. In addition, other types of ship safety management ranking systems can be structured using PSC perceptions and a slightly modified BOCR model.

Keywords: Shipping, Bulk carriers, BOCR model, Port state control (PSC), Maritime safety management

## 1. Introduction

The Royal Mail Steamer, Titanic, was a British registered four funnel ocean liner constructed at the Harland and Wolff shipyard in Belfast. She collided with an iceberg and sank on her maiden voyage, in 1912. Maritime nations were shocked and desirous of promoting safety at sea; so uniform principles and rules were established in a common agreement. This agreement led to the International Convention for the Safety of Life at Sea (SOLAS), in 1929. Since then, maritime nations have adopted newer versions to further protect maritime safety. The global view is conscious of the need to preserve the human environment in general and the marine environment in particular. The importance of this international convention, whose prime objective is protecting the environment, is widely recognized. The preservation of the environment, particularly the marine environment, along with prevention of pollution at sea, is the prime objectives of the treaty.

Global vision emerged in the 1980s, along with organization culture, system thinking and quality management. The consultancy process requires an interpretative ability that relies on the knowledge and experience of the organization's members, in order to jointly identify and solve problems (Grieves, 2000). Under the International Safety Management (ISM) code for the safe operation of ships and for pollution prevention was adopted and amended by the International Maritime Organization (IMO) and entered into force on 1 July 1998, ships must be periodically verified by the administration, or an organization recognized by the administration, or at the request of the administration by another contracting government to the convention. It requires shipowners to develop a safety management system that ensures that equipment has been properly tested and maintained, staff properly trained and deficiencies in the system promptly identified and rectified (Chen, 2000). Knapp and Franses (2010) noted that a revision of the ISM code could further enhance the level of

safety at sea and that an intelligent ship safety management system can be used as a good reference for bulk shipping carriers involved in the charter business (Chung *et al.*, 2011). This means that ship managers have to establish an intelligent ship safety management system to meet international standards for the safe management and operation of ships and the prevention of marine pollution.

The major dry bulk cargoes, *i.e.*, iron ore, coal, grain, bauxite/alumina and phosphate rock, carried by bulk carriers will increase in volume in the near future. One study to identify and map the common patterns of human and organizational causes found that collisions often involve a fishing boat and a bulk carrier (Macrae, 2009), which means that the huge numbers of bulk carriers are the main group to which the safe operation of ships and pollution prevention applies. The managers of shipping companies understand that major accidents have long been a key issue in assessments of risk and safety management and recognize the need to develop a safety management system that is controlled. It is necessary to control this system with limited boarding resources, before they find the best model for support, shipside.

The classification societies rely on their own subjective judgment and a rule of thumb supply registered shipowners with a reference guide on the management and maintenance of the safety system. However, such guidelines lack objectivity and a quantitative means of evaluating inside sourcing priorities, which barely ensures that the most appropriate limited boarding resources are allocated. The adoption of management techniques influences organizational performance, especially when supported by clear vision and mission statements (Arzu *et al.*, 2008). Therefore, the adoption of safety management techniques for shipping companies should influence the performance of bulk carrier operation in the system, especially when supported by a clear vision and mission statements with priorities. The purposes are explained briefly as follows: (1) to use observed deficiencies categorized according to the main deficiency in the view of Port State Control (PSC) to establish a hierarchy structure; (2) to use the hierarchy structure to compute the relative priorities for each hierarchy in the perception of PSC; (3) to visualize the differences in the relative priorities of each hierarchy from the view of PSC, using an Analytic Hierarchy Process (AHP), which may apply to the crews and managers of shipping companies. Governments can also use this model as a relative governmental guide.

The development of PSC began more than thirty years ago, in January 1982, when fourteen European states agreed to establish a harmonized system of control, resulting in the signing of the Paris MOU (Memorandum of Understanding) on PSC. The authors agree that PSC regimes provide an objective inspection of foreign ships entering a country's waters. Knapp and Velden (2007) and confirm that differences between PSC inspections exist, but these differences would be eliminated by the use of combined training and an exchange of databases. The PSC programs are effective in raising the maritime safety level (Li and Zheng, 2008). However, shipping companies focusing more on existing infrastructure could easily be asked to carry out the additional task of collection, processing, storage and interchange of safety information, including failure rates in all sections (Wang and Foinikis, 2001).

Thai and Grewal (2006) applied a two-stage methodological approach, in which a focus group discussion was first used to explore the initial ideas from maritime experts, followed by a mail survey, to reflect the perceptions of the international shipping community of the maritime safety management system. It must be remembered that crews are the operators on board and every port state should nominate experienced people who are fully qualified, well-trained and familiar with ships as PSC officers (PSCO). The authors found a few articles discussing maritime safety that use the PSC view and crew perception to improve the maritime safety system.

## 2. Literature Review

Since the IMO adopted the ISM code in 1994, shipping companies have assumed duties in safety and environmental protection policy, corporate responsibilities and authority, designated person(s), master's responsibility and authority, resources and personnel, development of plans for shipboard operations, emergency preparedness, reports and analysis of abnormalities, maintenance of ships and equipment, documentation and company audits. Although the ISM documents may prove that the shipowner has done much to adhere to good practice in shipping (Chen, 2000), it is necessary to have efficient paper work and a

safety culture. Knapp and Velden (2007), used correspondence analysis to study the distribution of observed deficiencies, categorized according to the main deficiency codes. Li and Zheng (2008) studied the methods adopted by the regional PSC in identifying substandard ships. There was no emphasis on the improvement of the safety management on ships, so this study investigates the shipping industry using the viewpoint of PSC.

The formal safety assessment (FSA) is a new approach to marine safety, which combines various techniques to develop risk and cost benefit assessments. Container ships following the general pattern have similar structure, strength and stability, cargo and ballast operations, maneuverability, power and propulsion, cargo carried, cargo recipients, ports and terminals (Wang and Foinikis, 2001). The contents of an effective maritime safety plan should include operating systems, emergency response procedures, occupational health and safety management plans and security management plans (Thai and Grewal, 2006) that apply a two-stage methodological approach to be defined by maritime experts. The major content is the establishment of a safety management system for shipping companies, the enhancement of ship safety, the improvement of the quality of seafarers, the construction of a safe traffic environment, the reinforcement of the PSC for substandard ships, the establishment of an efficient response system for maritime safety culture for maritime safety (Cho, 2007). In view of the nature and semantics of the measurement indicator descriptions of the respective factors of quality management, there is senior management commitment and participation, quality information and performance measurement, employee training and empowerment and customer focus (Cheng and Choy, 2007). In summary, the components of a safety management system for the shipping industry are shown in Table 1.

Rules/Authors	Components
	Safety and environmental protection policy, company responsibilities and
International code for	authority, designated person(s), master's responsibility and authority, resources
fire safety system, as	and personnel, development of plans for shipboard operations, emergency
amended (2000)	preparedness, reports and analysis of abnormal, maintenance of the ship and
	equipments, documentation, and company audits.
Wang and Foinikis	Structure, strength and stability, cargo and ballast operations, maneuverability,
(2001)	power and propulsion, the cargo carried, cargo recipients, ports and terminals.
Thai and Grewal	Operating systems, emergency response procedures, occupational health and
(2006)	safety management plan, security management plan.
	Establishment of safety management for shipping companies, enhancement of
	ship safety, enhancement of quality of seafarers, building of a safety traffic
Cho (2007)	environment, reinforcement of the PSC for substandard ships, establishment of an
	efficient response system for maritime accidents, advancement of a maritime
	safety management system and establishment of maritime safety culture.
Cheng and Choy	Senior management commitment and participation, quality information and
(2007)	performance measurement, employee training and empowerment and customer
(2007)	focus.

Table 1: The Components of a Safety Ma	agement System for the Shi	pping Industry
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Some papers have used the normative Delphi method to check how the information system managers of large Spanish firms value information system outsourcing (Gonzalez *et al.*, 2010). The modified Delphi method is used to accumulate expert opinions and to establish an appropriate assessment criterion (Hsu *et al.*, 2008). The AHP is a multi-criteria process that combines the priorities of the alternatives derived using the different criteria (Saaty, 2006). This paper presents a model based on the modified Delphi method and AHP approach to visualize the differences in the relative priorities of each hierarchy, across the PSC perception.

In general, there are two kinds of structures that represent problems: hierarchies and networks (Saaty and Shih, 2009). Classification uses a hierarchy that aids understanding of the complexity of the world. A variety of information is gained from experience, or from the order and distribution of influences that make certain outcomes happen. The users of AHP should be aware of AHP's assumptions and their corresponding implications (Leung and Cao, 2001). The result from a pairwise comparison matrix is a normalized set of priority values that allow ranking of the options considered (Beynon, 2002). Using conventional AHP, Saaty

proposed a four-step methodology, comprising modeling, valuation, priorization and synthesis (Altuzarra *et al.*, 2007).

#### 3. The Methodology

Four rating priorities are used to synthesize the priorities of each alternative evaluated within the benefits, opportunities, costs and risks (BOCR) framework (Saaty, 2006). Appropriate rankings must be normative objectively and systematically from the mentioned items, using the concept of BOCR (Saaty, 2005). The Delphi method shows the reasons underlying the first conclusions, since knowledge of the actual worlds of the interviewees allow a better understanding of the results obtained (Gonzalez *et al.*, 2010). The Delphi technique uses three survey rounds, in which the panel of experts provides a probability of occurrence for the given event and their rationale behind their prediction (Baldwin and Trinkle, 2011). The modified Delphi method performs a questionnaire survey to achieve consistency in the opinion of experts and subjective factors are identified using an objective measurement method (Hsu *et al.*, 2008).

The AHP is used with relative and absolute measurement and paired comparisons are performed through the hierarchy (Saaty, 1990). The measuring criteria,  $C_1$ ,  $C_2$ , ...,  $C_n$ , denotes the set of measuring elements required to establish a pairwise comparison matrix, A.  $a_{ij}$  represents a quantified judgment of a pair of measuring elements,  $C_i$ , and  $C_j$ . The relative importance of the two measuring elements is a numerical value and the perceptions are: 1=equal importance, 3=weak importance, 5=essential importance, 7=very strong importance and 9=absolute importance, along with intermediate values (2, 4, 6, 8) to allow comparisons within one unit. When i = j, let  $a_{ij} = 1$ , and  $a_{ji} = 1/a_{ij}$ , i, j = 1, 2, ..., n, has positive entries everywhere. This yields a  $n \times n$  matrix, A, as follows:

$$C_{1}, C_{2}, ..., C_{n}$$

$$A = \begin{bmatrix} a_{ij} \end{bmatrix} = \begin{bmatrix} C_{2} \\ \vdots \\ C_{n} \end{bmatrix} \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$
(1)

The problem involves assignment to the *n* measuring elements,  $C_1, C_2, ..., C_n$ . A set of numerical weights,  $W_1$ ,  $W_2, ..., W_n$ , reflects the recorded judgments in matrix *A*. These processes create a ratio scale from the fundamental scale of absolute numbers.

 $P_i$  is the criteria weight,  $W_i$ , and after normalization they sum to 1. They can be written as:

$$\sum_{i=1}^{n} P_i = 1 \tag{2}$$

If there are *r* surveyors to measure the criteria and  $P_{ik}$  represents a priority of the *i* th criteria measured by the *k* th surveyor and to be accepted, the following are available:

$$\hat{P}_{i} = \frac{1}{r} \sum_{k=1}^{r} P_{ik} \text{ for } \sum_{k=1}^{r} \sum_{i=1}^{n} P_{ik} = r$$
(3)

If A is a consistency matrix, the relationship between the weight,  $W_i$ , and judgment,  $a_{ij}$ , can be simply calculated by  $W_i/W_j = a_{ij}$  (for i, j = 1, 2, ..., n) and  $C_i, C_2, ..., C_n$ .

$$A = \frac{C_1}{C_2} \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix}$$
(4)

Saaty (1990) suggested that the largest eigenvalue,  $\lambda_{max}$ , is satisfied:

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i}$$
(5)

If *A* is a consistency matrix, the eigenvector, *X*, can be calculated by

$$A - \lambda_{\max} I X = 0 \tag{6}$$

Saaty (1990) proposed the use of a consistency index (CI) and a consistency ratio (CR), to verify the consistency of the comparison matrix. CI and CR are defined as follows:

$$CI = (\lambda_{\max} - n)/(n-1) \tag{7}$$

$$CR = CI / RI \tag{8}$$

If  $CR \le 0.1$ , the estimate is accepted; otherwise, a new comparison matrix is solicited, until  $CR \le 0.1$ . CR verifies that the judgments from the different decision makers are acceptably inconsistent.

#### 4. Priority Model

All concepts are seen from the PSC view. The modified Delphi method was used to accumulate the opinions of maritime experts and to identify a normal criterion. The AHP method is used to establish a model to compare with the crew's concepts.

The problem PSC faces for quality ship control is that there is only one incentive scheme used in the world today (Shinohara, 2005). According to the main deficiency categories of the Paris MOU and the Tokyo MOU, 16 items are grouped, as listed in Table 2.

	Tuble 21 Main 2 cherencies by Caregories									
No.	main deficiencies	No.	main deficiencies							
1	Ship's certificate and logbooks	9	Water and weather tight conditions							
2	Crew's certificate	10	Structural conditions							
3	Living and working conditions	11	Safety of navigation							
4	Life saving appliances	12	Radio communication							
5	Fire safety	13	Pollution prevention							
6	Additional measures to enhance maritime safety	14	Propulsion and auxiliary machinery							
7	Alarm signals	15	ISM related deficiencies							
8	Cargo operations including equipments	16	Other deficiencies							

Table 2: Main Deficiencies by Categories

- 1. Ship's certificate and logbooks: Ship's certificates must be issued and logbooks recorded under the rules of international conventions, as amended.
- 2. Crew's certificate: Crew's certificates must be issued under the international convention on the standards of training, certification and watchkeeping (STCW) for seafarers and its Code 1995, as amended.
- 3. Living and working conditions: Living and working conditions must be maintained under the merchant shipping (minimum standards) convention, 1976 (ILO Convention No. 147), as amended, and the maritime labour convention (MLC), 2006, as amended.
- 4. Life saving appliances: Life saving appliances must be maintained under the international life saving appliances code 1996, as amended.
- 5. Fire safety: The relative equipment for fire safety must be maintained under the international codes for fire safety systems 2000, as amended.
- 6. Additional measures to enhance maritime safety: Diverse measures to enhance maritime safety must comply with the relevant rules.
- 7. Alarm signals: Alarm signals must be maintained under the relevant rules.
- 8. Cargo operations including equipments: Cargo operations, including equipment, must be maintained under the international maritime solid bulk cargos code 2010, and the relative rules, as amended.

- 9. Water and weather tight conditions: Water and weather tight conditions of the ship must be maintained under the 1988 Protocol for international conventions on load lines, 1966, and the relative rules, as amended.
- 10. Structural conditions: Structural conditions must be maintained under the relevant rules.
- 11. Safety of navigation: Safety of navigation must be maintained under international conventions for the safety of life at sea, 1974, and the international regulations for preventing collisions at sea, 1972, as amended.
- 12. Radio communication: The equipment for radio communication must be maintained under the international conventions for the safety of life at sea, 1974, as amended.
- 13. Pollution prevention: Pollution prevention is enacted under the 1978 and 1997 Protocol to international conventions for the prevention of pollution from ships, 1973, as amended.
- 14. Propulsion and auxiliary machinery: Propulsion and auxiliary machinery must be maintained under the international conventions for the safety of life at sea, 1974, as amended.
- 15. ISM related deficiencies: The management for ships must comply with the ISM code 2000, as amended.
- 16. Other deficiencies: Deficiencies under other relative rules.

Table 1 synthesizes four rating criteria under the concept of BOCR. 'Benefits to shipping companies', 'crews and ship safety', 'ship structure and equipment' and 'risk factors' are appropriate evaluation criteria. Table 2 categorizes the evaluation criteria using experts, in which the modified Delphi method is adopted to reach a consensus among maritime experts. A list of the criteria list is shown in Table 3.

Concepts of BOCR	Criteria	Subcriteria		
		Ship's certificate and logbooks		
Banafits	Banafits to shinning companies	Crew's certificate		
Delients	benefits to simpping companies	Cargo operations including equipments		
		Living and working conditions		
		Life saving appliances		
Opportunities	Craws and ship safety	Fire safety		
	Crews and sinp safety	Alarm signals		
		Water and weather tight conditions		
		Structural conditions		
Costs	Ship structure and equipment	Safety of navigation		
COSIS	Ship structure and equipment	Radio communication		
		Propulsion and auxiliary machinery		
		Additional measures to enhance maritime safety		
Dicke	Rick factors	Pollution prevention		
NISKS	KISK Idetois	ISM related deficiencies		
		Other deficiencies		

#### Table 3: Criteria List

Quality bulk carrier safety management is the principal goal of this hierarchy and Table 3 allots the remaining levels. A hierarchy structure is constructed as Figure 1.



## Figure 1: Hierarchical Structure for Priority

## 5. Empirical Study

The shipping companies and crews shipside must rectify the deficiencies identified by administration, or by any authorized person or organization, any institution for insurance, PSC, or by any relevant person, as soon as possible, to ensure the quality of bulk carriers. This paper uses the 2009-2011 statistical ratios of deficiencies calculated by the Paris MOU and the Tokyo MOU, as indicated in Table 4.

Table 4 is a ratio scale that uses the criteria and subcriteria from the annual reports of the past three years on PSC. A normalized priority of the PSC view is constructed for the criteria or subcriteria by determining the ratio scale. Arithmetic mean is used for they sum to 1. Table 5 summarizes those results.

Table 5 shows that the Paris MOU focused on 'benefits to shipping companies' (31.27%), but the Tokyo MOU focused on 'crews and ship safety' (37.06%). The sum of top six subcriteria was 68.61% in Paris MOU and 69.93% in Tokyo MOU, for the respective factors in PSC regimes.

Table 4. Katios of deficiencies of the Laris widd and the Tokyo MOU								
	MOU	Paris MOU			Tokyo MOU			
	Ratio (%)	2009	2010	2011	2009	2010	2011	
	Ship's certificate and logbooks		13.02	12.79	27.09	26.75	26.46	
Benefits to	Crew's certificate		2.59	2.15	1.58	1.72	1.59	
shipping companies	Cargo operations including equipments		0.83	0.89	0.56	0.64	0.62	
	Living and working conditions	14.7	15.36	14.79	3.27	3.23	3.21	
	Life saving appliances	9.55	8.66	9.35	13.70	11.95	11.56	
Crows and shin	Fire safety	11.55	11.82	12.89	16.51	17.26	17.06	
safety	Alarm signals	0.83	0.76	0.91	0.60	0.72	0.66	
	Water and weather tight conditions	4.44	4.38	5.08	6.83	6.67	7.66	
	Structural conditions	4.29	4.54	5.49	7.30	7.47	7.77	
Ship atmusture	Safety of navigation	13.28	13.30	12.76	16.04	16.88	16.42	
and aquipmont	Radio communication	3.37	3.38	3.33	3.79	3.25	2.89	
and equipment	Propulsion and auxiliary machinery	6.29	6.52	5.77	6.46	6.73	6.75	
	Additional measures to enhance maritime safety	3.64	3.37	3.82	1.36	1.48	1.30	
Risk factors	Pollution prevention	3.73	4.06	4.59	8.32	8.37	8.96	
	ISM related deficiencies	5.91	5.32	3.21	8.49	7.84	7.93	
	Other deficiencies	1.74	2.09	2.19	2.50	3.13	2.95	

Table 4: Ratios of deficiencies of the Paris MOU and the Tokyo MOU

#### Table 5: PSC perceptions of the Paris MOU and the Tokyo MOU

Criteria	Paris MOU	Tokyo MOU	Subcriteria	Paris MOU	Tokyo MOU
Denefitede			Ship's certificate and logbooks	13.08 (3)	2.68 (12)
Benefits to	31.27	8.15	Crew's certificate	2.42 (13)	1.63 (13)
snipping	(1)	(4)	Cargo operations including equipments	0.82 (16)	0.61 (16)
companies			Living and working conditions	14.95 (1)	3.24 (10)
			Life saving appliances	9.19 (5)	12.40 (3)
Crews and	26.74	37.06	Fire safety	12.09 (4)	16.94 (1)
ship safety	(3)	) (1)	Alarm signals	0.83 (15)	0.66 (15)
			Water and weather tight conditions	4.63 (9)	7.05 (7)
Shin atmusture			Structural conditions	4.77 (8)	7.51 (6)
ship structure	27.44	33.91	Safety of navigation	13.11 (2)	16.44 (2)
anu	(2)	(2)	Radio communication	3.36 (12)	3.31 (9)
equipment			Propulsion and auxiliary machinery	6.19 (6)	6.65 (8)
			Additional measures to enhance maritime safety	3.61 (11)	1.38 (14)
Dials factors	14.55	20.88	Pollution prevention	4.13 (10)	8.55 (4)
KISK factors	(4)	(3)	ISM related deficiencies	4.81 (7)	8.09 (5)
			Other deficiencies	2.01 (14)	2.86 (11)

## 6. Discussion

Ships must be under the direction of the administration or an organization recognized by the administration that provides guidelines on maritime safety management. The check table or list may be used as guidance. The authors could find no ranking system already in existence for this purpose. Even PSC regimes, which provide statistics and an analysis of main deficiencies, by category, every year, do not clearly show ship managers of shipping companies or governments how to improve the internal system, step by step.

An intelligent ship safety management ranking system could be structured by using PSC perceptions and the

BOCR model. Table 5 shows the result of AHP for this research. The findings reveal that 'benefits to shipping companies' (31.27%) in the Paris MOU and 'crews and ship safety' (37.06%) in the Tokyo MOU, under main criteria, has more priority. This means that 'benefits to shipping companies' and 'crews and ship safety' are often ignored by crews. The ship manager must concentrate on the management of those criteria. The Paris MOU and the Tokyo MOU show more correspondence on 'ship structure and equipment' (27.44% and 33.92%) and 'risk factors' (14.56% and 20.88%). These respected perceptions of PSC regimes correspond to improve deficiencies in ships.

The Paris MOU focuses on 'ship's certificate and logbooks' (13.08%) and 'living and working conditions' (14.95%), while the Tokyo MOU focuses less on 'benefits to shipping companies'. The Paris MOU and the Tokyo MOU almost correspond on the subcriteria of 'crews and ship safety', 'ship structure and equipment' and 'risk factors'. The findings of this paper confirmed that the treatment of ships across PSC regimes shows differences (Knapp and Velden, 2007; Li and Zheng, 2008) that are a reference for ship managers.

The PSC regimes maintain and report a trend in development and achievement of PSC activities every year. The crews or ship managers of shipping companies or governments are asked to identify the subjective factors using the objective measurement method, which provides knowledge of how to enhance concentrated management of those criteria and the differences in perceptions between different PSC regimes, using the model or the minor modified model.

## 7. Concluding Remarks

In an AHP procedure, this study identifies a model of the PSC perception on maritime safety management for bulk carriers. The conclusions are explained briefly, as follows:

- According to the main deficiencies in the view of PSC, this paper uses expert opinion to confirm an AHP structure for the maritime safety management assessment for bulk carriers. An intelligent ship safety management ranking system is structured using PSC perceptions and the BOCR model.
- The AHP structure validates the relative priorities of each hierarchy, in the view of different PSC regimes. The PSC regimes show differences that are a controlling reference for ship managers.
- The structure compares the view of different PSC regimes with the perceptions of crews or ship managers of shipping companies or governments, using absolute measurement, with paired comparisons performed throughout the hierarchy for each bulk carrier.

Overall, this study contributes to the structure by expanding the PSC view of maritime safety management for bulk carriers and by deepening the understanding of the factors that influence maritime safety management in bulk carriers. Each type of ship should be manned with qualified, certificated and medically fit seafarers, in accordance with national and international requirements. Future research could use this structure to compare the view of different PSC regimes with the perceptions of crews or ship managers of shipping companies, for other ship types. They should ensure that the safety management ranking system for other ship types could be structured by using PSC perceptions and a BOCR model that is slightly modified.

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## Research on the Evolution and Competition Situation of the Container Port Cluster System in China<sup>i</sup>

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#### Abstract

With the globalization of the world economy, the container transportation and ports have witnessed a massive increase in the recent years. Today ports play an important role in global commerce and the logistics and supply chain management practice and strategy. This paper analyzed the evolution and the competition situation of the Chinese coastal container port cluster system for the period of 2001-2011 using Herfindahl-Hirschman Index (HHI) and Shift - share Analysis methodologies. The study revealed the emergence of concentration among the port clusters and de-concentration within the port cluster. Meanwhile, the competition among the ports in the inner cluster is fiercer than that between the port clusters. The results provide improvement opportunity for policy makers and ports managers.

Keywords: Port cluster, Herfindahl – Hirschman Index, Shift - share Analysis, Container Ports Cluster, Evolution, Competition Situation

#### 1. Introduction

The division of labor, the development of information technology, the advancement of transportation tools and technologies and the increasing uncertainty of consumer demand speed up the economic globalization, promote the flow of people, goods, information and capital in the world (Wang 2009). The emergence and usage of the container technology since the 1950s, has improved the transport efficiency, reduced transportation costs, expanded the transportation market, caused the global logistics and international trade revolution, and changed the traditional mode and system of shipping (Yang 2005). Containerization has been steadily increasing from less than 10% in 2000 to 17.5% in 2010 (Kuang et al. 2012). At the same time, the trend of economic globalization and specialized division of labor makes the port play a more important role in the economic development. The proportion of the international trade in the world's GDP (Gross Domestic Product) has reached to 43.1% in 2009<sup>ii</sup>, where over 90% percent of the international trade was shipped by water. Even with the advancement of aviation technology and the advent of the information era, the growth of air cargo is continuously decreasing (International Air Transport Association (IATA) 2012 air cargo report), mainly because of the economic downturn and high operating costs. The cost advantage of shipping by sea still makes it the dominant powerhouse in international transportation market. As a result, waterborne or seaborne ports around the globe, which constitute the backbone of the international marine transportation and logistics system, have been experiencing dramatic changes. In developed countries or regions like North America and Europe, marine port systems have been either deteriorated or been reorganized. Except for several global hub ports such as Rotterdam port, Amsterdam port, Los Angeles port and New York port, the overall port industry has been experiencing declination in the past several decades. However, the scenario in developing countries is quite different. Marine port and logistics industry has been booming and heavy capital investment has been attracted to these regions. It is proven by economists that investment in infrastructure directly contributes to the boost of GDP. According to Song, the port's direct and indirect contribution to the GDP of the port city is calculated to be 20% (Song 2001). In the report titled "the YTP's contribution to the regional economic by the CCCC-FHDI engineering in 2002", the ratio of the direct and indirect contribution to the GDP was 1:6.21. In 2000, the share of the contribution of the Rotterdam port and the port industry was 34 % (Zhao & Lv 2005). For example, Chinese government had been invested 4000 billion RMB to help the economic recovery right after the global financial crisis in 2007 and major part of it had been devoted to the infrastructure improvement in the whole nation. Therefore, port infrastructure system has been upgraded, ports' operational efficiency has been improved and more cargo has been attracted and broader hinterland has been covered in developing countries. The rapid development of port and distribution network systems composed of railway, highway and inland water transport, contributed to the formation of port clusters and blurred the traditional definition of port's hinterland since the same region might be effectively covered by a number of ports. The increasing size of container ship further intensified the competition of the marine ports and the ports in a certain port cluster. To avoid repetitive investment in marine ports and to coordinate and maintain continuous development of port clusters and ports in a cluster, quantitative methods to depict the port clusters' evolution process and further to evaluate the competitive status of port clusters are in great demand.

Since the reform and opening in 1978, "import serves export" trade mode has greatly promoted economic and trade development in China. From 1978 to 2012, the volume of international trade increased from \$ 20.64 billion to \$3.6421 trillion, GDP increased from 3,624.1 trillion to 519,322 trillion RMB, and the volume of Freight Handled in Main Coastal Ports increased from 198.3 million tons to 8.909 billion tons<sup>iii</sup>. Especially after entering the WTO in 2001, China's total foreign trade volume increased tremendously, at an average rate of 21% per year (Figure 1).



Figure 1: China's Foreign Trade\*

As the world businesses and industries shifted towards China, the center of marine ports also transferred from the United States and Europe to Asia. Five of the top ten ports in the list of World container throughput ports are Chinese, wherein Shanghai port has been claiming the top position since 2010<sup>iv</sup>. The port management mode in China has been changed from "centered government administration" mode to "central government administration plans the whole ports development frame and the local government operate and manage the local port" mode. Along with the trend of large-scale container vessels, intermodal development and the regional economy integration, the business mode of ports need to change from standalone and zero-sum competition to port cluster mode, where ports in the same cluster are coordination both at governmental and operational levels. To cater for this trend, the Ministry of Transport of the People's Republic of China (MOT) had classified coastal ports into five clusters as shown in figure 2.

#### **Figure 2: Spatial Distribution of Chinese Coastal Port Clusters**



To facilitate the synchronization of port clusters, this paper applies HHI and shift-share methods to quantify Chinese port clusters' evolution process and competitive situation based on statistical data from 2001-2011.

#### 2. Literature

For domestic and overseas geographic scholars, port architecture research is a popular topic including port architecture evolution and formation mechanism analysis. Six stage model (Taaffe, 1963) and Anyport model (Bird, 1971) had a notable impact on the other scholars. Based on the Taaffe mode, Rimmer(1967) studied the liner factors affecting port architecture and divided the port spatial structure evolutionary process into four stages. Hilling (1977) analyzed Gana's port's system system evolution and proposed that large ports as a hub can coexist with small ones feeding hub ports and the hub status of large port in the regional port cluster also can be substituted by small port because of the change of itself and its hinterland. Havuth (1998) proposed a five-phase model which illustrates the dynamic development process of a container port system and the rationale behind such development. Baird (1997) proposed the container hub port life-cycle model and selected European container ports as a case study. According to Hayuth's model, Cao Youhui (1999) indicted that the lower Yangtze River Delta container port system has experienced three development stages: (1) Initial adoption from the early 1970s to the early 1980s. (2) Diffusion during the period of 1986 and 1995. (3) Primary concentration of 1996. Han Zenlin et al (2000) made an in-depth analysis of the formation and evolvement mechanism and development mode of Container load center in the world and also discussed the development stratagem of Container load center in China. Wang Jixian(2000) and Slack James(2004) studied the government effect on the port system. Wu Qitao (2011) analyzed the concentration and decentralization process influencing factors and built the port system dynamic model which explained factors affecting the port system evolution and driving mechanism. The overseas scholars discovered the port system evolvement mechanism theory and proposed development model with empirical analysis, and the domestic analyzed Chinese ports development stages and evolvement mechanism based on the classic port theory. Kuang((Kuang,H.B., Li,W.,& Zhang,X. 2012) pointed that he trend of supply exceeding demand expanded Chinese container port.

The dominating power shifting of global port clusters around the globe in the past three decades has attracted attention from both the industry and academia. Qualitative and quantitative measures have been utilized to quantify the shifting process. However, quantitative measure and evaluation of Chinese coastal port clusters are still in its infant stage owing to the difficulties in obtaining sufficient empirical data. Based on more than ten years consistent empirical investigation in international logistics of China, the authors apply HHI and shift-share method to quantify the evolution and competition profiling of Chinese coastal port clusters.

## 3. Research Scope and Data Collection

While doing research on the system and competition pattern of container port in China from the year 1992 to 2001, Cao Youhui et al. (2004) indicated that three port clusters have been formed, the Bohai port cluster, the Yangtze River Delta port cluster and Pearl River Delta port cluster, and that the port cluster system is becoming concentrated. The international trade volume has grown at a remarkable rate, averaging almost 14 percent per annum from 1978 to 2001. Since entering the WTO, the growth rate has averaged almost 26% percent per annum from 2001 to 2008, almost double the rate from the 1978 to 2001. The rapid international trade and economic growth promoted port's development and made Chinese ports new power engine of international shipping.

In this paper, five port clusters as indicated in Figure 2 are covered and 40 ports are considered, among which 11 from Bohai port cluster, 12 from Yangtze River Delta port cluster, 4 from Southeastern port cluster, 9 from Pearl River Delta port cluster and 4 from Southwest port cluster, respectively. Data of container port throughputs is collected from China Port Statistic Yearbook, Ministry of Transport of the People's Republic of China and the official websites of the ports for the period ranging from 2001 to 2011.

### 4. The System Evolution and Formation Mechanism of the Container Port Cluster

Gini Coefficient and Lorenz curve are widely used in quantify the imbalance of a system, especially an economic system with only one overall indicator resulted which could not pinpoint on which part of the system is imbalanced to what degree. However, for the quantification of a port logistics system, geographical impartial information is crucial to the integration of port clusters or ports in certain cluster. Therefore, Herfindahl-Hirschman Index (HHI) is applied in this piece of research. The Herfindahl–Hirschman index (also known as Herfindahl index, or HHI) is a measure of the size of firms in relation to the industry and an

indicator of the amount of competition among them. Named after economists Orris C. Herfindahl and Albert O. Hirschman, the HHI which is a commonly accepted measure of market concentration is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. For example, for a market consisting of four firms with shares of 30, 30, 20, and 20 percent, the HHI is 2,600. It can have a theoretical value ranging from close to zero to 10,000. If there exists only a single market participant which has 100% of the market share the HHI would be 10,000. If there were a great number of market participants with each company having a market share of almost 0% then the HHI could be close to zero. These values are used by the U.S. Department of Justice when evaluating whether to permit a merger of two companies. 1) When the HHI value is less than 100, the market is highly competitive. 2) When the HHI value is between 100 and 1000, the market is said to be not concentrated. 3) When the HHI value is above 1800, the market is said to be highly concentrated. Mathematically, the HHI index can be represented as follows:

$$HHI = \sum_{i=1}^{n} (shares_i)^2$$
(1)

$$Share_{i} = \frac{TEU_{i}}{\sum TEU_{i}}$$
(2)

Where the HHI is the whole port cluster concentration index, Share<sub>*i*</sub> is the proportion of *i*th port's throughout to the whole port cluster,  $\text{TEU}_i$  is port *i*th's throughput, whereas *n* is the total port number in the port cluster. The HHI ranges from 1/n to 1. The meaning of the two extreme points of the interval is explained as following: HHI = 1 means that the port cluster is highly concentrated whereas HHI = 1/n means that the port cluster is de-concentrated. The results are shown in Table 2. The concentrated port system tends to decentralization, similar to the scenario of American container ports in late.

#### 4.1 The five port clusters are relatively independent and the concentration is gradually emerging

Taking the five port clusters as a whole, the HHI is between 0.2833 and 0.2998 and also is gradually increasing over the years, shown in the Figure 3. Compared to the other three port clusters, the Southeastern and the Southwestern port clusters' throughputs are relatively small. So, removing the southwestern and the southeaster the two port clusters, the HHI value from 2001 to 2011is given in Table 1. We can see that the value is gradually increasing and nearly closed to 1/3 which is the extreme point of the HHI. The HHI trend can be concluded that the port clusters are relatively independent and the concentration is emerging among the port cluster system.

Year	HHI	2006	0.2964
2001	0.2833	2007	0.2998
2002	0.2926	2008	0.2968
2003	0.2914	2009	0.2938
2004	0.2938	2010	0.2978
2005	0.2994	2011	0.2977

 Table 1: The HHI Value except the Southeastern and Southwestern Port Cluster

Studies has shown that the proportion of road transportation proportion is more than 80% (Shi et al. 2005, Ma 2006, Ma 2009, Zhao 2011), which is mainly due to the backward infrastructure of rail container transportation, the imperfection in the multimodal transport networks and the lack of communication with the related operation department. The road transmission economic range is less than 300km whereas rail and water transmissions are in between 300km to 500km and more than 500km, respectively (Zhen 1999). Evidently the main type of port transportation is short-distance, so the cross hinterland among the three port clusters is not obvious. The whole port cluster system in China with no serious competition for the hinterland is relatively independent.

## 4.2 Each of the regional port systems is changed from highly concentration to de-concentration, but the port cluster system is changed to the concentration

It's shown that the HHI of Yangtze River Delta and the Bohai port cluster are declining. The Pearl River Delta HHI was gradually increasing from 2001 to 2004, declining rapidly from 2005 to 2007, and finally declining slowly from 2007 to 2011, the southeastern port cluster was witnessed a rise, then dropped and finally again rose as shown in the figure 3. As it's shown that the HHI of whole port cluster is lower than of the each regional port, which indicated the port cluster system is more de-concentrated than the regional port system. Meanwhile, the HHI of the port cluster system is increasing compared with the declining of the each regional port system, which indicated that the port cluster system will turn to concentration, but the regional port system to de-concentration. Although the trend of the regional port system is the same, the starting time of the change is different. The Pearl River Delta port cluster continually developed toward the high concentration from 2001 to 2006 and changed to the de-concentration from 2007 to 2011. The time of Bohai was in the year of 2005. The reason for the different is because of the different economic development. So the longer the economy has been developed, the earlier the de-concentration has emerged.



## 4.3 The regional port system is changing from concentration with one hub to de-concentration with more than one center ports

With the emergence of container technology and the larger-size container vessel, the port cluster architecture has formed the hub-branch-feeder port model. Each of the HHI except the all is gradually declining, which indicates that the de-concentration is emerging and there will exist more than one load center ports with high competition, as shown in the figure 3. Such as Yangtze River Delta port cluster with Shanghai and Ningbo port, Pearl River Delta port cluster with Guangzhou and Shenzhen port, and so on.

#### 5. Analysis the Competition Situation of the Container Port Cluster based on the Shift - share Analysis Method

Shift-share analysis is a widely used analytical technique, sometimes used for retrospectively decomposing changes, usually in employment, in a set of urban areas or regions. The analysis is meant to identify industries considered to have a comparative advantage in that particular area. Shift-share Analysis breaks down regional employment growth into three components: 1) National share,2) Industry mix,3)Regional shift. Since its inception proposed by the U.S. economist Daniel (1942) and Creamer (1943) in the years 1940s, over seventy academic contributions have criticized, defended, and extended the original concept. In China, Cao Youhui(2004),Liang Shuangbo(2008) analyzed Chinese container port competition situation and the total shift of the Yangtze River Delta port system by the method of Shift-share Analysis from 1992 to 2001. In the research of the port competition situation, Shift-share Analysis includes three parts: the self-growth, growth sharing with the regional and growth sharing with the total.

$$t_i = [T + (T_i - T) + (t_i - T_i)]$$
(3)

$$\Delta t = [T + (T_i - T) + (t_i - T_i)] * e$$
(4)

Where T is the total growth,  $T_i$  is the *i*th regional port cluster growth,  $t_i$  is the *i*th port self-growth.  $t_i - T_i$  is the shift-growth,  $T_i - T$  is the growth sharing the regional, T is the growth sharing the total.  $\Delta t$  is the growth

volume, e is the port's throughput,  $(t_i - T_i) * e$  is the shift-growth volume. When  $(t_i - T_i)$  is positive the port is advantage in competition, otherwise the port is weaken in competition. The results are shown in table3.

# 5.1 The competition of Yangtze River Delta and the Southwestern port cluster are strengthened, while the Pearl River Delta, the Southeastern and the Bohai are weakened

According to Table 3, from 2001 to 2011 most shift-growths of the Yangtze River Delta are positive, that of the Southwestern port cluster has been positive since 2008, but that of the Pearl River Delta, the Southeastern and Bohai port cluster are negative. As we know that the competence of port mainly comes from the hinterland economy and international trade, transportation, location, infrastructure, logistics efficiency and so on (Feng,X.J., Jiang,L.P., Yan,Y.X., &Li,C.C.2011).The International Financial Center development of the Shanghai city, efficient environment of port clearance, Yangtze River Delta economic zone and the international hub port position of Shanghai, provided a good development opportunity for the Yangtze River Delta port cluster, So its competition is strengthened.

Voor	Pearl River Delta		Yangtze River Delta		Bohai Port cluster		The Southeastern		The Southwestern	
Teal	volume	growth	volume	growth	volume	growth	volume	growth	volume	growth
2001	350.8	0.1	-367.0	-0.1	28.5	0.0	-29.0	0.0	16.8	0.2
2002	418.0	0.1	600.3	0.1	-758.6	-0.1	-354.9	-0.2	95.2	0.8
2003	157.7	0.0	154.4	0.0	-589.5	-0.1	347.7	0.2	-70.3	-0.3
2004	-222.9	0.0	447.5	0.0	-89.7	0.0	-91.4	0.0	-43.5	-0.2
2005	-472.0	0.0	1111.5	0.1	-270.8	0.0	-346.2	-0.1	-22.5	-0.1
2006	-972.2	0.0	-264.8	0.0	1261.6	0.1	-20.2	0.0	-4.4	0.0
2007	7029.6	0.3	-3261.3	-0.1	-2522.6	-0.1	-1183.6	-0.2	-62.2	-0.1
2008	-9003.4	-0.2	3796.9	0.1	4314.7	0.2	763.4	0.1	128.4	0.2
2009	1355.6	0.0	-6954.7	-0.2	4742.2	0.2	673.5	0.1	183.4	0.3
2010	-4491.5	-0.1	10452.5	0.3	-4788.7	-0.2	-1312.4	-0.2	140.1	0.2
2011	-2274.9	-0.1	650.1	0.0	1374.9	0.0	18.3	0.0	231.6	0.2

 Table 3: The Shift-Growth and Shift-Growth Volume of Five Port Cluster from 2001 to 2011

In 2006, the State Council issued the policy about accelerating the industries structural adjustment and upgrade. In July 2007, the Ministry of Commerce and General Administration of Customs jointly issued the restricted catalogue of processing trade to limit the new established enterprises to do the restricted business in the eastern ten provinces. In November 2007, the Ministry of Commerce and the National Development Bank jointly issued the policy of "suggestion of supporting the central and western regions to undertake processing trade" to promote the development of the western region's foreign trade. These polices brought new vigor and vitality for the Southwestern port cluster, hence the shift-growth has been positive since 2008. The Pearl River Delta with export-oriented economy and labor-intensive and simple process industries is the lack of economic development potential. After the world crisis the decreasing foreign trade order and the increasing labor cost seriously affected the hinterland economy and thus the lack of port cargo in the Pearl River Delta port cluster weakened its competition.

## 5.2 *The competition situation of main ports in the port cluster*

This paper only listed the major ports' shift-growth volume and analyzed their competitive advantage. The results provided in Table 4 indicate that the growth of the hub or the center load port in a port cluster is slower than that of the branch or feeder ports which increase their cargo attraction through increasing infrastructure investment and adopting preferential policies, such as the Shenzhen compared with Guangzhou port and the Shanghai compared with the Ningbo port. It is shown in table 4 that the Guangzhou Port's shift-growth volume has increased by million TEU each year since 2004, compared with the Shenzhen Port's negative shift-growth. The same thing has happened in the Shanghai and Ningbo Port, where the shift-growth has been negative in the Shanghai port and positive in the Ningbo port since 2001. In the Bohai port cluster, Dalian and Tianjin port shift-growth are negative, but the Qingdao port is positive. The reason for this trend is that diseconomy of scale emerged in the hub ports and caused the hub cargo flowing to the peripheral ports. With

the peripheral ports gradually developed, the port cluster system model has changed from one hub port to many center- load ports and the hub ports' competition is relatively weakened.

Year	Shenzhen	Guangzhou	Tianjin	Dalian	Qingdao	Shanghai	Ningbo	Xiamen	
2001	38.43	-65.86	-58.27	-7.94	4.00	-143.47	171.46	6.85	
2002	436.23	-285.53	-92.73	-161.25	19.06	-481.97	85.19	229.68	
2003	403.99	-160.91	-11.17	-29.08	-0.69	-291.91	306.99	-246.03	
2004	272.74	-157.33	9.96	103.21	13.85	-112.48	410.61	26.25	
2005	-372.73	663.65	158.76	-3.18	3.76	-297.54	26.43	15.93	
2006	-859.59	1045.92	-376.07	-328.54	61.60	-932.11	402.67	-77.83	
2007	-1002.11	1318.87	-308.82	-187.60	50.91	-1471.05	715.75	-45.14	
2008	-1195.75	1048.61	254.76	96.59	54.13	-2457.65	737.98	57.78	
2009	-1278.94	1183.18	-106.42	-121.60	-83.46	-1878.87	182.09	-188.36	
2010	770.15	-807.29	-112.25	-89.03	-51.14	777.29	-66.68	25.36	
2011	-1302.28	985.60	-68.17	318.82	37.33	-1076.75	-130.72	-56.59	

 Table 4: The Main Shift-Grown Volume (Unit: thousands TEU)

#### 6. Conclusions and Suggestion

This paper collected five port cluster throughput data including forty-one ports and analyzed evolution and competitive situation of Chinese container port cluster system with the methods of HHI and Shift-share Analysis. The results show that the relatively independent system of the port clusters tend to concentration, while the inner system of the port cluster has been highly concentrated and tends to decentralization. After the world economic crisis and the adjustment of industries structure, the competitive advantage of Yangtze River Delta and the southwestern port cluster have been obviously strengthened in recent years, while the Pearl River Delta and the Bohai port cluster have been weakened. The hub-branch-feeder port model with two or more load center ports will make the competition between ports even higher. For example, the Guangzhou and Shenzhen port, the Shanghai and Ningbo port, all are competing for cargo and being the international shipping center.

The concentrated port clusters system and the de-concentrated port cluster system indicate that there is high competition for international shipping center among the port clusters and strong competition for the hub in the port cluster, which will certainly cause repeated investment and wastage of resource without proper policy and management. The larger-sized vessel and multimodal transportation will strengthen it. With a background of green logistics and "the center control, the local government manage" port development model, the port administration must make overall plan to coordinate the port to the regional economy and integrated logistics including proper transportation, policy and operation model. The local government must make the proper strategy and evaluate the competitive strength of the port, such as building the efficient transportation system, making the logistics integration, enhancing the port informatization, cooperating with the port related department to increase the logistics service level and reduce the total cost.

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<sup>ii</sup> Data source : International Statistical Yearbook 2011

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iii Data source: China Statistical Yearbook

<sup>&</sup>lt;sup>iv</sup> Data source: Shanghai International Shipping Institute

## The Elasticity of Substitution between Owned and Leased Containers

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#### Abstract

In shipping practice, the utilizations of owned and leased containers are generally regarded as homogenous factor inputs and perfect substitution in providing container shipping service. In economics theory, the characteristic of perfect substitution implies an extremely price-sensitive pattern of factor input utilization. To follow the input ratios and price ratios of owned to leased containers, the former one shows a relatively stable pattern, but the latter one presents a trend with gradually decreasing rental rates of leased containers in recent years. Obviously, the practical observations on the pricing behavior of international container leasing market and the theoretical implications of the production function with perfect substitution are contradicted. The paper shows that the substitution between leased and owned containers is not perfect even though these two kinds of containers are homogeneously treated in shipping operation. By contrast, a fixed proportion production function is verified. Given a production function with fixed proportion technology, theoretically, it implies that the optimal combination between owned and leased containers will be located at a fixed ratio which is completely determined by some exogenous factors, other than the price ratios of owned and leased containers. As a consequence, the result suggests that some unknown factors not included in the production function may play the key roles on determining the combination between owned and leased containers in the operation of container shipping.

Keywords: container leasing, container shipping, elasticity of substitution, perfect substitution, fixed proportion technology

#### 1. Introduction

In international container shipping industry, it is a critical and complicated issue for carriers to determine a proper stock of containers for maintaining their operations and services along the port network they call. In practice, shipping lines need to keep a container fleet to support their ongoing operations, and prefer to buy a relatively fixed proportion of owned containers, irrespective of the whims of the market (Containerisation International Yearbook, 2007, p. 15). Due to the tremendous burden of capital cost associated with holding required amount of containers by container carriers, there are only a few carriers, especially in the early stage of containerization, able to afford the costly expenditure on expanding their containers fleet without sacrificing the growth of containerships fleet.

However, the fluctuations of market demand have brought an extreme difficulty for carriers to remain the balance between the demand and supply of containers. Facing with a volatile transportation demand in global container shipping, an aggressive attitude toward the development of containers fleet may lead to a number of idle containers scattered at the ports called and a huge capital burden for holding excessive containers. In contrast, a conservative attitude may incur a loss of business opportunities due to containers shortages. Therefore, a development strategy of container fleet by mixing with leased and owned containers has been widely adopted by container shipping lines to support transportation demand and to hedge against the risk of

capital loss as holding too many owned containers or suffering devalued container price under a low-demand market condition.

In addition, Theofanis and Boile (2009) and Rodrigue (2009) also indicate that the empty container reposition caused by the trade imbalance between the eastern and western hemisphere after 1980s is a highly cost-consuming problem for container shipping lines and leasing companies. Since the beginning of containerization in the 1970s, as a consequence, the container leasing industry has emerged to offer an alternative tool in the management of containers fleet, enabling shipping companies to cope with temporal and geographical fluctuations in the demand (Rodrigue, 2009). Obviously, it will be helpful for shipping lines, container leasing companies and researchers to foresee the market development in global container leasing industry if the factors on determining the combination of leased and owned containers among container shipping lines are discovered.

The purpose of this paper is mainly to investigate the elasticity of substitution between owned and leased containers. By utilizing industry-specific data with the viewpoint of global container shipping industry, this study has applied a production function with constant elasticity of substitution (CES) to analyze the elasticity of substitution between owned and leased containers. Different from the practical observation viewing owned and leased containers as a pair of homogenous factor inputs in shipping operation, interestingly, the finding shows that a fixed proportion, but not perfect substitution, production function is a proper function form to describe the behaviors of shipping lines on holding a container fleet mixed with owned and leased containers.

### 2. Practical Observation and Theoretical Implications

#### 2.1 *Observation on container leasing market*

On the purpose of delivering cargos, it is generally indifferent for a container shipping line to use owned or leased containers to load cargoes in transportation. And therefore, the two kinds of containers can be regarded as perfect substitution in shipping practice. In literature, Wang (2012) points out that the perfect substitution between owned and leased containers has benefited the shipping lines by utilizing and expanding their own container fleet to erode the market power of container leasing companies. In turn, any attempt by leasing companies to exert market pressure on rental rates will simply result in the purchase of more containers by shipping lines. Due to the sound financial structures among the huge container shipping lines and more friendly and accessible international capital market under a fairly low interest rate during the past decade, it has also facilitated most container shipping lines to purchase more containers for building up their own container fleet. As a result, the container leasing industry has experienced a gradual evolution with decreasing rental price per diem and lost market share to the carriers own containers since 1990s.

Compared with the rising trend on the price ratios of owned to leased containers, as shown in Figure 1, the input ratios of owned to leased containers present a relatively stable level around 1.2. It demonstrates that the global container fleet in the container shipping industry is mixed with a roughly fixed proportion of owned and leased containers, regardless of the per diem rates of leased containers gradually becoming cheaper than the ones of carriers own containers.



#### 2.2 The elasticity of substitution

In economics, neoclassical production theory recognizes the possibility of substituting one factor of production for another. Under a production technology, an isoquant is the set of all possible combinations of inputs that are sufficient to produce a given level of output. And, the elasticity of substitution ( $\sigma$ ) is generally used as an index to reflect the geometric expression for the curvature of an isoquant. Graphically, the index shows changes in relative factor demand with respect to changes in the marginal rate of technical substitution. Meanwhile, it is also equivalent to the elasticity of input ratio with respect to input prices ratio. Therefore, the elasticity of substitution in a production function with two factor inputs can be expressed as:

$$\sigma = \frac{dx_{/X}}{dW_{/W}} \tag{1}$$

where  $X = \frac{X_1}{X_2}$ ,  $W = \frac{W_1}{W_2}$ . And,  $W_1$  and  $W_2$  are the factor prices corresponding to input factors,  $X_1$  and  $X_2$ . By definition, the value of  $\sigma$  varies between 0 and  $\infty$ . Following with economics theory, each of the extreme values, as shown in Figure 2, implies a special case of production pattern with a L-shaped or straight line isoquant cure, respectively. In other words, the production function presents a pattern with fixed proportion<sup>i</sup> or perfect substitution between factor inputs, as  $\sigma \rightarrow 0$  or  $\sigma \rightarrow \infty$ , respectively.



According to the theory of production in economics, the optimal input combination for an L-shaped isoquant curve, as shown in Figure 2, must be located at the points along the arrow line OT, which is completely determined by an exogenously given ratio of factor inputs. In fact, it reflects an isoquant with zero elasticity of substitution, and therefore indicates that there is no possibility to substitute one input factor with the other one at the optimal point even if the input price ratio has been greatly changed. Apparently, the price ratio plays no role on determining the optimal combination of factor inputs if the production function is characterized with fixed proportion technology.

In perfect substitution case, the optimal input combination is always located at either one of the corner points along the straight line isoquant, and therefore totally dependent on the price ratio of the two factor inputs. For example, an isoquant curve specified as  $X_1+X_2=1$  and shown in Figure 2 implies that the firm will merely use input  $X_1$  to produce the given amount of output if the price ratio,  $W = \frac{W_1}{W_2}$ , is less than one. Under a production technology with perfect substitution, the most cost-saving input combination for the firm is to use input  $X_1$  only while the price of the input  $X_1$  is less than input  $X_2$ . Accordingly, it implies that container shipping lines will completely utilize the type of containers with lower price if the two types of containers are perfect substitution.

With reference to the curves shown in Figure 1, it shows that the price ratios of owned to leased containers,  $P_O/P_L$ , have been over one since 2002 to indicate a relatively higher cost for a container carrier holding its own containers. Nevertheless, the more expensive owned containers have never forced shipping lines to completely abandon developing their own container fleet. Furthermore, the less expensive leased containers did not make container leasing companies to earn a dominant role with share over half amount of global containers either. On observing the coexistence of owned and leased containers in the container shipping industry, obviously, it is implausible to argue that the two kinds of containers are perfect substitution.
#### 3. The Estimation of Elasticity of Substitution

#### 3.1 Production function with constant elasticity of substitution

To follow the production theory in economics, it is well recognized the possibility of substituting one factor of production for another. In order to investigate the extent of substitution between the owned and leased containers in the international container shipping industry, it is assumed that there are only two inputs, owned containers ( $X_1$ ) and leased containers ( $X_2$ ), used to support a given output level (Y), measured by the unit of TEU (twenty-foot equivalent unit). In addition, a time variable (t) is also included into the function to represent the exogenously disembodied technological change in container shipping transportation. Accordingly, the production function of shipping industry can be specified as:  $Y_t = f(X_{1,t}, X_{2,t}, t)$  (2)

In order to know the substitution between the factor inputs of production function, it is necessary to specify a production function. In empirical studies, the Cobb-Douglas (CD) function is the most commonly utilized form in the specification of the production function because it can be easily linearized to estimate important production parameters. However, a priori condition with a unitary elasticity of substitution is the most suspicious idea, while assessing the adequacy of function form in the studied cases. Hence, the strong assumption to restrict a unitary elasticity of substitution under a CD production function is still questionable and proved to be an improper specification of production function in some empirical studies (Hsing, 1996; Bonga-Bonga, 2009). Since the main goal of this study is focused on investigating the substitution between owned and leased containers in container shipping industry, the unity of elasticity of substitution implies the inadequacy of CD production technology. Instead, a CES production function is applied in this study to investigate the substitutability between owned and leased containers in international container shipping industry. In recent years, the CES production technology has gained much popularity in empirical studies, and can be addressed a wider range of elasticity of substitution embodied in a production function.

In this study, a CES production function will be selected to investigate the substitution between the owned and leased containers in container shipping industry. It is assumed that the production function at time t is specified as:

$$Y_t = A_0 e^{\gamma t} \left[ \alpha X_{1,t}^{-\rho} + (1-\alpha) X_{2,t}^{-\rho} \right]^{\frac{-n}{\rho}}$$
(3)

where  $A_0$ ,  $\gamma$ ,  $\rho$ , and h are scale, technological change, substitution and return to scale parameters. And,  $\alpha$  and  $(1-\alpha)$  are factor distribution parameters. Based on the definition and theoretical derivation, the elasticity of substitution corresponding to equation (3) can be measured by

$$\sigma = \frac{1}{1+\rho} \tag{4}$$

Hence, the range of values for  $\rho$  is  $-1 < \rho < \infty$ . By equation (4), the CES function is a L-shaped isoquant to represent a fixed proportion production function as  $\rho \rightarrow \infty$  and  $\sigma \rightarrow 0$ . And, the isoquant curve becomes a straight line to represent a perfect substitution case as  $\rho \rightarrow -1$  and  $\sigma \rightarrow \infty$ . When  $\rho \rightarrow 0$  and  $\sigma \rightarrow 1$ , the CES function is reduced being a CD function with a constant elasticity of substitution equal to one. Therefore, the CD function is a special case of CES function.

#### 3.2 Estimation approach

Other than the estimation of CD function only needs a logarithmic transformation for its linearization, the CES function is non-linear and cannot be easily transformed to be linear regression equation. Thus, the standard linear estimation methods cannot be applied to the estimation of the parameters in a CES function<sup>ii</sup>. By utilizing the marginal production of factor input, in this study, an indirect estimation with two-step approach is applied to estimate the parameters of the CES production function (Erol, 2006, Xu, 1999, Fitzroy, 1995).

In the first step, the marginal productivity of factor input is derived as follows:

$$\frac{\partial Y}{\partial X_1} = A_0 e^{\gamma t} \left[ \alpha X_1^{-\rho} + (1 - \alpha) X_2^{-\rho} \right]^{\frac{-h-\rho}{\rho}} h \alpha X_1^{-(\rho+1)}$$
(5)

$$\frac{\partial Y}{\partial X_2} = A_0 e^{\gamma t} \left[ \alpha X_1^{-\rho} + (1-\alpha) X_2^{-\rho} \right]^{\frac{-h-\rho}{\rho}} h(1-\alpha) X_2^{-(\rho+1)}$$
(6)

Under a competitive shipping market, the first order condition for profit maximization implies that the optimal condition for the demand of the owned and leased containers can be expressed as:

$$\frac{\partial Y}{\partial X_1} = MP_{X_1} = \frac{W_1}{P_Y}$$

$$\frac{\partial Y}{\partial X_2} = MP_{X_2} = \frac{W_2}{P_Y}$$
(7)
(8)

Dividing equation (7) by (8), the ratio of owned to leased container prices is derived as:

$$\frac{\alpha X_1^{-(\rho+1)}}{(1-\alpha)X_2^{-(\rho+1)}} = \frac{W_1}{W_2}$$
(9)

Next, by taking natural logarithm to equation (9), a linear regression equation can be developed as:

$$\ln \frac{X_1}{X_2} = \beta_0 + \beta_1 \ln \frac{W_1}{W_2} \tag{10}$$

where  $\beta_0 = -\frac{1}{\rho+1} ln \left(\frac{\alpha}{1-\alpha}\right)$  and  $\beta_1 = -\frac{1}{\rho+1}$ .

In fact, equation (10) is utilized as the first step in the linearization of the CES function. At this step, the elasticity of substitution,  $\sigma$ , is estimated as well as the distribution parameter  $\alpha$ . In the meantime, the hypothesis for testing the elasticity of substitution corresponding to the production function specified in equation (3) can be set as:

$$H_0: H_0: -\beta_1 = \frac{1}{\rho+1} = \sigma = 0$$
(11)

Statistically, this hypothesis testing implies a fixed proportion production function if the hypothesis can't be rejected.

Given the estimated values for the two parameters,  $\sigma$  and  $\alpha$ , furthermore, a composite explanatory variable,  $Z_t$ , is constructed and expressed as:

$$Z_t = \left[\alpha X_{1,t}^{-\rho} + (1-\alpha) X_{2,t}^{-\rho}\right]^{\frac{-\rho}{\rho}}$$
(12)

By replacing equation (12) into equation (3) and taking a natural logarithm transformation for the resulting equation, the second step for linearizing a CES function is performed to construct a linear regression equation as:

$$lnY_t = lnA_0 + \gamma t + h * lnZ_t \tag{13}$$

Obviously, the parameters,  $A_0$ ,  $\gamma$ , and h, in the CES production function can be estimated by equation (13).

#### 3.2 Data sources and empirical results

In the empirical study, two regression equations specified in equation (10) and (13) will be estimated for computing the elasticity of substitution and other parameters in the production function. On estimating the parameters in equation (10), two ratio variables respectively representing the input prices  $(W_1/W_2)$  and factor input usages  $(X_1/X_2)$  should be measured at first. Hence, there are only four variables needed to perform the regression estimation for equation (10) and (13). In this study, the discounted present values of newly built containers with 8-year life time and zero residual value are computed to measure the holding cost of containers owned by container shipping lines. The sample period spans from 1990 to 2010. All the data for the four variables are mainly drawn from the relevant issues of the *Containerisation International Yearbook* and *Review of Maritime Transport*.

Initially, the ordinary least square (OLS) technique is utilized to estimate the parameters in equation (10) and (13). Since the residual errors of the OLS estimation reveal a significantly serial correlation, an autocorrelation model is applied. The estimated parameters of the two equations along with their *p*-values are reported in Table 1. The  $R^2$  values for equation (10) and (13) are 0.76, 0.98, respectively. In equation (10), the estimate of constant term reveals statistically significant. However, the key parameter,  $\beta_I$ , which represents negative elasticity of substitution, is not significantly different zero, and therefore implies that the elasticity of substitution is statistically equal to zero. Accordingly, the argument of perfect substitution between the owned and leased containers is not supported by this empirical result. By contrast, it significantly suggests that the CES production function specified in equation (3) is developed from a fixed proportion production function function function, surprisingly, the empirical result implies that the utilization of the fixed proportion production function with the prices ratios of owned and leased containers.

In fact, the finding reflects the relationship between the two curves shown in Figure 1 that the increasing input ratios of owned to leased containers are associated with increasing price ratios. Since 2004, in particular, the uprising trend of input ratios is unexpectedly corresponding with an increasing trend of price ratios. Therefore, it illustrates that the utilization of factor inputs does not follow the theoretical implication to present a negative relationship between the input and price ratios if the two types of containers are substitute each other. Implicitly, the result indicates that some unknown factors not included in the production function may play the key roles on determining the combination of owned and leased containers in the global operation of container shipping.

In equation (13), the estimates of parameters show to be significant in technical parameter,  $\gamma$ , but insignificant in scale parameter, *h*. The result indicates that the growth rate of technical progress in the operation of global container shipping is significant with an annual rate of 7 percent. Surprisingly, the insignificant scale parameter presents an outcome to show the ineffectiveness of expanding the scale of global container fleet on the productivity growth of international container shipping industry. Obviously, this finding implies that an over-capacity of global container fleet has been deployed into shipping market by the container shipping lines and leasing companies. Given the higher container price under the more expensive steel price, in fact, the persistently low cost of capital caused by the historically low interest rate during the past several years may have outpaced the disadvantage of higher container prices, and push container shipping lines and leasing companies eager to expand their container fleet. Under a fixed proportion technology of production, in addition, this finding may provide some clue to investigate the factors for determining the mix of owned and leased containers among the shipping lines and leasing companies.

Table 1						
Equation (10)				Equatio	n (13)	
Variable	Coefficients	P-value	Variable	Coefficients	P-value	
β <sub>0</sub>	0.303	0.003	γ	0.07	0.001	
β1	0.207	0.235	h	0.00001	0.359	
$R^2$	0.76		$R^2$	0.98		

# 4. Conclusion

In shipping practice, the utilizations of owned and leased containers are generally regarded as homogenous factor inputs and perfect substitution in providing container shipping service. In theory, the characteristic of perfect substitution implies an extremely price-sensitive pattern on the utilization of factor inputs. By observing the input ratios and price ratios of owned to leased containers, however, the former one shows a relatively stable pattern and latter one presents a trend with a gradually decreasing rate of leased containers in the past two decades. Accordingly, the theoretical implication for the production function with perfect substitution and the practical observation on the price ratios and utilization ratios of owned and leased containers are contradicted.

By applying a production function with CES technology, this paper finds that the substitution between owned and leased containers is not perfect. In contrast, it follows a pattern with fixed proportion technology. Given a production function with fixed proportion technology, theoretically, it implies that the optimal combination between owned and leased containers will be located at a fixed ratio which is completely determined by some exogenous factors, except the price ratios of owned and leased containers. In other words, the finding suggests that some unknown factors not included in the production function may play the key roles on determining the utilizations of owned and leased containers in the global operation of container shipping.

In the further study, this paper can be extended to investigate what and how the key factors have played on determining the fleet developments of owned and leased containers for container shipping lines. And therefore, the findings of the study will be very helpful on forecasting the individual growth of the leased and owned containers in the future.

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<sup>&</sup>lt;sup>i</sup> By definition, an isoquant curve with a zero value of  $\sigma$  implies no possibility of substitution between different factor inputs, conditional on producing a given level of output. Conceptually, this type of isoquant is just like the case of perfect complement in consumer theory. Thus, the fixed proportion can be viewed as a complementary case in the usage of the two factor inputs.

<sup>&</sup>lt;sup>ii</sup> Kmenta (1967) provides an approach that directly estimates the CES production function by approximating the non-linear CES specification with Taylor transformation around  $\rho = 0$ , and linearizing it by dropping the terms involving powers of  $\rho$  larger than one. However, the application of Kmenta approximation is limited because it only returns reliable results if  $\rho$  is close to its point of approximation, i.e. zero (Thursby and Lovell, 1978). Hence, the linearization of non-linear CES production function by employing Kmenta approximation is only applicable for elasticities of substitutions in the neighborhood of unity. In addition, other problems with Kmenta approximation include that it is only applicable to a two input case and presupposes that the elasticity of substitution is unity (Hoff, 2004). Also, the estimation of CES function by using the non-linear methods cannot either perform very well due to the problems, a large flat of surface of objective function to cause local minima, the discontinuity of CES function and considerable rounding errors at specific parameters (Henningsen and Henningsen, 2012).

# Liability Regime of the Carrier under the Rotterdam Rules

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#### Abstract

The Rotterdam Rules set up a new regime of liability of the carrier in the law of carriage of goods wholly or partly by sea. It re-structured the current liability regime in the Hague-Visby Rules which is a world-widely accepted international convention for the carriage of goods by sea. This paper is a comprehensive study of liability regime of the carrier under the Rotterdam Rules in the context of the Hague-Visby Rules and common law (see appendix). The conclusion is that the liability regime in the Rotterdam Rules is not a successful liability regime of the carrier in the carriage of goods by sea. Respect should be given to the Hague-Visby Rules and current common law practices.

Keywords: Liability regime, The Rotterdam Rules, The Hague-Visby Rules, common law

## 1. Introduction

In 2008 the United Nations adopted a Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea (the "Rotterdam Rules").<sup>i</sup> The Rotterdam Rules build upon, and provide a modern alternative to, earlier conventions relating to the international carriage of goods by sea, in particular, the International Convention for the Unification of Certain Rules of Law relating to Bills of Lading (Brussels, 1924) ("the Hague Rules"), and its Protocols ("the Hague-Visby Rules"), and the United Nations Convention on the Carriage of Goods by Sea (Hamburg, 1978) ("the Hamburg Rules").

Liability regime is always the core issue for the law of carriage of goods by sea,<sup>ii</sup> especially embodied in the Hague-Visby Rules, the Hamburg Rules and the Rotterdam Rules. For the Rotterdam Rules, Anthony Diamond QC has published an authoritative article in 2009,<sup>iii</sup> although later his critical analysis in this article seemed unaccepted to some extent by legal scholars from non-common law jurisdictions.<sup>iv</sup> It is believed that there is still space for further analysis on the liability regime in the Rotterdam Rules with comparative study with the Hague-Visby Rules and common law. The present author asserts that the liability regime in Rotterdam Rules is a not workable solution in law for current shipping practices. A better solution may be a new protocol to the Hague Rules, but not a new convention, e.g. the Rotterdam Rules.

# 2. Liability Regime in the Rotterdam Rules

# 2.1 Basis of liability

In principle the Rotterdam Rules apply fault-based liability regime<sup>v</sup> of the carrier for loss of or damage to the goods, as well as for delay in delivery.<sup>vi</sup> Although the Hague-Visby Rules adopt the same principle, there are substantial differences between the two Rules.

The first difference is the liability for delay. The Hague-Visby Rules do not cover such a liability of the carrier, while the Rotterdam Rules do.<sup>vii</sup> Because in the Rotterdam Rules the carrier's obligations are not only to carry the goods to the place of destination, but to deliver them to the consignee,<sup>viii</sup> it is possible that the carrier may be liable for delay in delivery of goods.<sup>ix</sup> The Hague-Visby Rules do not regulate the liability for delay but leave this issue to national laws. In shipping practice, the contract of carriage evidenced by the bill of lading normally does not provide exact time for delivery of goods.<sup>x</sup> Unless the time for delivery is concluded, if the delivery of goods is late, the issues of reasonable despatch or deviation always arise at common law. If the time for delivery is not agreed, the goods should be delivered at reasonable time. And reasonableness is

always a question of fact at common law.

More importantly, the carrier's liability for unseaworthiness of the ship in the Rotterdam Rules is stricter than that of the Hague-Visby Rules. In the latter Rules, the carrier shall be bound before and at the beginning of the voyage to exercise due diligence to make the ship seaworthy.<sup>xi</sup> The Rotterdam Rules however extend the period for seaworthiness obligation to the whole carriage, that is, "before, at the beginning of, and during the voyage by sea".<sup>xii</sup> This substantial change of seaworthiness obligation of the carrier may not be welcomed by the liner service provider in shipping practice. Although any term in bill of lading purporting to exclude or limit this obligation may be void if the Rotterdam Rules apply to the bill of lading,<sup>xiii</sup> the carrier may however minimise such a strict liability by purchasing corresponding liability insurance and raising freight rate in tariff. The real change might be the increase of ocean freight but decrease of the premium for cargo insurance. Therefore, the cargo interests may not be benefited from the change of obligation and liability regarding seaworthiness in the Rotterdam Rules.

Although seaworthiness is the carrier's obligation, in the Hague-Visby Rules both the carrier and the *ship* shall be liable for loss or damage arising or resulting from unseaworthiness caused by want of due diligence on the part of the carrier.<sup>xiv</sup> By comparison, the Rotterdam Rules do not specify the ship's liability. When bills of lading are to be used with charterparties, the charterers may act as the carrier and the shipowners as an independent contractor<sup>xv</sup> according to the Himalaya clause in the bills of lading. When the charterers become insolvent, it is necessary to clarify the ship's liability. The importance of the ship's liability in the Hague-Visby Rules was embodied in the common law. In *The Starsin*,<sup>xvi</sup> the owners of the ship were the actual carrier, not the contractual carrier under the Hague-Visby Rules, thus they were held to be liable for the damage to the goods.

# 2.2 Burden of proof

The burden of proof is not a special issue in the law of carriage of goods by sea. In general civil and commercial litigation, the burden of proof is upon the party who claims. In the Hague-Visby Rules, this principle is embodied by article IV rule 2 (q) for exception of liability in case of absent of fault of the carrier. It provides that neither the carrier nor the ship shall be responsible for loss or damage arising or resulting from any cause arising without the actual fault or privity of the carrier, or without the fault or neglect of the agents or servants of the carrier, but the burden of proof shall be on the person claiming the benefit of this exception to show that neither the actual fault or privity of the carrier nor the fault or neglect of the agents or servants of the carrier contributed to the loss or damage. This simple and common practice of burden of proof is however structured with unparalleled complexity in the Rotterdam Rules.<sup>xvii</sup>

It is common that the initial burden of proof shall be on the claimant, e.g. cargo interests. This becomes first stage<sup>xviii</sup> of proof in the Rotterdam Rules. Although the Rotterdam Rules provide obligations of the carrier in chapter 4, the claimant does not need to prove a breach of these legal obligations or contractual obligations. If the claimant proves that the loss, damage, or delay, or the event or circumstance that caused or contributed to it took place during the period of the carrier's responsibility, it then successfully shifts the burden of proof to the carrier.<sup>xix</sup> The second stage occurs when the carrier can prove that the cause or one of the causes of the loss, damage, or delay is not attributable to its fault or one or more of the listed exceptions<sup>xx</sup> caused or contributed to the loss, damage, or delay, the carrier is relieved of its liability.<sup>xxi</sup> The second stage seems derived from article IV rule 2 (q) of the Hague-Visby Rules as aforesaid. In the Rotterdam Rules, the provisions of burden of proof in the first and second stages have not substantially changed the rule of burden of proof in the Hague-Visby Rules.

The substantial change appears in the third stage.<sup>xxii</sup> The Rotterdam Rules provide that notwithstanding the exceptions in article 17, paragraph 3, the carrier is still liable for the loss, damage, or delay if the claimant proves that the fault of the carrier caused or contributed to the event or circumstance on which the carrier relies in the listed exceptions.<sup>xxiii</sup> Unlike the Hague-Visby Rules, the exceptions of the carrier's liability is not unconditional in the Rotterdam Rules. According to the qualification to the exceptions in the third stage, the exceptions in the Rotterdam Rules may be divided into categories, one is the events or circumstances to which the carrier's fault could not cause or contribute, e.g. Act of God (article 17, paragraph 3 (a)) and act or

omission of the shipper (article 17, paragraph 3 (h)), whereas the other is that the carrier's fault might do so, e.g. saving or attempting to save life at sea (article 17, paragraph 3 (l)). For the exceptions in the former category, the third stage will not happen; but for those in latter category, the carrier's defence based on the exception could be overturned if the carrier's fault caused or contributed to the occurrence of the event or circumstance in those exceptions. It is doubtable however whether the third stage in the Rotterdam Rules is reasonable or practical. The essential meaning of exception is to exempt the carrier's liability in certain events or circumstances. If such exceptions could be excluded again, then what is the function of these exceptions in law? At least, this stage is inconsistent with the practice of common law. At common law, for example, if delay happened due to deviation, the criterion for justifiable deviation is the existence of a danger and not in its cause.<sup>xxiv</sup>

In the practice of carriage of goods by sea, the main fault of the carrier is "Act, neglect, or default of the master, mariner, pilot, or the servants of the carrier in the navigation or in the management of the ship."<sup>xxv</sup> It is an exception of the carrier's liability in the Hague-Visby Rules. It is also the main fault that the claimant could prove so as to contest the carrier's defence based on exceptions. It is noted that such an exception of fault in navigation or management of the ship has been removed from the exception list in the Rotterdam Rules. In other words, if the fault in navigation or management of the ship existed, the carrier should have failed to discharge the burden of proof in the second stage and the game is over. All parties in the dispute do not have to move to the third stage.

The Rotterdam Rules also provide a non-essential provision relating to the burden of proof. According to such a provision, if the claimant proves that an event or circumstance not listed in exception provisions contributed to the loss, damage, or delay, and the carrier cannot prove that this event or circumstance is not attributable to its fault, the carrier is liable for the loss, damage, or delay.<sup>xxvi</sup> This is undoubtedly the logic result of the aforesaid stages. If the carrier could not reply on the exceptions in the third stage and failed to discharge the burden of proof in the second stage, the carrier is liable for loss, damage or delay if the claimant succeeded in proving that the loss, damage, or delay, or the event or circumstance that caused or contributed to it took place during the period of the carrier's responsibility in the first stage. Therefore, this provision seems to restate the aforesaid stages in another way.

The last but not least issue relating to the burden of proof is seaworthiness. It is an important obligation in both the Hague-Visby Rules<sup>xxvii</sup> and the Rotterdam Rules.<sup>xxviii</sup> In the latter Rules, it is provided that the carrier is liable for the loss, damage, or delay if the claimant proves that the loss, damage, or delay "was or was probably caused" by or contributed to by the unseaworthiness of the ship,<sup>xxix</sup> and the carrier is unable to prove either that unseaworthiness did not cause the loss, damage, or delay; or it complied with its obligation to exercise due diligence. It means, in other words, that the initial burden of proof is on the claimant and the burden of proof on the carrier for exemption is not to prove the ship seaworthy, but the exercise of due diligence. A question however arises about the term "probably" in the provision of the Rotterdam Rules. It is unclear to what extent the claimant can "probably" discharge the burden of proof for unseaworthiness of the ship.<sup>xxx</sup> It may affect the necessity of causation for the carrier's liability in respect of seaworthiness. The wording in the Hague-Visby Rules looks better as below:

"Neither the carrier nor the ship shall be liable for loss or damage arising or resulting from unseaworthiness unless caused by want of due diligence on the part of the carrier to make the ship seaworthy...Whenever loss or damage has resulted from unseaworthiness the burden of proving the exercise of due diligence shall be on the carrier or other person claiming exemption under this article."<sup>xxxi</sup>

#### 2.3 Exceptions

The exceptions in the Rotterdam Rules are mostly identical to those under the Hague-Visby Rules, except the removal of the fault of the carrier in navigation and management of the ship and some other changes. First, the exception of fault in navigation and management of the ship is a traditional and important exception in the law of carriage of goods by sea, i.e. the Hague-Visby Rules.<sup>xxxii</sup> It is the Hamburg Rules that eliminated such an exception for the first time. Because of limited world-wide acceptance of the Hamburg Rules, this attempt to eliminate this exception has not been world-widely accepted by both shipping practice and national

legislation.

The Rotterdam Rules have also removed the general exception rule in the Hague-Visby Rules<sup>xxxii</sup> which has become the second stage of burden of proof in the Rotterdam Rules.<sup>xxxiv</sup> Another change is the exception of "Fire on the ship"<sup>xxxv</sup> in the Rotterdam Rules. In the Hague-Visby Rules, the exception is qualified as "Fire, unless caused by the actual fault or privity of the carrier".<sup>xxxvi</sup> As stated aforesaid, in the Rotterdam Rules all exceptions could be qualified by the fault of the carrier which caused or contributed to the event or circumstance in the exceptions.<sup>xxxvii</sup> Therefore, it is useless to repeat the qualification to the exception of fire on the ship in the Rotterdam Rules. Furthermore, the Rotterdam Rules provide a new exception "Reasonable measures to avoid or attempt to avoid damage to the environment".<sup>xxxviii</sup> It seems useful to encourage reasonable activities to avoid damage to the environment caused by shipping carriage.

Another new but unintelligible exception in the Rotterdam Rules is the cargo operation. The exception is described as "Loading, handling, stowing, or unloading of the goods performed pursuant to an agreement in accordance with article 13, paragraph 2, unless the carrier or a performing party<sup>xxxix</sup> performs such activity on behalf of the shipper, the documentary shipper or the consignee".<sup>xl</sup> Article 13, paragraph 2 provides that the carrier and the shipper may agree that the loading, handling, stowing or unloading of the goods is to be performed by the shipper, the documentary shipper<sup>xlii</sup> or the consignee. Therefore, this exception could be restated as cargo operation performed by the shipper, the documentary shipper or the consignee. It is very difficult to understand, when any damage, loss, or delay occurs, how the shipper for instance can claim against the carrier just because the carrier acted on behalf of the shipper as an agent, not an independent contractor. It is probably an issue of agency law, or general contract law if the contract of carriage provides relevant clauses for this matter. Supposing the consignee claims against the carrier for the damage, loss, or delay due to the loading operation performed by the carrier on behalf of the shipper, why should the carrier not be exempted from the liability if it discloses the shipper as the principal?

The last but needless exception in the Rotterdam Rules is "Acts of the carrier in pursuance of the powers conferred by articles 15 and 16".<sup>xlii</sup> Articles 15 and 16 refer to the carrier's right when the goods may become a danger including the sacrifice of the goods during the voyage by sea. Of course the carrier shall not be liable for loss, damage, or delay if it is caused by the dangerous goods provided by the claimant. That is one of the reasons why this exception is needless. The other reason is the uncertainty caused by this exception in practice. For instance, if the damage is caused by a combination of the dangerous goods and a non-excepted peril by the carrier, a question may arise whether the carrier shall be liable for such damage. Although when the carrier is relieved of part of its liability, the carrier is liable only for that part of the loss, damage or delay under the Rotterdam Rules,<sup>xliii</sup> the precondition is that the liability for loss, damage, or delay should be separable. If, for instance, the dangerous goods self-ignited and exploded, and the operative fault lay in the negligence of the crew in using and heating the relevant bunker tank, it is hard to calculate the partial liability of the carrier.<sup>xliv</sup> However, it is unclear in such a case whether the carrier can rely on the exception of dangerous goods and be exempted from its liability for damage, loss, or delay in the Rotterdam Rules.

# 2.4 *Carrier's liability for others and maritime performing party*

Besides the liability caused by its own fault, the carrier is also liable for the breach of its obligations under the Rotterdam Rules caused by the acts or omissions of (a) any performing party, (b) the master or crew of the ship, (c) employees of the carrier or a performing party, or (d) any other person that performs or undertakes to perform any of the carrier's obligations under the contract of carriage, to the extent that the person acts, either directly or indirectly, at the carrier's request or under the carrier that performs or undertakes to perform any of the carrier's obligations under that the carrier that performs or undertakes to perform any of the carrier's request or under the carrier that performs or undertakes to perform any of the carrier's obligations under a contract of carriage with respect to the receipt, loading, handling, stowage, carriage, care, unloading or delivery of the goods, to the extent that such person acts, either directly or indirectly, at the carrier's request or under the carrier's supervision or control.<sup>xlvi</sup> In traditional shipping practice the performing party is called the independent contractor. Therefore, the list of persons for whom the carrier is liable actually includes the independent contractor, the master or crew of the ship, and employees of

the carrier or the independent contractor.

By contrast, the Hague-Visby Rules limits the list of person to agents or servants of the carrier<sup>xlvii</sup> excluding the act, neglect, or default of the master, mariner, pilot, or the servants of the carrier in the navigation or in the management of the ship for their fault or neglect.<sup>xlviii</sup> Furthermore, in the Hague-Visby Rules the carrier is liable for agents or servants' fault or neglect only, whereas the carrier in the Rotterdam Rules is liable for the aforesaid persons' acts or omissions even if such acts or omissions are not fault or neglect provided that the carrier breached its obligation under the Rotterdam Rules. As regards the independent contractor, the carrier at common law is liable for damaged goods due to the unseaworthiness of vessel caused by an independent repairer resulting from its lack of diligence.<sup>xlix</sup> However, it is unclear whether it is practical if the carrier is made liable in the Rotterdam Rules for an independent contractor who performs any of the carrier's obligations under a contract of carriage with respect to the receipt, loading, handling, stowage, carriage, care, unloading or delivery of the goods. Alternatively, the claimant may claim an independent contractor directly in tort and the independent contract is normally protected by a "Himalaya clause" in bills of lading. Such protection has been regulated in the Rotterdam Rules for maritime performing parties.<sup>1</sup>

Maritime performing party in the Rotterdam Rules means a performing party to the extent that it performs or undertakes to perform any of the carrier's obligations during the period between the arrival of the goods at the port of loading of a ship and their departure from the port of discharge of a ship.<sup>li</sup> In other words, the maritime performing party is the independent contractor during the port-to-port period. It distinguishes the independent contractors for non-sea carriage in door-to-door transport. A maritime performing party is subject to the obligations and liabilities imposed on the carrier under the Rotterdam Rules (not the contract of carriage of goods by sea)<sup>lii</sup> and is entitled to the carrier's defences and limits of liability as provided for in the Rotterdam Rules.<sup>liii</sup>

The Rotterdam Rule further provide that if the carrier and one or more maritime performing parties are liable for the loss of, damage to, or delay in delivery of the goods, their liability is joint and several but only up to the limits provided for under the Rotterdam Rules.<sup>liv</sup> This provides more protection for the claimant if it claims against both the carrier and the maritime performing party because their liabilities are joint and several. In case that the carrier is insolvent, the claimant may have a chance to be indemnified from the maritime performing party.<sup>lv</sup> The provisions on performing parties and maritime performing parties have clarified certain matters in shipping practice that were not set up in the Hague-Visby Rules, which, as believed, should be welcomed.<sup>lvi</sup>

#### 2.5 Deck cargo and live animals

The Hague-Visby Rules do not apply to live animals and deck cargo which by the contract of carriage is stated as being carried on deck and is so carried.<sup>Ivii</sup> There is no special rule in respect of the loss or damage to the deck cargo and live animals when the Hague-Visby Rules apply. The Rotterdam Rules changed this traditional practice of application with special rules in respect of liability of the carrier. It provides that goods may be carried on the deck only if: (a) such carriage is required by law; (b) they are fit for deck carriage, and the decks are specially fitted to carry such goods; or (c) the carriage on deck is in accordance with the contract of carriage, or the customs, usages or practices of the trade in question.<sup>Iviii</sup> If the goods have been carried on deck as permitted in accordance with aforesaid circumstances (a) or (c), the carrier is not liable for loss, damage, or delay caused by the special risks involved in their carriage on deck. If the special risk could be understood by comparison with the normal risk in the carriage under deck, it is difficult to explain why the carrier should be liable for loss, damage, or delay caused by the special risks involved by the special risks involved in carriage on deck in accordance with aforesaid circumstances (b). Furthermore, it is unclear whether the carrier could be exempted from liability for loss, damage, or delay caused by the special risks involved in the carriage on deck in accordance with aforesaid circumstances (b). Furthermore, it is unclear whether the carrier could be exempted from liability for loss, damage, or delay caused by the special risks involved in the carriage on deck in accordance with aforesaid circumstances (a) and (b) or (b) and (c).

The Rotterdam Rules further provide that if the goods have been carried on deck in cases other than those permitted, the carrier is liable for loss of or damage, or delay that is exclusively caused by their carriage on deck, and is not entitled to the defences in the Rotterdam Rules.<sup>lx</sup> The carrier however is still entitled to the

benefit of the limitation of liability in this circumstance. The carrier is not entitled to the benefit of the limitation of liability for any loss, damage, or delay if the carrier and shipper expressly agreed that the goods would be carried under deck but actually carried on deck provided that such loss, damage, or delay resulted from the carriage on deck.<sup>1xi</sup>

If the goods are live animals, without prejudice to special rules for volume contracts,<sup>lxii</sup> the carrier and a maritime performing party may exclude or limit its obligations or the liability in the contract of carriage. However, any such exclusion or limitation will not be effective if the claimant proves that the loss, damage, or delay resulted from an act or omission of the carrier or of a person for whom the carrier is liable, done with the intent to cause such loss, damage to the goods or such loss due to delay or done recklessly and with knowledge that such loss or damage or such loss due to delay would probably result.<sup>lxiii</sup> The new rules for the carrier's liability for the deck cargo and live animals in the Rotterdam Rules may reflect the legislation style in civil law jurisdictions, but may not be welcomed by common law jurisdictions in which the doctrine of freedom of contract, rather than newly created and complicated rules, is a better solution when the Hague-Visby Rules do not apply.

## 2.6 *Limits of liability*

In the Hague-Visby Rules, unless the nature and value of such goods have been declared by the shipper before shipment and inserted in the bill of lading, neither the carrier nor the ship shall in any event be or become liable for any loss or damage to or in connection with the goods in an amount exceeding 666.67 units of account<sup>lxiv</sup> per package or unit or 2 units of account per kilogramme of gross weight of the goods lost or damaged, whichever is the higher.<sup>lxv</sup> The Rotterdam Rules preserve the dual system with some amendments. First, the Rotterdam Rules increased the carrier's liability limit to 875 units of account per package or other shipping unit, or 3 units of account per kilogram of the gross weight of the goods.<sup>lxvi</sup> This increase seems reasonable after the adoption of the Hague-Visby Rules in 1979 with the development of the world's economics.<sup>lxvii</sup> The Rotterdam Rules also provide that the liability for economic loss due to delay is limited to an amount equivalent to 2.5 times the freight payable on the goods delayed.<sup>lxviii</sup> It is however pointed out that there is no provision for revising the limits should they become out of date.<sup>lxix</sup>

Secondly, like the provisions on the liability regime, the limits of liability in the Rotterdam Rules apply to the carrier, but not the ship. It is therefore unclear whether the shipowner who acts as actual carrier, not the contractual carrier, is entitled to the limits of liability. Thirdly, the limits of liability in the Hague-Visby Rules is "for any loss or damage to or in connection with the goods", whereas the carrier's limits of liability in the Rotterdam Rules is "for breaches of its (the carrier's) obligations under this Convention (the Rotterdam Rules)". The Hague-Visby Rules also provide that the limits of liability shall apply in any action against the carrier in respect of loss or damage to goods covered by a contract of carriage whether the action be founded in contract or in tort.<sup>1xx</sup> Although the Rotterdam Rules have a similar rule, <sup>1xxi</sup> it seems that the Hague-Visby Rules may apply the limits of liability in a wider extent, including the breaches under the both the Hague-Visby Rules and the contract of carriage of goods by sea.

Furthermore, the Hague-Visby Rules provide that if an action is brought for loss or damage to the goods against a servant or agent of the carrier (such servant or agent not being an independent contractor), such servant or agent shall be entitled to avail himself of the defences and limits of liability which the carrier is entitled to invoke under these Rules.<sup>lxxii</sup> And the aggregate of the amounts recoverable from the carrier, and such servants and agents, shall in no case exceed the limit provided for in these Rules.<sup>lxxiii</sup> In the Rotterdam Rules, nothing of those rules imposes liability on the master or crew of the ship or on an employee of the carrier or of a maritime performing party.<sup>lxxiv</sup> However, such persons may be liable based not on the Rotterdam Rules, but the contract of carriage or in tort. That is why any provision of the Rotterdam Rules that may provide a defence for, or limit the liability of, the carrier or a maritime performing party; the master, crew or any other person that performs services on board the ship; or employees of the carrier or a maritime performing party.<sup>lxxv</sup> The Rotterdam Rules further provide that the aggregate liability of the carrier or a maritime performing party; the master, crew or any other person that performs services on board the ship; or employees of the carrier or a maritime performing party.<sup>lxxvi</sup> without considering parties shall not exceed the overall limits of liability under those Rules, <sup>lxxvi</sup> without considering the possible liability of the master, crew and employee of the carrier or of a

maritime performing party. The extent of protection by the limits of liability in the Rotterdam Rules is narrower than that of the Hague-Visby Rules. The carrier may extend the protection by providing special clauses in bills of lading, but such contractual clauses may be understood as to limit the liability of the carrier and thus invalid due to the infringement of the Rotterdam Rules.<sup>lxxvii</sup>

Last but not least change in the Rotterdam Rules is deviation in respect of the liability and limits. In the Hague-Visby Rules, any deviation in saving or attempting to save life or property at sea or any reasonable deviation is permitted, and the carrier shall not be liable for any loss or damage resulting therefrom.<sup>lxxviii</sup> It is unknown in the Hague-Visby Rules whether the carrier shall be liable and entitled to the limits of liability if the deviation is not to save or attempt to save life or property at sea or is not reasonable deviation. At common law, any unjustifiable deviation has been traditionally regarded as a fundamental breach of the contract of carriage.<sup>lxxii</sup> The innocent party in a fundamental breach is entitled to repudiate its obligations under the contract and sue for damages irrespective of any exceptions or limits of liability in the contract. Although there is some doubt whether the strict view of the effect of deviation,<sup>lxxx</sup> the common law practice has not been changed for the law of carriage of goods by sea. It means that unreasonable deviation will deprive the carrier of exceptions and limits of liability under the Hague-Visby Rules. The Rotterdam Rules however are tolerant towards the effects of deviation that constitutes a breach of the carrier's obligations pursuant to applicable law that, except the loss of the limits of liability,<sup>lxxxi</sup> such deviation of itself shall not deprive the carrier or a maritime performing party of any defence or limitation under the Rotterdam Rules.<sup>lxxxii</sup>

## 3. Conclusion

It is the time to conclude whether the liability regime in the Rotterdam Rules is successful. It may be too severe for the drafter of the Rotterdam Rules with more than ten years' hard work<sup>lxxxiii</sup> if the answer is too negative. Unfortunately such a liability regime is obviously not a success as an international legislation.<sup>lxxxiv</sup> It is noted that the original motivation to reform the international legislation on the carriage of goods by sea is not to revise the current liability regime under the Hague-Visby Rules, but to consider the issue of uniformity in the applicable legal regimes for maritime transport documents.<sup>lxxxv</sup> In other words, there had been no commercial demands in shipping practice to reform the liability regime under the Hague-Visby Rules, or substantial criticisms in academic circles in respect of it, when the reform was proposed. From the perspective of common law,<sup>lxxxvi</sup> it is not a correct decision to draft a new convention to replace the current Hague-Visby Rules, at least for the liability regime. Suppose we need to amend the liability regime in the Hague-Visby Rules to some extent, a better approach may be not to draft a totally new convention,<sup>lxxxvii</sup> but a new protocol to the Hague-Visby Rules. This is however an assumption, not a truth so far.

# Appendix

COMPARATIVE STUDY OF INTERNATIONAL CONVENTIONS ON CARRIAGE OF GOODS BY SEA

COMI			
	Hague-Visby Rules 1968	Hamburg Rules 1978	Rotterdam Rules 2009
Geographical	Covers the period from the	Carrier responsible while "in	In addition to sea carriage:
application	time when the goods are	charge" of the goods at port	• Stevedoring / terminal
	loaded on the ship until they	of loading, during the	storage services
	are discharged from the ship.	carriage, and at port of	<ul> <li>Freight-forwarding</li> </ul>
		discharge i.e. normally from	services
		time goods are taken over	• Domestic inland road and
		from the shipper to time	rail carriage
		delivered to the consignee.	• Inland water carriage
		6	• International inland road
			and rail
Carrier	Owner or charterer "who	"Any person by whom or in	A person who enters into a
Currier	enters into contract of	whose name a contract of	contract of carriage with a
	carriage with a shipper"	carriage has been concluded	shipper
	currage with a simppor .	with a shipper" Covers	Inclusion of a "Performing
		"actual" and "contractual"	party" and a "Maritime
		carrier	performing party"
Carrier's	Carrier must exercise due	Carrier his servants and	Same as Hague-Visby
general duty	diligence before and at	agents must take all	Rules however the carrier's
of core	beginning of voyage to:	measures that could	obligation to evercise due
or care	• make ship seaworthy	reasonably be required to	diligence to make the ship
	• properly man equip and	avoid the event causing loss	segworthy is extended to
	supply the ship	and its consequences	seaworthy is extended to
	• make holds at fit and sofe	and its consequences.	is now "to make and keep
	• make noids etc. In and sale		the ship accurately."
	for reception, carriage and		the ship seaworthy .
	Corrigo and a correct and a correct and		It also includes an
	Carrier must property and		obligation to deriver the
	carefully load, handle, stow,		goods.
	carry, keep, care for and		
<b>a</b> • •	discharge goods.		
Carrier's	• Act, neglect, or default of	No specific list of defences.	Additional defences to
defences	the master, mariner, pilot or	Carrier must prove he, his	those listed in the
	the servants of the carrier in	servants or agents, took all	Hague-Visby Rules
	the navigation or in the	measures that could	include:
	management of the ship	reasonably be required to	• War hostilities, armed
	• Fire, unless caused by the	avoid the occurrence and its	conflict, piracy, terrorism
	actual fault or privity of the	consequences.	• Loading, handling,
	arrier		stowing, or unloading of
	• Perils, dangers and		the goods, unless the
	accidents of the sea or other		carrier or a performing
	navigable waters		party performs such
	• Act of God		activity on behalf of the
	• Act of war		shipper or the consignee
	• Act of enemies		• Reasonable measures to
	<ul> <li>Arrest or restraint of</li> </ul>		save or attempt to save
	princes, rulers or people, or		property at sea
	seizure under legal process		• Reasonable measures to
	Quarantine restrictions		avoid or attempt to avoid
	• Act or omission of the		damage to the environment
	shipper or owner of the		• Acts of the carrier in
	goods, his agent or		pursuance of the powers

	representative • Strikes or lockouts, or stoppage or restraint of labour from whatever cause • Riots and civil commotions • Saving life or attempting to save life • Wastage in bulk or weight or any other loss or damage arising from inherent defect, quality or vice of the goods • Insufficient packaging • Insufficiency or inadequacy of marks • Latent defects not discoverable by due diligence • Any other cause arising without the actual fault or privity of the carrier		conferred by articles 15 and 16 (in relation to goods that may become dangerous and need to be sacrificed for the common safety) "Error of navigation" defence and "any other cause" defence have been removed.
Limitation of Liability	2 SDRs per kg or 666.67 SDRs per package – whichever is higher	2.5 SDRs per kg or 835 SDRs package or shipping unit – whichever is the higher.	3 SDRs per kg or 875 SDRs package or shipping unit – whichever is the higher.
Liability for delay	Rules are silent.	2.5 times freight payable on goods delayed, subject to upper limit of total freight on all goods or amount of limitation if goods have been lost or destroyed.	Liability for economic loss due to delay is limited to an amount equivalent to 2.5 times the freight payable on the goods delayed. The total amount payable not to exceed the limits of liability under the rules.
Loss of right to limit liability	Right to limit lost if carrier intends to cause loss or is reckless knowing loss would probably result.	Right to limit lost if damage caused by intention, with knowledge that damage could occur or recklessness. Also when goods are carried on deck contrary to express agreement to carry under-deck.	The carrier cannot limit if the claimant proves that the loss resulting from the breach of the carrier's obligation was attributable to a "personal act or omission done with the intent to cause such loss or recklessly and with knowledge that such loss would probably result". Damage/loss due to delay included.
Burden of Proof	Shipper must show cargo was delivered to the carrier in good order and condition but received at destination in damaged condition. A clean B/L is prima-facie evidence of this. Under English law the claimant must establish breach of a seaworthiness	Carrier must prove that reasonable steps to avoid loss were taken unless damage is caused by fire.	Detailed wording on how the burden of proof operates. The carrier is liable for loss, damage or delay if the claimant proves that such loss, damage, delay or event (which was causative or contributed by) took

	obligation or failure to properly and carefully carry the goods. Once this is established, the burden of proof shifts to the carrier to show either due diligence or the application of one of the defences.		place during the carrier's responsibility for the goods. The carrier is liable if the claimant proves that loss, damage or delay was caused or attributed by a) unseaworthiness of the ship, b) improper crewing, equipping or supplying of the ship, c) if the holds or other parts of the ship (including containers) were not fit and safe for carriage, reception and preservation of the goods. The carrier is relieved from liability if it can prove that the cause or one of the causes is not attributable to its fault or the fault of its subcontractors, agents or employees. Alternative to proving absence of fault, the carrier must prove that the damage was caused by one of the exceptions in the
Deck cargo	Excluded from Rules if stated to be carried on deck on face of B/L. Undeclared deck carriage may affect carrier's ability to rely on defences, although the carrier may still rely on package limitation.	Rules do not expressly exclude deck cargo. Carrier can undertake deck carriage if agreed with shipper or in accordance with the usage of a particular trade in which case B/L should so state that goods are carried on deck. Carrier liable for unauthorised deck carriage if carried on-deck contrary to express agreement, and can be deprived from its defences and limitations of liability.	Goods may be carried on deck if: • Such carriage is required by law • Carried in containers or vehicles fit for deck carriage and the decks are specially fitted to carry such containers or vehicles • Carriage on deck is in accordance with the contract of carriage, customs/usages and practices of the trade in question If goods carried on deck in cases not permitted by above and damage/loss is caused exclusively by such deck carriage, carrier not entitled to its defences. If carrier agreed to carry the goods under-deck and carries them on deck which causes loss/damage, carrier not entitled to its limitations of liability.

<sup>i</sup> For historical background to the Rotterdam Rules, see Michael F. Sturley et al., The Rotterdam Rules: the UN Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea, London: Sweet & Maxwell, 2010, ch I.

<sup>ii</sup> Francis Reynolds, "The Rules Governing Carriage of Sea-An Incipient Breakdown in Uniformity", paper for seminar organised by Centre for Comparative and Foreign Law Studies, Rome, 1999.

<sup>iii</sup> Anthony Diamond QC, "The Rotterdam Rules" [2009] LMCLQ 445.

<sup>iv</sup> Francesco Berlingieri, "Revisiting the Rotterdam Rules" [2010] LMCLQ 583.

<sup>v</sup> It was also considered as a qualified presumed fault regime (see D Rhidian Thomas, "An appraisal of the liability regime established under the new UN Convention" (2008) 14 JIML 496) and a fault-based regime with a reverse burden of proof (see Yvonne Baatz et al., The Rotterdam Rules: a practical annotation, London: Informa, 2009, p49).

<sup>vi</sup> Art 17 of the Rotterdam Rules.

<sup>vii</sup> The title of Chapter 5 in the Rotterdam Rules is "Liability of the carrier for loss, damage or delay".

<sup>viii</sup> Art 11 of the Rotterdam Rules.

<sup>ix</sup> Delay in delivery means the goods are not delivered at the place of destination provided for in the contract of carriage within the time agreed. See art 21 of the Rotterdam Rules.

<sup>x</sup> It is relatively unusual for a shipper and a carrier to make an express agreement for the time for delivery in the context of carriage by sea. It is possible that a carrier's agreement to deliver by a certain date might be inferred from the carrier's public schedule of arrivals, but effect might have to be given to any express disclaimer that the time of delivery is not contractual. See Anthony Diamond QC, "The Rotterdam Rules" [2009] LMCLQ 445, 479-480. See also Yvonne Baatz et al., The Rotterdam Rules: a practical annotation, London: Informa, 2009, pp 67-68.

<sup>xi</sup> Art III, r 1 of the Hague-Visby Rules.

<sup>xii</sup> Art 14 of the Rotterdam Rules.

<sup>xiii</sup> See art 79, para 1 of the Rotterdam Rules.

<sup>xiv</sup> Art IV, r 1 of the Hague-Visby Rules.

<sup>xv</sup> It could be considered as a maritime performing party in the Rotterdam Rules.

<sup>xvi</sup> [2003] UKHL 12; [2003] 1 Lloyd's Rep 571.

<sup>xvii</sup> Anthony Diamond QC, "The Rotterdam Rules" [2009] LMCLQ 445, 472.

xviii The term "stage" is leant from Diamond's paper "The Rotterdam Rules".

<sup>xix</sup> Art 17, para 1 of the Rotterdam Rules.

<sup>xx</sup> Art 17, para 3. The listed exceptions will be discussed below.

<sup>xxi</sup> Art 17, paras 2 and 3 of the Rotterdam Rules.

<sup>xxii</sup> The allocation of burdens of proof in the Rotterdam Rules was described as a game of tennis in which the burden of proof passes back and forth like a tennis ball crossing an imaginary net between the carrier and cargo interest. And it was also noted that the multi-step process was not a script for trial but rather an analytical framework that the decision-maker used to determine the allocation of responsibility. See Michael F. Sturley et al., The Rotterdam Rules: the UN Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea, London: Sweet & Maxwell, 2010, pp 96 and 97.

<sup>xxiii</sup> Art 17, para 4 (a) of the Rotterdam Rules.

<sup>xxiv</sup> In *Kish* v *Taylor* [1912] AC 604, because charterers failed to provide full cargo, Master procured a cargo for minimising loss. The deck was overloaded to such an extent as to render the ship unseaworthy. Then the ship was obliged to deviate from her course in order to put into a port of refuge for repairs, and, after repairing, she completed the voyage in safety. It was alleged by the charterers to be an unjustifiable deviation. The House of Lords rejected this argument and held the deviation to be justified even though it resulted from initial unseaworthiness. In their view justification was to be sought in the existence of a danger and not in its cause.

<sup>xxv</sup> Art IV, r 2 (a) of the Hague-Visby Rules.

<sup>xxvi</sup> Art 7, para 4 (b) of the Rotterdam Rules.

<sup>xxvii</sup> See art III, r 1 of the Hague-Visby Rules.

<sup>xxviii</sup> See art 14 of the Rotterdam Rules.

<sup>xxix</sup> Art 17, para 5 (a) of the Rotterdam Rules.

<sup>xxx</sup> It was believed that in some civil law jurisdictions proof of a fact is left to the discretion of the judge and the term "probably" give a guide to the judge and indicate that the balance of probabilities approach ought to be adopted. See Francesco Berlingieri, "Revisiting the Rotterdam Rules" [2010] LMCLQ 583, 600.

<sup>xxxi</sup> Art IV, r 1 of the Hague-Visby Rules.

<sup>xxxii</sup> Art IV, r 2(a) of the Hague-Visby Rules.

<sup>xxxiii</sup> Art IV, r 2(q) of the Hague-Visby Rules.

<sup>xxxiv</sup> Art 17, para 2 of the Rotterdam Rules.

xxxv Art 17, para 3 (f) of the Rotterdam Rules.

<sup>xxxvi</sup> Art IV, r 2(b) of the Hague-Visby Rules.

xxxvii Art 17, para 4 (a) of the Rotterdam Rules.

xxxviii Art 17, para 3 (n) of the Rotterdam Rules.

<sup>xxxix</sup> For the definition of "performing party", see art 1, para 6 of the Rotterdam Rules.

<sup>x1</sup> Art 17, para 3 (i) of the Rotterdam Rules.

<sup>xli</sup> For the definition of "documentary shipper", see art 1, para 9 of the Rotterdam Rules.

<sup>xlii</sup> Art 17, para 3 (o) of the Rotterdam Rules.

<sup>xliii</sup> Art 17, para 6 of The Rotterdam Rules.

xliv At common law, the indemnity due to the dangerous goods for the carrier under article IV, rule 6 of the Hague-Visby Rules could not be relied on where the casualty was caused by a combination of a dangerous cargo and a non-excepted peril such as a want of due diligence to make the ship seaworthy or negligence in the loading handling or carriage of the cargo. See The Aconcagua [2010] 1Lloyd's Rep 1.

<sup>xlv</sup> Art 18 of the Rotterdam Rules.

<sup>xlvi</sup> Art 1, para 6 (a) of the Rotterdam Rules. Art 1, para 6 (b) provides that performing party does not include any person that is retained, directly or indirectly, by a shipper, by a documentary shipper, by the controlling party or by the consignee instead of by the carrier.

<sup>xlvii</sup> Art IV, r 2 (q) of the Hague-Visby Rules.

<sup>xlviii</sup> Art IV, r 2 (a) of the Hague-Visby Rules.

<sup>xlix</sup> The Muncaster Castle [1961] 1 Lloyd's Rep 57.

<sup>1</sup> Art 19, para 1 of the Rotterdam Rules.

<sup>li</sup> An inland carrier is a maritime performing party only if it performs or undertakes to perform its services exclusively within a port area. See art 1, para 7 of the Rotterdam Rules.<sup>11</sup><sup>11</sup><sup>11</sup> Art 19, para 2 of the Rotterdam Rules provides that "If the carrier agrees to assume obligations other than those

imposed on the carrier under this Convention, or agrees that the limits of its liability are higher than the limits specified under this Convention, a maritime performing party is not bound by this agreement unless it expressly agrees to accept such obligations or such higher limits."

Art 19, para 1 of the Rotterdam Rules.

liv Art 20, para 1 of the Rotterdam Rules. Art 20, para 2 also provides that "The aggregate liability of all such persons shall not exceed the overall limits of liability under this Convention". However, there is no relevant concept or provision on the "overall limits of liability".

<sup>1v</sup> However, nothing in the Rotterdam Rules imposes liability on an employee of the carrier or of a maritime performing party. See Art 19, para 4 of the Rotterdam Rules.

Anthony Diamond QC, "The Rotterdam Rules" [2009] LMCLQ 445, 491.

lvii Art I (c) of the Hague-Visby Rules.

Art 25, para 1 of the Rotterdam Rules.

<sup>lix</sup> Art 25, para 2 of the Rotterdam Rules.

<sup>1x</sup> Art 25, para 3 of the Rotterdam Rules.

<sup>1xi</sup> Art 25, para 5 of the Rotterdam Rules.

<sup>1xii</sup> See art 80 for the special rules for volume contracts in the Rotterdam Rules.

<sup>1xiii</sup> Art 81, para 1 of the Rotterdam Rules.

<sup>lxiv</sup> The unit of account is the Special Drawing Right as defined by the International Monetary Fund.

lxv Art IV, rule 5 (a) of the Hague-Visby Rules.

<sup>lxvi</sup> Art 59, para 1 of the Rotterdam Rules. The words "loss or damage to or in connection with the goods" in the Hague-Visby Rules have been changed to "of the goods that are the subject of the claim or dispute" in the Rotterdam Rules, but there is no substantial change between them.

<sup>lxvii</sup> The Hamburg Rules which were adopted in 1978 and took effect in 1992 increased the limit to 835 SDRs per package or other shipping unit or 2.5 SDRs per kilogram of goods lost or damaged. <sup>Ixviii</sup> Art 60 of the Rotterdam Rules.

<sup>1xix</sup> Anthony Diamond QC, "The Rotterdam Rules" [2009] LMCLQ 445, 484.

lxx Art IV bis, rule 1 of the Hague-Visby Rules.

lxxi Art 4, para 1 of the Rotterdam Rules.

lxxii Art IV bis, rule 2 of the Hague-Visby Rules.

<sup>1xxiii</sup> Art IV bis, rule 3 of the Hague-Visby Rules.

<sup>lxxiv</sup> Art 19, para 4 of the Rotterdam Rules.

<sup>1xxv</sup> Art 4, para 1 of the Rotterdam Rules.

<sup>lxxvi</sup> Art 20, para 2 of the Rotterdam Rules.

<sup>1xxvii</sup> Art 79, para 1 of the Rotterdam Rules.

<sup>1xxviii</sup> Art IV, rule 4 of the Hague-Visby Rules.

<sup>lxxix</sup> Hain SS Co v Tate & Lyle (1936) 41 Com Cas 350.

<sup>1xxx</sup> Photo Production v Securicor [1980] AC 827.

<sup>lxxxi</sup> See art 61 of the Rotterdam Rules.

<sup>lxxxii</sup> Art 21 of the Rotterdam Rules.

<sup>lxxxiii</sup> The preparation work of the Rotterdam Rules started in 1996.

<sup>lxxxiv</sup> D Rhidian Thomas, "An appraisal of the liability regime established under the new UN Convention" (2008) 14 JIML 496, 511.

<sup>lxxxv</sup> "Report of the Working Group on Electronic Data Interchange (EDI) on the Work of its Thirtieth Session", UNCITRAL, New York, 28 May-14 June 1996, (A/CN.9/421), para 33.

<sup>1xxxvi</sup> In *The Jordan II* [2005] 1 Lloyd's Rep 57, the House of Lords refused to revise the shipping practice with "f.i.o.t." term. Lord Steyn pointed out that for revision of law, one would have expected British cargo interests to have raised it when Parliament considered the Bill which was to become the Carriage of Goods by Sea Act, 1971, but the matter was not raised at all; or one would have expected it to have been a matter of discussion in trade journals and publications in the United Kingdom, but there had been no such criticisms. Therefore, he refused to depart from the current common law practice (see paras 27, 28 and 29).

<sup>1xxxvii</sup> It was worried that the danger existed in that the disharmony of the laws would increase if a new convention could not be accepted to replace the previous convention. See "Report of the United Nations Commission on International Trade Law on the work of its twenty-ninth session", United Nations, New York, 28 May-14 June 1996, (A/51/17), paras 213 and 214.

# Varying Patterns in Vessel Operation Quality and their Governance Implications

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#### Abstract

The paper examines the quality of vessel operations as a governance problem. It applies correspondence analysis to explore patterns in vessel operation quality among four groups of vessels operated in the Baltic Sea in 2009-2011 using port State control inspection data. The observed regularities in shipping quality patterns are discussed in the light of institutional theory, emphasizing the dynamic character of governance as a process of institutional change and development. The paper claims, that observed variation indicates that some sectors of the shipping industry receive stronger incentives and/or possess better capabilities to deliver high quality in vessel operation. The claim is supported through a discussion of factors which influence vessel operation quality, drawing attention to multiple institutional contexts which embed shipping quality governance. The paper concludes that in the context of globalized markets no 'one size fits all'-approach can be used to address shipping externalities and suggests designing policy measures specifically aiming at groups of maritime actors associated with different segments of shipping market.

Keywords: shipping externalities, vessel operation quality, port State control, correspondence analysis, clean shipping, Baltic Sea Region.

#### 1. Introduction

Shipping externalities have been widely and versatile investigated in maritime studies (DeSombre, 2006; Kalli et al., 2012; Lun et al., 2013; Ng and Song, 2010; Roe, 2012). Measures to reduce the external cost of shipping have been acknowledged to be both technical and operational in their nature (Faber et al. 2011). Since significant reduction of shipping externalities may be achieved by clean and safe fleet utilization, this paper focuses upon the quality of vessel operation and proposes a complex view on shipping externalities governance. It contributes to maritime environment and policy studies by investigating the quality of vessel operation as a governance problem.

The theoretical starting point of this research can be found in the conceptions of governance rooted in institutionalist tradition (McGinnis, 2011; Kooiman, 2003). Institutions are defined here as "rules of the game" (North, 1990), which constrain or enable social interactions. Institutions embrace a large variety of formal and informal rules, norms and strategies, which evolve over time. The process of interaction in which institutions are being formed, applied, interpreted and reformed is referred to as governance (McGinnis, 2011, p.171). An overview on the conceptions of governance in the context of maritime studies is presented in Roe (2012). Scholars of maritime policy have shown that traditional forms of maritime governance based upon the nation-state led system of command-and-control regulation failed to accomplish the mission of mitigating the adverse impacts of shipping. Some studies emphasized the role of institutions in the maritime governance evolution, stressing that new governance mechanisms are needed in order to overcome collective action problems in shipping (Corbett and Winebrake, 2009; Roe, 2012; Tan, 2006). They indicated that despite the blurring of national borders in the process of globalization, specific institutional arrangements may emerge within shipping industry at different levels. However, less attention has been paid to the institutional variation between shipping industry segments. This study seeks to clarify how institutional variation and emergence of alternative strategies within the segments of shipping industry can alter maritime governance process.

This paper claims that given the universal character of international and regional regulation, differences in order to illustrate this claim this paper uses correspondence analysis (CA) to investigate performance of four groups of vessels in the Baltic Sea Region (BSR) on the basis of port State control (PSC) inspection data. The empirical investigation considers safety and environment as components of the same on-board management system in which both technical ('hardware') and operational ('software') components interact with each other. In particular, it aims at investigating how divergent contexts, including non-technical and/or informal governance, can affect adaptation of quality practices. The paper criticizes the focus upon technological and technical components of shipping operations in current policy-making and suggests that policy measures should focus more on the non-technical side and encourage further development of safety and environmental culture on-board, as well as throughout the maritime transport chain.

The paper proceeds as following. Section 2 provides a literature review on determinants of vessel operation quality regarding the adverse environmental impacts of shipping in the light of governance approach. Section 3 empirically explores the differences in quality of vessel operation associated with various segments of shipping market and demonstrates that variation in operation quality has a coherent pattern which cannot be solely explained by technical factors (such as deterioration). Section 4 examines the results and suggests approaches to their explanation based on theoretical premises. Section 5 discusses the policy implications of the discovered patterns, stressing ways to improve existing situation.

# 2. Literature Review

Shipping, a private business of commodities transportation, has multiple negative effects upon human health and the environment (Corbett et al., 2007; Fuglestvedt et al., 2009; Ng and Song, 2010; Scott and Sinnamon, 2009), in particular climate change (Asariotis and Benamara, 2012). In the light of the growing intensity of shipping, its contribution to environmental deterioration, in particular in maritime regions, is growing respectively. In order to protect global oceans and marine species from introduction of pollutants and other disturbances a complex architecture of international, regional and national agreements targeting maritime transport safety, security and environmental performance was set up in the past few decades. Conceptualizing negative impacts from shipping as technical issues, this system drew upon the traditional regulatory command-and-control approach, prescribing technical specifications, prohibiting wasteful discharges and punishing incompliant behaviour. The extensive proliferation of targeted international and regional regulation in some cases advanced the environmental quality (Payoyo, 1994; Knapp and Fransen, 2009; Knudsen and Hassler, 2011), while in others failed to incentivize the respective stakeholders and reorient their practices towards delivering higher quality of operation (Corbett and Winebrake, 2009; Roe, 2012; Tan, 2006).

To date maritime research has advanced significantly in understanding shipping as a public policy problem. Conceptualizing negative environmental impacts from shipping as externalities (DeSombre, 2006), it identified shipping quality as the key to effective mitigation of shipping adverse impacts (Shinohara, 2005; Haralambides, 1998). Quality of vessel operation is embedded into ship management practices which assure safety of navigation and protection of marine environment (Shinohara, 2005). Empirically, shipping quality can be understood in terms of vessel's environmental and safety performance, i.e. its adherence to high standards in prevention of accidents and incidents and associated accidental pollution as well as in terms of minimization and illumination of negative environmental impacts of routine operations and maintenance. Enhancing the quality of vessel operation urges the maritime industry to take action in internalizing the external cost, thereby reliving the pressure from the society. At the same time it means, that the scope of governing actors enlarges beyond the nation states and intergovernmental authorities, demanding new institutional mechanisms which can ensure functioning of this complex system.

The literature also investigated factors which influence the quality of vessel operational performance. It has shown that technical (design, construction, equipment etc., see for ex. Cariou et al., 2007; Knapp and Franses, 2007; Knapp and van de Velden, 2011) and operational (maintenance, human factor, crew qualification and motivation, see for ex. Grabowski et al. 2007; Kuronen and Tapaninen, 2010; Bhattacharya, 2012; Heijari and Tapanainen, 2010), regulatory (command-and-control legislation, monitoring and control, see for ex. Payoyo 1994, Kujala et al., 2009; Knudsen and Hassler, 2011) and non-regulatory (market incentives and reputational concerns see for ex. Bennett 2001; Shinohara 2005; Frynas 2009) factors play a role in how a vessel performs

during all stages of its utilization at berth and sea. Considering that operational and accidental discharges from shipping technically can be kept at low levels (Kontovas and Psaraftis, 2011; Lai et al., 2011; Ng and Song, 2010), a distinct body of research on environmental impacts of shipping and perspectives on technical optimization was developed. It acknowledged that effective governance of shipping externalities needs to ensure safety and quality of routine shipping operations not only in terms of innovative design and construction, but also in terms of effective safety and environmental management on-board. Yet, this literature has rather emphasized technical measures. It tended to treat the vessel operation quality factors separately from each other and from the institutional contexts in which they are embedded. This paper regards all factors as components of a single quality management system, suggesting a complex view on governance of shipping externalities to overcome the deficits of existing approaches (Figure 1).





Eventually, effective maritime governance is among the biggest challenges posed by the current economic and environmental situation in globalized shipping. This paper adopts a broad understanding of governance, taking into account the existence of various ways in which governance denotes a capacity to 'get things done' drawing upon multiple actors, various rules which structure the actions of the actors and different modes of coordination between these actors. Thus, it regards vessel operation quality as a product of multiple interactions in different dimensions of maritime sector, including design, construction, maintenance and operation. It focuses specifically on advancing the understanding regarding the reduction of shipping externalities arising from daily operational decisions within both onshore and on-board vessel management systems. Recently a model for green shipping operation was developed by Lai et al. (2011). However, due to a lack of research on routine shipping operations there are no widely accepted key performance indicators for environmental performance in vessel operation quality. Quality of vessel routine operations, i.a. use of chemicals on board, handling of cargo and waste, daily maintenance during vessel's voyage, manoeuvring, port operations, has proven to be difficult to ensure (independent from vessel's technical specifications). Since governance of shipping externalities is a complex build-up of multiple (and sometimes conflicted) formal and informal rules, norms and strategies at different levels and scales, the question of how to improve the implementation of new technologies and operational practices is closely connected to developing policy solutions capable of catalysing institutional changes.

#### 3. Regularities is Vessel Operation Quality: A Correspondence Analysis

#### 3.1. Data: A different look at PSC data

Research data for empirical analysis was obtained from the European Maritime Safety Agency (EMSA) website. The Hybrid European Targeting and Inspection System (THETIS) hosted by the EMSA provides data on all inspections conducted under the Paris Memorandum on Port State Control (Paris MOU) held between January 2008 and the present moment. According to Paris MOU inspection and selection rules, prior to 1.1.2011 inspections were conducted for 25% of vessels calling at a port and after 1.1.2011 for 100% of vessels operating in the Paris MOU area by joint effort of all ports. PSC data has mainly been used in earlier investigations to assess effectiveness of the port State control as a regulatory instrument (Bloor et al., 2006; Knapp and Franses, 2007), effectiveness of international conventions implementation by nation states (Knapp and Franses, 2009; Knudsen and Hassler, 2011; Stiles, 2010), or safety risk of the vessels to prevent accidents (Heij and Knapp, 2012; Knapp and van de Velden, 2011; Li, 1999). Although in previous research the

inspection data was mainly used to study maritime safety, nothing precludes from using it for investigation of quality of vessels operation in broader HSE (health, safety, and environment) scope. An inspection conducted under the Paris MOU along with structural and navigational safety includes vessels environmental performance (Part 14 'Pollution prevention' investigates compliance with MARPOL Annexes I-VI and antifouling regulations), as well as the ISM code, which explicitly includes "safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular to the marine environment" (ISM, §1.2.1). Thus vessels operation quality can be investigated on the basis of PSC data when deficiencies are conceptualized as an indicator of quality of vessel's sound operation and regular maintenance.

Correspondence analysis is applied to the inspection data to find patterns which explicate the relationship of vessel's performance, age, flag and type of transported cargo. In order to investigate the implications of these factors we consider them in a stepwise manner. We are particularly interested in the interplay between the particularities of a vessel (age, flag) and its type. The variables are summarized in Table 1. In comparison to other concepts used in empirical investigation of shipping operation quality, our approach to deficiencies as an *ex ante* indicator of potential future malfunctions and as an *ex post* indicator of technical maintenance has several advantages. First, it describes both technical and operational side of precaution which is taken by the ship owner/operator. Second, it can be operationalized in quantitative terms through number of deficiencies revealed during an inspection. Operational performance has a high quality when there are none or few deficiencies, since it means that technical state and utilization of a vessel and its equipment are at the high level and potential future malfunctions are prevented at early stages by careful operation. Third, it does not reduce the investigation to safety performance, emphasizing that good performance in port State control also indicates compliance with environmental standards.

Variable	Definition	Description
name		
Def (deficiency)	Number of deficiencies reported during an inspection measured at a continuous measurement level, categorized in five classes: 0, 1-3, 4-5, 6-10, >10 deficiencies. Source: THETIS inspection database.	Number of reported deficiencies is used as an ex ante indicator of potential future malfunctions and as an ex post indicator of technical maintenance. We assume that with increasing incentives to deliver high operational quality, the maintenance of vessels and routine operational practices improve and eventually fewer deficiencies can be found. If a vessel indicates zero deficiencies during an inspection, a ship-owner/operator can be considered to make sufficient investments into the technical maintenance as well as in crewing and manning.
Age (Vessels age)	Age in years at the moment of inspection (from keel laying date) measured at a continuous measurement level, categorized in five classes: age<10, age<20, age<30, age<40, age40+. Source: THETIS inspection database.	The rule of thumb suggests that the newer the vessel, the better is its condition and more advanced its technology, thus, easier to maintain better quality of operation at a lower investment cost.
Type (Vessels type)	Type of vessel based on type of transported cargo with the following categories included: TANKER (oil tankers (crude)); CONTAINER (container vessels (fully cellular)); BULK (dry bulk); CARGO	The UNCTAD categorization of vessels defines five groups: (1) oil tankers carrying crude products; (2) dry bulk carriers transporting primarily five cargo types: iron ore, grain, coal, bauxite/alumina and phosphate; (3) general cargo, including vessels for refrigerated cargo, specialized cargo, roll on-roll off (ro-ro) cargo; (4) fully cellular container ships; (5) other ships, i.a. chemical and other tankers, LNG carriers, passenger, tank barges,

 Table 1: Definitions and descriptions of variables

	(general cargo/multipurpose	fishing, offshore supply.
	(excluding ro-ro)). Source:	For the purpose of this study we include only the first
	THETIS inspection database.	four groups.
Flag	Flags under which vessels are	Differences in adoption of legislation between flags
(Vessels flag)	registered, categories defined	result in different requirements of flag States to their
	on the basis of the Paris	respective fleets, and consequentially different
	MoU so-called White-Grey-	operational practices. The basic measure used to identify
	Black List 2011 as following:	flag's performance is the total number of inspections and
	WHITE (W) for white flags,	detentions over a 3-year rolling period. Respectively, the
	GREY (G) for grey flags and	white flags represent higher operation quality with a
	BLACK (B) for black flags.	consistently low detention record, whereas black flags
	Source: THETIS inspection	indicate higher risk in terms of safety and environmental
	database.	performance. Ship owners/ operators under the white
		flags are expected to invest more into the development of
		their integrated vessel management than those under the
		grey and black flags.
Inspection	Date when inspection took	01.01.2011 a New Inspection Regime ("NIR") was
date	place, time ranges from	introduced under the Paris MOU. The NIR aims at
	1.1.2009 to 31.12.2011,	achieving full coverage inspection of all ships visiting
	categorized in three classes	ports and anchorage in the Paris MOU region. A
	standing for full years (2009,	difference in the total number of inspection can be
	2010, 2011). Source: THETIS	observed between 2009-2010 and 2011, however,
	inspection database.	without an influence upon the performance trends.

Data and information retrieved from the EMSA website are provided on an "AS IS" basis, without warranty of any kind, and may contain errors or be incomplete. The selection of data is justified by several reasons. First, the four types of ships included represent the major part of all vessels sailing the Baltic Sea (Baltic Port Barometer, 2010). Second, though some vessels were inspected more than once, such instances were included into the analysis, since the number of deficiencies revealed during an inspection constitutes a unit of analysis, thus, its value is a subject to change even if the same vessel is being inspected. Third, though inspection instances under the Paris MOU are made selective basing on risk estimations (vessel risk profiles under the new inspection, thus, creating a veil of uncertainty for the ship owners/operators (Paris MOU Annex 8). For these reasons, the inspection data can be considered representative of the vessels sailing the Baltic Sea and suitable for the purpose of this research. The Baltic Sea Region was chosen for this investigation for several reasons. First, the Baltic Sea is a particular vulnerable environment with a high intensity of shipping where the problem of negative environmental impact of shipping has long been recognized and addressed at intergovernmental level (Helsinki Convention). Secondly, the BSR is positioning itself as a leader in clean shipping and innovations in sustainability in Europe (COM (2009) 248 fin).

The original data was cleaned in order to improve the efficiency of data analysis. Four categories of vessels (oil tankers, container vessels, bulk carriers and general cargo/multipurpose vessels) were selected. Only inspections in ports situated on the Baltic Sea were included. In order to preserve the coherency of flag classification, only inspections conducted during the years reflected in the 2009-2011 White-Grey-Black (WGB) List were included. A small number of vessels carrying undefined flag (not included in the WGB List) were removed. The data includes all inspection instances ranging from those with a 'clean' inspection report (no deficiencies recorded) to those which led to a detention. The final dataset N=8139. The data was constructed, cleaned, analyzed and visualized using Survo, an interactive computing environment (Mustonen, 1992).

# 3.2. Methodology: Correspondence Analysis

Correspondence analysis is an exploratory data analytic technique designed to analyze and visualize tabular information containing some measure of correspondence between the rows and columns. As opposed to

traditional hypothesis testing design of empirical investigations, CA is used to identify systematic relations between variables. CA is typically used to explore and reveal patterns in the data in order to generate hypotheses for further statistical analyses or in-depth qualitative investigation. For this purpose, CA is marked by several advantages. First, it allows for simultaneous consideration of multiple categorical variables. Additionally, it provides simplification of the initial data and its detailed description with minimal losses of information. Moreover, CA enables graphical display of row and column points in biplots, where row and column geometries have similar interpretations, facilitating analysis and detection of relationships. Finally, CA has highly flexible data requirements. Similarly with cross-tabulations, there are no assumptions of scales or distributions of variables. Hence also nominal scale variables can be analysed (Greenacre, 2007). Flexibility of data requirements defined the choice of CA versus other tests for examining the associations of categorical variables, since the data set under scrutiny contains both nominal scale and non-normally distributed variables. Eventually, CA shows how the variables and their categories are associated, not only that an association between the variables exists, which is the case in chi-square tests of pairwise crosstabulations. However, this method is not without limitations. The major limitation of CA is that the selection of variables and their categories might be somewhat arbitrary. It remains a matter of thorough preliminary research to assure that the relevant ones are included in the analysis (Hair et al., 1995). Of course, the old rule correlation does not imply causation applies similarly with CA, as the causational interpretations of the directions of the relations must be based on the substantive reasoning and not on statistical findings alone. In maritime research CA was previously used to analyze individual ship risk profiles (Knapp and van de Velden, 2011).

#### 3.3. Results

The four biplots in Figure 2 a-d plot PSC performance profiles for four different types of vessels operated in the BSR 2009-2011. In Figure 2a the relative positioning of the various types of vessels regarding the number of deficiencies revealed during a PSC inspection illustrates a considerable discrepancy in operation quality for different types of vessels. The proximity of TANKER, the tanker vessel profile, to the point DEF0, representing zero deficiencies recorded during a PSC inspection, indicates that the lowest number of deficiencies is demonstrated by tankers. The profiles CONTAINER and CARGO, representing container and general cargo/multipurpose vessels respectively, are situated close reflecting similarities in quality of operations, though proximity of CARGO to the point DEF6-10 indicates its poorer average performance. BULK has a more distinct profile. The reason for this is at least partially beyond the current data, most likely to appear as a side-effect of a concentrated inspection campaign on Structural Safety and the International Convention on Load Lines (ICLL) organized by the Paris MOU in 2011.

In the next step we add vessel's age to the list of variables 2b. This slightly shifts the positions of TANKER and CONTAINER profiles and considerably shifts the positions of BULK and CARGO profiles, changing their order. The age is mostly following the shape of deficiencies, indicating a close though non-linear association of these two variables. A closer investigation of contingency tables explained why unlike in Figure 2a BULK indicates better performance than CARGO. General cargo/multipurpose vessels are more likely to fly a low-quality flag (3% versus 0,6% for bulk) and likewise contain more aged vessels (7,6% aged over 40 years versus 0% within bulk, 18,1% aged between 30 and 40 versus 15,8% for bulk). Since both increasing age and 'black' flag registration are strongly associated with poor PSC performance (13,7% of all inspections which detected over 10 deficiencies were performed on vessels flying a 'black flag' and 16% of vessels aged more than 40 registered under a 'black flag'), the profile for a general cargo vessel is associated with poorer performance than that of a bulk carrier.

In the next step we consider the flag variable. The resulting biplot 2c yields the same order of vessel types as the previous one 2bA. The similarity is in line with the findings indicating a relation between vessel's flag and age, i.e. a trend to flagging out of aging vessels (the descriptive statistics indicated that among the newbuildings aged less than 10 years 98,2% are registered under high-performance ('white') flags, up to 16% among the vessels aged more than 40 years are flying a 'black' flag). Here we see a considerable similarity in profiles of BULK and CONTAINER, both being very distant from the point plotting the 'black' flag registration.

In the final biplot 2d we use all the variables and observe the over-all pattern unchanged: the proximity of tanker vessel profile to both lower age and zero deficiencies; the proximity of container and bulk fleet profiles to each other in terms of age and flag, but a distinction in terms of deficiencies; finally, general cargo/multipurpose vessels are positioned relatively close to both increasing age and high number of deficiencies indicating that they have the poorest performance profile. The fact that the years 2009, 2010 and 2011 (NB: only 2011 labeled in 2d) are strongly clustered reveals that this trend is observed for all years. Eventually, consecutive observation of four biplots shows that the performance of four types of vessels under scrutiny of this investigation in PSC inspections has a regular pattern. As a rule, TANKER reflect high quality in operation, CONTAINER is next to it, followed by BULK with increasingly aging fleet and considerable discrepancies in performance, and CARGO profile demonstrating poorer performance than all the other types.

Figure 3 illustrates the distribution of deficiencies regarding vessels age. Deterioration of the ship and its equipment is a natural process occurring due to the operation of the ship and exposure to effects from outside, such as air, water, humidity etc. As the time passes by, the deterioration progresses and a vessel requires more investment into technical maintenance, both preventive (i.e. to prevent a deficiency before it occurred) and corrective (to maintain deficiency after it has occurred). Moreover, newbuildings tend to be equipped with more advanced and more environmentally-friendly technology, built in more energy-efficient way and using materials of superior quality. This would suggest a linear relationship between the age and the number of deficiencies detected in PSC inspections and indirectly point out to the fact that technological innovation has a crucial role to play in mitigation of adverse shipping impacts. However, Figure 3 suggests that the relationship is not linear. The relative positioning of BULK and CARGO in Figures 2a and b illustrate it clearly: when age axis is added, BULK variable changes its position accordingly, preserving the relative proximity to the DEF>10 point. Another interesting result regarding the age and performance variables is that though an average age of tanker and container vessels does not differ considerably (11,0 and 11,6 respectively), all biplots indicate better performance of tankers. Whereas age and flag are related factors, regularity can be established regarding different types of vessels independent from other factors. These empirical findings contradict to the hypothesis of deterioration widely exploited in political rhetoric, thus undermining the focus upon purely technological solutions in current policy-making.



Figure 2: Stepwise CA: a) Type, Year & Def; b) Type, Year, Def & Age; c) Type, Year, Def & Flag; d) Type, Year, Def, Age & Flag.



Figure 3: Distribution of deficiencies and age for four types of vessels

#### 4. Discussion

The results of CA presented in Section 3.3 explicate systematic patterns in the quality of operation within the four explored types of shipping. In governance terms this variation means that some sectors of the shipping market are receiving stronger incentives and/or possessing better capabilities to deliver high quality in vessel operation. The findings also demonstrate inability of technical factors (prominently, the deterioration hypothesis) to account for the observed variation, suggesting that a combination of factors play a role in quality of operations demonstrated by different types of vessels. Building upon the insight of institutional theorizing, which emphasizes the dynamic character of governance as a process of institutional change and development, in what follows we discuss the observed patterns in agreement with the model presented in Figure 1. In order to better understand the governance characteristics, multiple institutional contexts which embed governance process are put under scrutiny.

In the first place, attention shall be drawn to the differences arising from supply chain context. The type and monetary value of transported cargo are potentially connected to the maintenance investments and onboard operation quality management. Increasingly containerized manufactured goods are finished and ready for distribution to the end customer which usually makes them more expensive than raw materials including dry and liquid bulk (an exception constitute some oil and chemical products). Additionally, manufactured goods are usually associated with concrete brands, thus, with concrete market actors, exposing them to pressures from the end consumer than raw materials, which require consumers to handle larger amounts of far less transparent product information (Bloor et al., 2013; Rábade and Alfaro, 2006). Moreover, up to 70% of containerized cargo is being carried by major liner operators, which in the recent years are "increasingly adapting their market strategies to emphasize the ecological and social dimensions as factors of competitiveness business" (UNCTAD 2011).

The salient performance of tankers in comparison to other vessel profiles might be strongly influenced by the existence of the civil liability regime in oil transportation. Law and economics analysis of the International Convention on Civil Liability for Oil Pollution Damage (CLC) 1992 conducted by Xu (2009) indicated that private liability regime is a powerful means to create incentives reducing risk of potential oil spills. CLC encourages the ship owners to take care of vessels, which goes beyond technical maintenance and includes "various forms of precaution such as employing competent master and crew, safety and pollution combat training and avoiding the use of substandard ships" (Xu, 2009). Moreover, tankers are perceived as most risky vessels (Hassler et al., 2010; Knudsen, 2009; Rogowska and Namieśnik, 2010; Yu et al., 2012), upon which stricter public regulations shall apply. Against this background vetting inspections developed and proliferated, proving as an effective mechanism to secure high quality of operation among tankers (Haering, 2008).

Finally, the Baltic Sea Region constitutes a particular operational environment for shipping due to proliferation of the Clean Ship (CS) approach (in particular, it concerns liner shipping, tightly embedded within the regional context by its nature). CS approach emerged in Northern Europe in the late 1990s as an alternative to traditional shipping policy. By 2006 the Gothenburg Declaration established a comprehensive definition of Clean Ship as "the concept of vessels designed, constructed and operated in an integrated manner with the objective to eliminate, harmful discharges and emissions throughout their working life; the approach addresses all vessel operations and possible impacts on the environment". Though CS is not the only alternative approach to governance of shipping externalities, its integrated treatment of the problem is unique.

The proliferation of the CS approach in the BSR opened up the spaces for private initiatives in public governance process. However, different sectors of shipping market responded differently. Fleet renewal and 'green' investment are dependent on the gains received by the ship-owners versus their costs. For tanker owners fleet renewal pays off, since older vessels need much additional certification and are more difficult to charter to oil majors, which are very aware of the situation and have direct control mechanisms in a form of vetting inspections. For container carriers, mostly representing liner shipping carrying manufactured goods, fleet renewal and retrofitting also pays off in terms of reputation and competition for cargo owners, who have reputation to defend in front of their consumers and are likely to use environmental standards in shipping as a part of their CSR (Bloor et al, 2013; Wuisan et al., 2012). Increasingly aging conventional cargo vessels, in particular Ro-Ro, cause majority of air emissions (Jalkanen et al., 2009), whereas incentives for fleet renewal

in this segment are much weaker than for tanker and container fleet. The financial structure of the liner shipping companies allows for more frequent maintenance and upgrading investments compared to shipping companies operating a small fleet in tramp market. Differences in returns from 'green' investment account for this variation.

The quality of vessel operation varies both among and within the fleets, suggesting that incentives to design, construct and operate vessels in a safe and environmentally-friendly manner are distributed unequally within the shipping industry. Partially by virtue of more stringent regulation, partially due to differences in market constellations and stakeholder interactions, conditions under which high quality of operation pays off emerged in tanker and container segments. Respectively, those are tanker and container vessels which are more likely to benefit from the 'green' image by participating in voluntary regulation, environmental certification schemes and other initiatives emerging in the framework of the new shipping policies. This trend shows well through an investigation of the Clean Shipping Project. The participants of the project on the industry side are mainly producers of manufactured goods and chemicals who use for their transportation mostly container vessels and tankers/chemical carriers. Analyzing the Clean Ship Project as an example of private CS approach Wuisan et al. (2012) concluded that the potential of the initiative is constrained by a number of factors connected to its legitimacy, trust and robustness.

A principal innovation of present research was to consider shipping industry as a non-homogeneous environment when assessing how shipping externalities can be addressed. The empirical part of this research was built upon an assumption, that differences in quality of vessel operation are related to how green practices in shipping industry are embedded in multiple institutional contexts. Indeed, the intensification of pressures to internalize negative externalities from both public regulators and private clients of maritime transport has not created similar responses by maritime actors. Current measures to reinforce clean shipping non-regulatory (market instruments and voluntary certification) benefit the pioneers to get even better but do not motivate laggards to improve their performance. This means, that the shifts brought by reallocation of roles and responsibilities along supply chains in course of development and change of rules, norms and strategies governing the quality maintenance need to be accounted for in order to improve externalities governance.

# 5. Conclusions

This article analysed the quality of vessel operation as a governance problem. It concluded that technical advances in the areas of vessel design and construction are important, but they alone cannot ensure high quality of vessel operation. The quality of vessel operation is incentivized by a combination of weaker and stronger regulatory and non-regulatory mechanisms disseminated within the polycentric shipping governance arena. This fact emphasizes that no 'one size fits all' approach can be used to address shipping externalities. In order to improve the deficiencies of traditional regulatory governance, shipping quality needs to be regarded in the broad context of the global supply chain, but also in its embeddedness into the local and sectoral contexts. From the managerial point of view, it has implications for governance within the shipping industry, since it requires companies to redefine their position in the process of institutional change. Further investigation of this issue lies out of the scope of this paper. From the public policy point of view, ensuring shipping quality requires policy solutions which create synergies between already existing mechanisms to minimize the social cost of additional regulation. Basing on our analysis we suggest acknowledging the public governance implication of variation caused by differences (1) in on-board quality management and (2) between industry segments by setting up differentiated mechanisms involving the key stakeholders in all types of shipping.

Firstly, in order to address shipping externalities in a comprehensive manner, vessel maintenance and operation has to be performed at high level. However, vessel operation quality cannot be captured solely through vessel's key performance indicators (e.g., emission rate, energy efficiency, number of past incidents and accidents). Whereas in terms of design and construction differences between vessels (such as hull design, navigation equipment, exhaust scrubber, residuals segregation, dual engine, onboard recycling/closed loop waste treatment etc.) are 'fixed' once the construction process is completed (unless a vessel is retrofitted), in terms of vessel's immediate operation, including navigation, maneuvering, maintenance, use of chemicals on board, handling of cargo and waste, vessel's performance may vary independent from technically defined

parameters. This 'varying' component goes beyond the technical parameters and is defined by onboard safety and environmental management systems. Thus, a comprehensive approach to ensure vessel operations quality shall relate to all components of ship operation, including the human factor, education and training, cargo owners choices and safety and environmental culture of the vessel's management and crew. Quality shipping is thus not only a number of technically defined parameters, but also a complex relationship between shipping stakeholders.

Secondly, the analysis presented in this paper demonstrated that the current technological focus of policymaking proves dissatisfying because it assumes homogeneity of the shipping industry. However, type of shipping is a significant factor determining the quality of operation. Different segments of shipping industry have different financial structure and different composition of stakeholders. Thus, governance of shipping externalities has to account for these differences in regard to the regulatory mechanisms used and nonregulatory incentives set. In particular, attention of regulators has to be directed to those segments of the shipping industry, where markets proved to be less efficient in providing incentives for internalization of negative externalities. In practical terms that means that wider support for the introduction of vetting system for bulk and general cargo/multi-purpose carriers is desirable. Thus, a combination of regulation and stimulation shall be found to facilitate improvements in this segment.

This paper showed that a closer look at the multiple institutional contexts in which vessel operation quality needs to be sustained as an daily practice can assist in resolving maritime governance failure. The reputational gains from daily management of high environmental and safety standards onboard can be increased by raising public awareness of the detrimental effects of routine shipping operations and not only shipping accidents. As a result, a shipping governance system will improve its capability of addressing the negative environmental impacts of shipping in a more effective way.

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# A Study on the Construction of Safety Management Evaluation System for Shipping Company

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#### Abstract

Seaborne transportation is expanding in accordance with the growth of global economy and the increase of international trades between countries. Recently, as a result of FTAs (free trade agreements) between countries, worldwide cargo volume by ship is expected to keep on rising due to the unification of economic zones. Such an increase in maritime transportation leads to a maritime traffic, and this poses a greater risk of marine accidents in a country's coastal water.

Moreover, such risk factors that are threatening the safety of ships' navigation such as embarkation of multinational seafarer, piracy, changes in maritime climate by global warming and the like are in occurrence. What's more, the mounting traffic of yacht and pleasure boats in littoral sea as a result of the increase in maritime leisure activities triggers higher possibilities of marine accidents.

To cope with such changes in maritime environment well, it requires higher safety management skills from shipping companies, the main subject in charge of the safety matters. However, shipping companies tend to acknowledge safety just as a form of cost without profitability. They particularly have more tendencies to be inactive in managing ship safety and investment during a dull shipping season.

Therefore, in this paper, we propose SMES (Safety Management Evaluation System) for measurement of safety management levels on Korean shipping companies. We have drawn conclusions with an actual proof analysis in the paper. First of all, we established a concept for evaluating safety management of shipping companies, and classified shipping companies and their ships for evaluation. Second of all, we selected items for evaluating through questionnaire survey analysis to experts and built a database. Thirdly, we developed SSMEI(Ship Safety Management Evaluation Index) for an objective evaluation process and calculated weighted value members for each evaluation item. Lastly, we evaluated safety management level of Korean shipping companies using constructed database and SSMEI.

Keywords: maritime safety, marine accidents, safety management evaluation system

#### 1. Introduction

Maritime transportation by ship is expanding in the international trades between countries, and this trend is continuously on the rise. Especially, worldwide trade volume by ship is expected to continue due to the growth of Chinese economy and its shift of the world economy to Northeast Asia regions. And the number of international passengers by cruise ship, passenger ships and cargoes among the three countries of Korea, China and Japan keeps increasing. Such an increase in maritime transportation is leading to a higher maritime traffic, and this poses a greater risk of marine accidents in Korea's coastal water.

Moreover, human errors from aging of seafarers and multinational seafarers are threatening marine accidents. Above this, there are other factors that are putting maritime safety in danger such as shipping hazards affecting safe navigation of ships due to climate changes and mounting traffic of yacht and pleasure boats in littoral sea due to the increase in maritime leisure activities.

According to such Korea's economic growth, there is a huge demand on improvement of the safety level and the government is pushing ahead with tougher safety management level. Despite a change in maritime safety environment, shipping companies are just regarding safety as a cost with no profitability. This resulted in their inactivity in management of ship's safety and investment.

Therefore, in this paper, we propose a safety management evaluation system(SMES) to measure safety management levels on shipping companies. The purpose of this study is to induce the safety management skills and investment from shipping companies themselves.

In chapter 2, we analysed marine accidents, port state control, safety management system in Korea and some marine accident types caused by Korean shipping companies. We proposed safety management evaluation system which explains the concept, evaluation subject company, process measuring safety levels of Korean shipping companies in chapter 3. And we also proposed measures that can utilize the constructed evaluation system as a conclusion in the last chapter.

# 2. Analysis for Marine Accidents in Korea

In 2012, 84,790 vessels and 13,670 thousand gross tons are registered in Republic of Korea. The number of merchant vessels is 9,435 and its tonnage is 13,060 thousand gross tons. In case of fishing vessel, the number of its vessel is 75,355 and its tonnage is 610 thousand gross tons.

In the recent five years (2008~2012), marine accidents occurred 3,612 cases on Korean flag vessels and littoral sea in Figure 1. Marine accidents showed a tendency to increase annually, but 946 cases in 2012 compared to 726 cases in 2011 were decreased by 23 percent. By looking into the types of vessels, fishing vessels scored 77 percent and merchant vessels accounted for 23 percent.





Source: Modified by author from data of Ministry of Land, Transportation and Maritime Affairs, Korea

The ships which caused such marine accidents in recent five years from 2008 to 2012 were a total 4,650 vessels and increased each year, but in 2012, 21 percent decreased year-on-year. Marine accidents in 2012 were caused by 941 vessels, 288 merchant ships, and 653 fishing boats. In 2012, as for the registered vessels, the number of merchant vessels caused marine accidents was 288 vessels and of fishing boats were 653. As for the percentage ratio of marine accidents in comparison to the registered ships, its merchant ship ratio is 3.1 percent and the fishing boat is 0.9 percent. This clearly shows that the number of ships which causes marine accidents by fishing boats is 2.3 times higher than that of the merchant ship whereas in terms of the accident rate, that of the merchant rate was 3.4 times higher than the fishing boat.

Total			Merchant vessel			Fishing vessel			
Year	Registered vessel no.	Accident vessel no.	Accident ratio	Registered vessel no.	Accident vessel no.	Accident ratio	Registered vessel no.	Accident vessel no.	Accident ratio
2008	88,854	636	0.7	8,088	201	2.5	80,766	435	0.5
2009	86,087	915	1.1	8,374	190	2.3	77,713	725	0.9
2010	86,015	961	1.1	9,041	289	3.2	76,974	672	0.9
2011	85,025	1,197	1.4	9,396	309	3.3	75,629	888	1.2
2012	84,790	941	1.1	9,435	288	3.1	75,355	653	0.9

# Table 1: Marine Accident Ration of Registered Vessels in Korea

(Unit: number, 1000tons, %)

Source: Ministry of Land, Transportation and Maritime Affairs, Korea

When analyzing marine accidents by ships in 2012 as shown Table 2, cargo ships, tug boats and fishing boats decreased by more than 10 percent over the previous year. On the other hand, passenger ships, tanker ships increased more than 5 percent. Over the last five years in marine accidents by merchant ships, cargo ship presented the highest with 87 ships and then tug, tanker, passenger ship happened the most in order.

Vaar	Eiching wegel	Merchant vessel						40401
rear	Fishing vessel	Sub total	Passenger ship	Cargo ship	tanker	tug	etc	total
2008	435	201	19	63	25	52	42	636
2009	725	190	7	83	18	35	47	915
2010	672	289	18	107	42	65	57	961
2011	888	309	17	96	37	75	84	1,197
2012	653	288	24	86	39	65	74	941
Total	3,373	1,277	85	435	161	292	304	4,650
5 year average	675	255	17	87	32	58	61	930

**Table 2: Marine Accidents by Merchant Ships** 

(Unit: number, 1000 tons)

Source: Ministry of Land, Transportation and Maritime Affairs, Korea

Tonnage distribution of marine accidents, in 2012, the vessel under 100 ton accounted for 72.5 percent of all accidents. As a result, we can acknowledge that most of the accidents have happened in small ships such as a fishing vessel. Most of the accidents in merchant ships involved collision, and in case of fishing vessel involved mostly machinery damage and failure.

The marine accidents such as casualty, total loss, oil pollution occurred 242 times in 2012 as shown Table 3. The accident happened 69 times to merchant vessel and 173 times to fishing vessel. In 2012, the number of casualties by marine accidents is 229 peoples and among them merchant vessel rate was 31.9 percent and fishing vessel was 68.1 percent. Especially, as far as merchant vessel is concerned, in 2012 the total dead or missing was 30 people and the injured is 43 people.

Table 3: Major Accidents and Casualties by Merchant Vessel's A	Accid	ent	,	
	/		1.	,

				(Unit: sh	ip's no, person	
Year	Major accidents (	casualty, total loss,	Casualty in mercha	Casualty in merchant vessel		
	Merchant vessel	Fishing vessel	Sub total	Dead or missing	Injured	
2008	60	115	175	46	74	
2009	47	144	191	36	65	
2010	66	147	213	46	14	
2011	65	235	300	41	36	
2012	69	173	242	30	43	
Total	307	814	1,121	100	222	
Total	(27.4%)	(72.6%)	(100%)	177	232	

Source: Ministry of Land, Transportation and Maritime Affairs, Korea

By looking into the causes of marine accidents, about 93 percent turns out to be driven by the human error of crew. Among them, negligence of watch keeping and impropriety of ship maneuvering accounted for 58 percent. In recent 5 years, after analyzing 716 cases of marine accidents occurred in merchant ships, accidents due to human error were mostly accounted for 640 cases and poor handling or flaw, poor navigation infra the most in order. In terms of human error, there is poor handling, violation of voyage regulation, impropriety of ship maneuvering, and negligence of ship position check, etc; and in terms of poor handling or flaw include poor fire-producing material handling, worn out wires; and in terms of navigation infra, mainly the lack of waterway investigation attributed to marine accidents.

	·		·		•	(Unit: case)
Type of accident causation	2008	2009	2010	2011	2012	Sub total
Human error	146	100	142	133	119	640
Poor handling or flaw	7	6	4	2	7	26
Navigation infra	3	2	1	0	0	6
Environment	0	1	2	1	1	5
Etc	7	10	8	8	6	39
Total	163	119	157	144	133	716

Table 4: Analysis for Marine	e Accidents by Merchant Sh	nip
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Source: Ministry of Land, Transportation and Maritime Affairs, Korea

Understanding that most of the marine accidents by merchant ship are caused by human error such as negligence of crew's watch keeping, ship position check and violation of voyage regulation, etc, IMO introduced International Safety Management(ISM) Code and provided guidelines defining duties and processes to be taken by crew or safety manager, rendering the crew to perform according to the standardized manual to reduce marine accidents.

Accordingly, shipping companies operating ships should embed in an importance of safety management and implement safety management systematically in order to prevent marine accidents. With that, each company's safety management level should be evaluated and be referred to enhancement of safety by complementing lacking parts for the reduction of marine accidents.

# 3. Development of Safety Management Evaluation System

# 3.1 Concept of safety management evaluation system

Safety management evaluation sector should be simple and accurate enough to secure reliability from the subject evaluators when the results are presented. Therefore the fundamental concepts of objectivity, reliability and simplicity of the safety management evaluation system were applied for building a evaluation system. This SMES is consist of database for evaluation target management and marine accidents management, ship safety management evaluation index in Figure 2, and will be explained details as follow.





# 3.2 The target of evaluation

Of the Korea Maritime Safety Act, the owner of the ship or any other organization or person such as manager,

who has assumed the responsibility for operation of the ship from the owner of the ship and who on assuming such responsibility has agreed are required to formulate and implement a safety management system. In details, targets of the Act are passenger ships and cargo ships of 500 gross tons or more flying Korean flag or serving bareboat charter party hire purchase (BBCHP), which are subject to acquire Korea nationality at the end of charter party. In this study, as a basic research for the system development for safety management evaluation, the targets were narrowed down to ocean-going vessels of the Korea flagged ships and BBCHP which are only engaged in cargo transport.

In Korea in December 2011, the aggregated number of ocean-going cargo transporters was 187, and they have 1,536 vessels with 55.67 mil. gross tons(GRTs). Especially, the number of Korea national vessels is 577, among them and their GRTs are 10.37 mil. When it comes to BBCHP vessels, its number is 564 accounting for 21.86 mil. gross tons.

				()	Unit: 1,000tons)
Classification		Ship's no	GRT	DWT	TEU
National flag vessel	Korea flag	577	10,377	17,571	64,233
	BBCHP	395	21,861	33,448	367,981
	Sub total	972	32,238	51,019	432,214
Foreign flag vessel	Bareboat Charter	60	2,328	4,202	9,028
	Time charter	504	21,111	29,815	489,652
	Sub total	564	23,439	34,017	498,680
Total		1,536	55,676	85,036	930,894

Table 5: The Status of Korean Ocean-going Transporters in 2011 Year

Source: Ministry of Land, Transportation and Maritime Affairs, Korea

The ocean-going shipping companies can be classified depending on the size of their fleet such as the number of their owned vessels, aggregation of gross tons, etc. In reality, it is more outstanding. There is not only a large number of small sized companies operating just one or two ships but also big- sized companies operating hundreds of vessels for their business in Korea. Therefore, it is not reasonable enough that all different sized shipping companies are evaluated under the same condition but rather have to be done after grouping them together in accordance with similar fleet sizes first.

As shown in Figure 3, ship management organizational structure of most shipping companies in Korea consists of crew management team, ship technical management team and safety quality management team except accounting and general affairs. First of all, the crew management focuses on the crew manning and training. Second of all, the ship technical management deals with ship maintenance and repairing. Lastly, the safety quality management serves for maintaining and implementing safety management system in accordance with International Safety Management(ISM). After an interview with a staff in charge of the safety management work at a shipping company, it was dominantly agreed on the opinion that all the teams should be comprised for a systematic safety management. In reality, in case of a small company, a simple person has to take care of all the duties described above having a hard time coping with the safety management duty.





Source: Modified by author from shipping company website

In this study, the telephone survey was conducted to 190 ocean-going shipping companies in Korea in order for marine companies to perform a systematic safety management work. The purpose of the survey was to figure out the current management status of shipping companies such as the number of employees who work in the crew management team, technical management team and safety quality management team respectively, the number of safety supervisors and how many vessels are in operation to carry out tasks of systematic safety management. The respondents of 103 shipping companies answered to the questions as shown Table 6; the average number of operating vessels was 13.5, the average number of employees in crew management, ship technical management and safety management was 3.3, 4.4 and 2.4 respectively. Additionally, the minimum number of vessels required to build up the systematic safety management was 4.1. Therefore, reflecting this outcome of the survey, this study narrowed down the companies to those in possession of more than 4 ships or more as the evaluation subjects.

## Table 6: The Outcome of Practical Survey on Ship Safety Management Status of Korean Shipping Companies

(Unit: ship's no, person)

Average number of ships or employee					
operating Vessels	Crew management team	Technical management team	Safety quality management team	safety supervisors	The minimum number of vessels required to build up the systematic safety management
13.5	3.3	4.4	2.4	4.4	4.1

# 3.3 Grouping of shipping companies for evaluation

For recent three years, the aggregate number of ocean-going ship operators registered in Korea is 126 companies operating 923 vessels and average number of owned vessels of those companies is 7.5. The number of operators with their fleet below 7.5 is 92 companies accounted for 74% of total operators and the companies operating less than 2 vessels are 17% of the total. Additionally, 57% of the total companies operate their fleet between 2 and 7 and the companies operating more than 8 vessels take over 26% of the total. The operators owned more than 4 vessels which is a minimum standard for safety management evaluation in this study are 60 companies and they own 798 vessels. In other words, as for the Korean ocean-going ship liners, there are more companies in possession of less number of ships whereas there are a small number of large companies appear to be in possession of more ships.

This study shows that ocean-going shipping company's groupage has 60 companies which own more than four ships, thus the number of ships in possession is 13.3 and the gross tonnage per a ship is 39,185. Therefore, each group was set up based on 14 ships in number and 40,000 ton in gross tonnage. Group 1 represents a company in possession of 4~7 ships and the average gross tonnage per ship less than 20,000 tons, Group 2 represents a company in possession of 8~13 ships or the average gross tonnage 2~4 tons, Group 3 represents a company in possession of 14 ships and the average gross tonnage more than 40,000 tons. As a result, Group 1 turns out to be 21 companies with 103 ships, Group 2 is 30 companies with 322 ships, and Group 3 is 9 companies with 373 ships in groupage as shown Table 7.

		(Unit: number)
Class	No. of shipping company	No. of ship
Group 1	21	103
Group 2	30	322
Group 3	9	373
Total	60	798

 Table 7: The Result of Grouping for Shipping Company

#### 3.4 Model for safety evaluation

This study established the evaluation index, Ship and this barometer set up the ship safety evaluation index,

Eq.1 based on its validity, objectiveness, reliability, clear-accurateness and availability. Evaluating subjects in the ship safety evaluation index is comprised of the number of marine accidents, injuries, damages caused by marine accidents; and the results of port state control and screening results of the safety management system which are to prevent marine accidents.

## SSMEI = f (MARI, MAPRI)

(1)

MARI: marine accident result index which is consist of number of accidents, type of accidents, injuries, ship's damage.

MAPRI: marine accident prevention index which is consist of number of detention & deficiency by port state control (PSC) inspection and major non-conformity & minor non-conformity by ISM audit.

There are 17 different kinds of marine accidents such as collision, sinking, overturn, fire explosion and the like classified by the marine safety tribunal, the casualties include the number of dead or missing, seriously injured, slightly injured and the damage includes total loss, moderate damage and light damage. Marine accident data was used of the statistics released from Korea Maritime Safety Tribunal.

Sectors for evaluating the results of port state control are detention and deficiency, the data aggregated by the Korean government was used along with the results of screening conducted on ships once detained at overseas ports or with high target factor value(TFV) and cases about detention and deficiency released by each MOU.

Sectors for evaluating the results of safety management system are major non-conformity and minor non-conformity; data was used of the one managed by the Korean government.

## 3.5 Setting of weight by evaluation items

This study set weight on each factor of five evaluating sectors that comprise of ship safety evaluation index. It is because it shows disparity of quality when it comes to the types of marine accidents, injured, damage size, port state control's screening and safety management system. The setting of weights on marine accident and factors for marine accident prevention was done using a Delphi method through marine accident experts as shown in the Table 8.

Classification	Evaluation items	Weights
	collision	6.0
Marine accident's type	sinking, overturn, fire explosion	4.0
	others	3.0
Type of acqualtics	dead or missing	10.0
Type of casualties	the insured	5.0
	total loss	6.0
Ship's damage status	moderate damage	3.0
	minor loss	1.0
Port state control inspection	detention	3.0
Fort state control inspection	deficiency	1.0
ISM audit	major non-conformity	3.0
	minor non-conformity;	1.0

#### Table 8: The Result of Weight set by Evaluation Items

#### *3.6 The result of safety evaluation*

The number of Korean ocean-going ship operators who participated in the evaluation is 60 and the number of ships subjected to evaluation is 798 as shown Table 9. Among them, after evaluating 103 ships of 21 companies in Group 1, the average evaluation index recorded 7.729. The evaluation index of the top company in Group 1 was 0.755 with no marine accidents and obtaining satisfactory results from port state control and
safety management system audit. Also after evaluating 322 ships in 30 companies in Group 2, the average evaluation index recorded 6.332. The evaluation index of the top company in Group 2 was 0.172 with no marine accident s and obtaining satisfactory results from port state control and safety management system audit. After evaluating 373 ships in 9 companies in Group 3, the average evaluation index recorded 7.047 and the evaluation index of the top company in Group 3 was 0.731 with no marine accidents and obtaining satisfactory results from port state control and safety management system.

Class	No. of shipping company	No. of ship	Average of SSMEI	Highest score of SSMEI			
Group 1	21	103	7.296	0.755			
Group 2	30	322	6.332	0.172			
Group 3	9	373	7.047	0.731			

The distribution of result of ship safety management evaluation index is Figure 4. As Figure 4, ten companies scored below 1.0 after evaluation by SSMEI. Two companies of group 1 and one company of group 3 recorded respectively less than 1.0 of SSMEI, and seven companies got index less than 1.0.





### 4. Conclusion

This study proposed concepts of safety management evaluation system for shipping companies in order to evaluate Korean ocean-going shipping companies' ability to manage their safety management skills. Moreover, we developed ship safety evaluation index by selecting evaluating sectors through the questionnaire study toward safety supervisors and experts and then set up a weight on each sector. Finally, by using this index, we evaluated 60 companies after grouping them having similar fleet size together and were able to gauge the shipping company's safety management ability in each group through this outcome.

We enhanced the objectivity on safety level test by evaluating ship operators using ship safety evaluation index we proposed as well as by using the statistical date released by the Korean government for securing reliability about the evaluation results. No matter how excellent the index is, if it is complicated and hardly understandable for subjects evaluated could lead to a weak persuasiveness, we developed the most simplest and accurate index as possible.

This study is a fundamental research for evaluating shipping companies' safety management ability, thus it is essential to utilize this result for policies by building and performing the evaluation system for shipping

companies in the future. For instance, it is important to encourage companies to participate in more actively through practicing incentives like shipping inspection commission free or reduction for such companies with excellent safety management ability. Also laying the groundwork for market participants to voluntarily accommodate and utilize this evaluation in the market through applying discount premiums when estimating insurance rates or referring it to a screening test for bituminous license bidding is significant.

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# Environmentally Differentiated Port Fees in the Baltic Sea Ports: Building a Cost-Efficient Port Fee System

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### Abstract

The pressure has grown to develop cost-effective emission reduction strategies in the Baltic Sea. The forthcoming stringent regulations of the International Maritime Organization for reducing harmful emissions of shipping in the Baltic Sea are causing increasing expenses for the operators. This paper presents pilot scenarios of Pan-Baltic environmentally differentiated port authority fee system to create more effective incentives to reduce  $NO_x$  emissions beyond regulations by financial incentives. The objective of the port fee system is to be income neutral so that it does not create competitive disadvantage for ports who have introduced differentiated port dues.

The research contains an empirical examination of the relationship between the environmental and economic efficiency of the port fee system. The study is carried out in two phases, firstly by theoretical examination of the subject studied and secondly, the quantitative part of the study includes statistical analysis by creating a calculation model to analyze the possibilities of the system. Existing environmentally differentiated port fee systems will create a base for analyzing the possibilities of the model.

The value of this study is to provide fresh insight to the topic by examining the effect of the given economical incentive to the cost of the reduction technologies. This market-based attitude towards pricing of economic incentives is seen as a new approach for a successful application of the system. With differentiated port fees the decreasing of emission will automatically be executed by those with lowest cost and the more ports in the Baltic Sea will implement the environmentally differentiated port fee system the more incentive there will be for ships to cut emissions.

Results of this paper presents new information for decision makers to further develop environmentally differentiated incentives in shipping. The results of the pilot concept will be applicable all over the world.

*Keywords: The Baltic Sea, Maritime Transport, Maritime Environment, Port Management, Cost Management, NOx* 

### 1. Introduction

Shipping is as energy-efficient transport mode, compared to freight transports on land and air (Mellin & Rydhed, 2011). At the same time shipping is a major source of pollution. Problems concerning environmental issues in shipping have received more and more attention during the last decades as awareness of environmental issues has increased. Being a semi-enclosed brackish eco-system the Baltic Sea is especially vulnerable to eutrophication. Shipping contributes to the eutrophication by NO<sub>x</sub> emissions. Eutrophication leads to imbalanced functioning in an aquatic ecosystem. (HELCOM, 2006)

Marine pollution is regulated by International Convention for the Prevention of Pollution from Ships (MARPOL) and its Annex VI by IMO. Under the revised MARPOL Annex VI, IMO has defined an Emission Control Area (ECA) with limits on nitrogen oxide and sulphur. In the Sulphur Emission Control Area (SECA) the maximum sulphur content of the fuel will fall to 0, 1% after January 1<sup>th</sup> 2015. Possibility of proposing the Baltic Sea as Nitrogen Emission Control Area is currently under investigation. The Tier III standard for NO<sub>x</sub>

will apply for new vessels after January 1<sup>th</sup> 2016 in NECA. (IMO, 2012) The total reduction from Tier II level to Tier III level is 80 % (Karvonen et al. 2010). This level it is not achievable without specified technology for  $NO_x$  reduction. The drawback in Tier III effects to  $NO_x$  reduction is that it only applies to new vessels and the turnover of the fleet is slow (Kågeson, 2009).

Due to more stringent requirements for reducing emissions from ships, shipping industry in the Baltic Sea will be facing increased costs and needs for investments into low-emission technology and infrastructure. Economic incentives are gaining importance as a new approach to manage emissions worldwide. Economic incentives are instruments that use financial means to motivate actors to reduce emissions. Market-based policy instruments are regulations that regarding pollution levels or methods encourage behavior through market signals rather than explicit directives. (Stavins, 2001) Apart from differentiated port and fairway fees, also other economic instruments are used as incentives for emission reduction such as emission charges, taxes and cap-and-trade systems (Kågeson, 2009).

Differentiated port fees as economic incentives are seen as a possibility with many advantages. One interesting benefit is that with differentiated port fees the decreasing of emission will automatically be executed by those with lowest cost and the more ports in the Baltic Sea will introduce the environmentally differentiated port fee system the more incentive there will be ships to cut emissions. The main idea of the system is to grant a financial discount for environmental performance. In order to encourage ship owners to invest on additional emission reduction strategies beyond the mandatory emission reduction costs the incentive must be market based giving ship owners a large degree of flexibility as the choice a voluntary emission reduction is often driven by economics.

### 2. Methods and Material

The primary methodology is based on calculations done with Microsoft Excel to investigate the economic costs and benefits of the fee system. *The quantitative* part of the study includes statistical analysis from the Baltic Sea fleet, as the minimum and maximum discounts should be originated from the cost of emission reduction technology to the ship owners. Based on calculations, three different scenarios were created to examine impacts of discounts for vessel owners and to ports pricing decision. Material is also gathered from existing studies and literature, and also interviews were conducted to fill the data missing from other sources.

### 2.1 The Baltic Sea fleet

As the Tier III applies to new vessels, the pilot system created takes into account old vessels and their investments into  $NO_x$  reduction. The Baltic Sea fleet was investigated as the ships with passage transports between the Baltic Sea ports are the ships with most possibilities to gain financial incentives. Also to estimate the urea consumption, the fleet was well-wounded to categorize by their sailing time in the Baltic Sea. To investigate the fleet sailing only in the Baltic Sea area, calls from the Baltic Sea and North Sea was compared. Also additional ships of the commercial shipping fleet and vessels build before 1981 were excluded, as their estimated lifespan of 35 years will expire by 2016 when Tier III will come applicable.

Average Dullu Tear						
Ship types	No. of ships in the fleet studied	Average main engine power (kW)	Average build year			
General cargo ship	28	2620	1992			
Product tanker	6	2245	1986			
Chemical tanker	10	2390	1987			
Bulk ship	1	2729	1983			
RO-RO ship	12	15132	1993			
ROPAX ship	79	20337	1994			
Passenger ship	12	3824	1997			
SUM	148	13159				

 Table 1: Ship Types of the Studied Baltic Fleet, their Average Main Engine Power (kW) and

 Average Build Year

Source: The Baltic Sea Fleet

It should be highlighted that according to the Baltic Sea AIS data, there are approximately 2 000 vessels in the Baltic Sea area at any given moment and on monthly basis around 3 500-5000 vessels ply the waters of the Baltic Sea (HELCOM, 2012). The number of vessels with incentives to invest on  $NO_x$  reduction technology is not limited to the studied fleet.

### 2.2 The Baltic Sea ports

There are more than 200 commercial ports in the Baltic Sea region (WWF Baltic Ecoregion Programme, 2010). In 2011 the total amount of international cargo handled in these ports was 839 million tons (Holma et al. 2012). Ports earn income by charging ships for the use of the facilities provided by the port (Stopford, 2009). Port dues are normally based on the cargo quantity and on vessels gross tonnage. The Baltic Sea could function as a justifiable area for pilot projects to test emission reduction strategies as from the area can be found a shipping industry with strong knowledge about environmental aspects and the area itself is uniform.

In 1998 The Swedish Maritime Administration in co-operation with the Swedish ports and Ship owners decide to implement a system of environmentally differentiated charges to create incentives to use low sulphur oil and to reduce  $NO_x$  emissions. The fairway due is mandatory for vessels, loading and unloading cargo or passengers in Sweden, whereas the port dues are recommended to be implemented. (Swahn, 2002; Mellin & Rydhed, 2011) Table 2 shows the current  $NO_x$  discounts in three major Swedish ports.

(Used exchange rate 1 SEK = 0.11802613098540017 EUR, medium rate 22.2.2013)					
Ports	NO <sub>x</sub> /kWh	<b>Discount SEK/GT (EUR/GT)</b>			
Port of Stockholm	10g/kWh - 5g/kWh	0.15 (0.0177)			
	5g/kWh - 1g/kWh	0.25 (0.0295)			
	below 1g/kWh	0.30 (0.0354)			
Port of Malmö	6-12 g/kWh	0.05 (0.0059)			
	below 6g/kWh	0.15 (0.0177)			
Port of Gothenburg	6-9.9g/kWh	0.05 (0.0059)			
	2-5.9g/kWh	0.10 (0.0118)			
	below 1.9g/kWh	0.20 (0.0236)			
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 Table 2: The Current NOx Discounts in Important Swedish Ports

Source: Port of Stockhom (2011); Port of Malmö (2011); Port of Gothenburg (2013)

According to Mellin & Rydhed (2011) the experience and attitudes towards differentiated ports fees has been very positive among Swedish ports. In total 20 out of 30 ports responded that the implementation of differentiated port fees has been positive for the business and only one port responded that the effect has been negative. (Mellin & Rydher, 2011.)

Since 2011 in port of Rotterdam ship owners can get 10 % discount of port fees when they register for Environmental Ship Index (ESI) and receive more than 31 points or more (Port of Rotterdam 2012). ESI is an international standard for ports to reward ships for emission reduction. The object of the ESI is to grant discount for a vessel performing better than IMO regulations. (Atkins & Andersson, 2012) The ESI is formulated based on different parts for NO<sub>x</sub>, SO<sub>x</sub> and CO2, also additional bonus is granted for the presence of an Onshore Power Supply OPS. (ESI, 2012; Atkins & Andersson, 2012.) By October 2012, 1445 vessels and 16 ports have introduced ESI (Atkins & Andersson, 2012). The advantage of ESI is in its international nature; it would be easier for vessel and port owners to introduce a system already known worldwide. In addition, in particular ports of Belgium, Canada, Latvia, Lithuania, the Netherlands, Oman, New Zealand, Portugal and South Africa, by implementing the Green Award vessels receive a considerable reduction on port dues. Green Award certificate was introduced in 2007, and also NO<sub>x</sub> tax and NO<sub>x</sub> fund was implemented. The amount of tax is calculated based on the actual NO<sub>x</sub> emission (Kågeson, 2009).

### 3. Results

### 3.1 Nitrogen oxide reduction technology

According to Karvonen et al. (2010) the only standalone technology currently available for achieving the Tier III standards for NO<sub>x</sub> reduction is selective catalytic reduction (SCR). It should be addressed thought that new technologies are to be taken into consideration in the future (Karvonen et al. 2010). In order to meet with the Tier III limits, SRC technology is the most likely alternative for new ships after 2016 (Kalli et al. 2010). Selective catalytic reaction (SCR) is a chemical reduction accelerated with a catalyst. According to Karvonen et al. (2010) the reduction level of NO<sub>x</sub> with SCR system is 85-95%. This would mean reduction of NO<sub>x</sub> emissions below 2 g/kWh, meeting the Tier III limits and above (Karvonen et al. 2010). The approximate lifespan for SCR technology is from 10 to 15 years, depending on the equipment usage (Häkkinen, 2012). In this paper the estimations of the costs of SRC technology investments are based on the engine manufacturer Wärtsilä (Wärtsilä, 2011) and SCR technology producer Wilhelmsen Technical Solutions (Lovskar, 2011). This is argued by a fact that these are manufacturers of SRC technology so the prices are market-based and accurate. Also other sources were investigated. Between different sources available cost information indicated quite a uniform pricing level.

For 2-stroge engines d SCR costs are estimated to be from 13 to 40  $\in$  per kilowatt depending on the engines power (Wärtsilä, 2011) and approximately 10-55  $\notin$ kW depending on engine power for smaller 4-stoge engines. For 500 kW engines the price is up to 100 $\notin$ kW. (Lovskar, 2011) SCR-systems are tailor-made and designed according to engines specifications and fitted on an engine-by-engine basis. Due to the greater amount of design work necessary, cost for retrofitting is estimated to be 30% in accordance with Häkkinen (2012). In addition to purchase price also installation costs, operation costs and consumables were taken into account in the final calculations. The payback time for the investment, installation and dockyard costs equals to the lifespan of the technology. Equation 1 present the logic of calculating the total SCR price for a ship in particular year.

Cost of SCR technology for a vessel x in year a ( $\bigoplus$  = ((Engine kW \* SRC purchace price for a 4-stroge or a 2-stoge engine  $\bigotimes kW$ )\* number of engines+ System installation (1) and dockyard cost) / lifespan of SCR technology + Operations costs per year + Consumables per year

Operation costs are estimated in accordance with Häkkinen (2012) to be 20 000 € per year. Operation costs include operating and maintenance, urea nozzle costs, costs of replacement elements and other parts. Price for urea is estimated to be 300 € per ton in accordance with Häkkinen (2012). The urea consumption is estimated to be about 7.5 % of the fuel consumption. (EPA 2009, 5-15) According to Karvonen et al. (2009) urea consumption is estimated to be about 10 % of the fuel consumption and in Häkkinen (2012) research 7 % of oil consumption was mentioned. According to Entec the fuel consumption was calculated by the installed auxiliary engine and main engine power, average engine load factors and operating hours targeted into sea, berth and manoeuvring as presented in Equation 2 (2005) and urea costs per year according to Equation 3.

Fuel consumption of an specific vessel =  $\sum_{x=1}^{3} x$  = Main engine size (kW)\*engine load factor at x\*Operation hours at x\*Operation (% of time)\*Specific fuel consumption (2) factor + Auxiliary engine size (kW)\*engine load factor at sea\*operating hours at x\* Specific fuel consumption factor

Where *1* is at Sea, *2* is at berth and *3* is manoeuvring.

Urea cost for a specific vessel= Fuel consumption of an specific vessel (tons) \* urea/fuel (3) ratio \* urea price €ton

Quality assurance was done by calculating estimated urea consumption according to Wärtsilä (2011) with average consumption of urea 15l/MWh and assumed 40% urea solution price of  $0.3 \notin 1$ . From Equation 2 we can receive a total power used by engines per year by multiplying the representative installed capacity for engine by the engine loads and hours of operation. By multiplying this with typical urea operating cost of  $4.5 \notin MWh$  (Wärtsilä 2011), gives the same urea costs amount as with calculating urea cost with Equation 2 and 3.

Also using the liquefied natural gas (LNG) as fuel meets the Tier III requirements; the reduction level of  $NO_x$  is up to 98%. (Karvonen et al. 2010) In addition LNG meets the strict  $SO_x$  requirements in ECA's (Herdzik, 2011; Germanischer Lloyds, 2011). However, retrofitting a LNG-system asks for radical changes and is therefore expensive. According to CMTI (2011) the focus should be on the installation of LNG-systems on new vessels. Although, there is some information about the costs for retrofitting LNG technology to existing ships, because of the limited information, in this study only SCR costs are modeled.

### 3.2 Effect of the granted discount to ship owners

As the investments for  $NO_x$  reduction technology would be estimated to be conducted for vessels with the lowest investments cost and biggest discount, the vessels with frequent liner traffic in the Baltic Sea port would be the primary vessels to introduce  $NO_x$  reduction technology. This would mean that vessels with infrequent visits to the Baltic Sea ports would have to pay the increased basic fee. To determine the suggested base discount to the Baltic Sea ports different scenarios were created. For the first Scenario, actual discount granted in the Port of Stockholm is used as it will present the current situation and it is known that this is an amount of discount port is capable to grant. Scenarios 2 and 3 are determined in accordance to Scenario 1.

- Scenario 1: Discount 0, 0354 EUR/GT
- Scenario 2: Discount 0, 0654 EUR/GT
- Scenario 3: Discount 0, 1054 EUR/GT

It could be possible to examine also bigger incentives but considering their impact on ports regular fees, it would be impossible for ports to raise their regular fee so much without competitive disadvantage. Figure 2 illustrates the relationship between granted discounts to the annual SCR costs for ship owners.



### Figure 2: The Effect of Granted Port Fee Discount to Annual SCR Costs

As seen in Figure 2, it is clear that the amount of granted discount has an important effect as an economic incentive to emission reduction. The used percent value of annual SCR costs is the average value of the Baltic Sea fleet. Also the number of calls in the Baltic Sea port plays an important role in determining the rate of the incentive. With Scenario 1 the effect of granted discount to the average annual costs of SCR technology to the Baltic Sea fleet is between 2%-6%, depending on the amount of calls per year. The minimum and maximum values with 50 calls to the Baltic Sea ports in a year were 0, 50% and 13, 80%.

With Scenario 2 the effect of granted discount to the average annual costs of SCR technology to the Baltic Sea fleet is between 4%-12%. The minimum and maximum values with 50 calls to the Baltic Sea ports in a year were 0, 93 % and 25, 50%. With Scenario 3 the effect of granted discount to the average annual costs of SCR technology to the examined fleet is between 7%-19%. The minimum and maximum values with 50 calls to the Baltic Sea ports in a year were 1, 50 % and 41, 10 %. With Scenario 3 many ships had quite a significant (>20%) incentive to SCR technology investments.

Table 3 present 12 ships and their details used in calculation of impacts of port fee discounts into the annual costs of SCR. Presented ships are selected to present different types and sized ships, port calls are estimated.

Discount percent from annual SCR costs is presented with different Scenarios.

Table	Table 3: The Baltic Sea Fleet and their Possibility to Environmentally Differentiated Port Fee Discount						
	Туре	GT	SCR	Port calls to	Discount % from	Discount % from	Discount % from
			costs per	the Baltic Sea	annual SCR	annual SCR costs	annual SCR
			year	ports	costs with SC 1	with SC2	costs with SC3
10	ROPAX	14 398	389 049	30	3,93	7,26	11,70
24	ROPAX	10 067	251 107	30	4,26	7,87	12,68
37	ROPAX	48 915	809 851	50	10,69	19,75	31,83
43	GC	10 098	229 338	20	3,12	5,76	9,35
53	ROPAX	59 912	805 086	40	10,54	19,47	31,37
61	RORO	11 530	384 134	50	5,31	9,81	15,82
71	GC	4 071	129 039	20	2,23	4,13	6,70
88	GC	2 544	68 975	30	3,92	7,24	11,66
94	RORO	20 126	499 945	30	4,28	7,90	12,73
107	PAS	34 728	604 288	50	10,17	18,79	30,28
131	RORO	23 128	553 240	50	7,39	13,67	22,03
103	GC	16 690	395 427	40	5,98	11,04	17,79

### 3.3 Effect of the granted discount to the port authority fees

In Europe ports are being operated more and more commercially. As major of ports are public companies, ports pricing decisions are primary affected by the fact that on a long run the revenues must exceed the total costs. Pricing decisions must always be examined through the eyes of the customers, in this case shipping companies. Also competitors' reactions have an impact upon pricing decisions. Pricing decisions can be market- based or cost based. (Bhimani et al. 2012) The pricing decisions are made by port managers and based on ports transport flow, but giving the market-based nature of the port markets the environmental discount should be at the same level in every port to give the maximum incentives for emission reduction. Ports being public companies the granted discount cannot be mandatory but if recommendations would be widely acknowledged, incentives for introducing differentiated port fees would be major.

Creating a cost-efficient pan-Baltic environmentally differentiated port fee system would require that the level of discount is accurately set. Figure 2 illustrates the relationship between current port fee and modified port fee system with NO<sub>x</sub> differentiation. The two most important questions to determining the profile are 1)How many ships with passage transport with possible NO, reduction technology visits the port and 2) how many are irregular visits. Port fees should be flexible in case of changes in the profile.





To get the average price to be income neutral regardless the volume of the traffic entitled to the discount, the rate of regular price must be raised. The simple formula (Equation 3) is used for calculating the average price:

 $a_1 * b_1 + a_2 * b_2 = c$ 

(3)

Where, *a* is the price, *b* is the volume and *c* is the average price. In Port of Stockholm the normal tariff is between SEK 3.78 - 2.57 /GT. (Port of Stockholm, 2012) SEK 3.78 is used in this examination, this would mean EUR 0.447 with exchange rate 1 SEK = 0.11802613098540017 EUR (medium rate 22.2.2013). With Scenario 1, this would mean a discount price of 0, 4116 EUR/GT and average price of 0, 4435 EUR/GT at volume of 10% entitled to the discount.

Table 4. Calcu	Tuble 4. Calculation of Trices with Different Volumes with Scenario 1					
Regular Price	0.447 EUR/GT	0,4506 EUR/GT	0,4541 EUR/GT			
Volume	90 %	80%	70 %			
<b>Discount Price</b>	0,4116 EUR/GT	0,4152 EUR/GT	0,4187 EUR/GT			
Volume	10%	20%	30%			
Average price	0,4435	0,4435	0,4435			

 Table 4: Calculation of Prices with Different Volumes with Scenario 1

Fee prices in Scenario 2 are calculated in accordance with Equation 3 where c,  $b_1$  and  $b_2$  is known and the ratio between  $a_1$  and  $a_2$  in accordance to Scenario 2 is 0,0654 EUR/GT.

<b>Regular Price</b>	0,450 EUR/GT	0,4566 EUR/GT	0,4631 EUR/GT
Volume	90 %	80%	70 %
<b>Discount Price</b>	0,3846 EUR/GT	0,3912 EUR/GT	0,3977 EUR/GT
Volume	10%	20%	30%
Average price	0,4435	0,4435	0,4435

Fee prices in Scenario 3 are calculated in also accordance with Equation 3 where  $b_1$ ,  $b_2$  and c is known and the ratio between  $a_1$  and  $a_2$  in accordance to Scenario 3 is 0,1054 EUR/GT.

Table 0. Calculation of prices with unrefent volumes with Scenario 5					
<b>Regular Price</b>	0,454 EUR/GT	0,4646 EUR/GT	0,4751		
Volume	90 %	80%	70 %		
Discount Price	0,3486 EUR/GT	0,3592 EUR/GT	0,3697		
Volume	10%	20%	30%		
Average price	0,4435	0,4435	0,4435		

In the Baltic Sea all countries have a charging system that enables provision of services to shipping, infrastructure investments, dredging, lighthouse and fairway maintenance, icebreaking, hydrological surveys, etc. (Helcom, 2007). These operations are normally provided by fairway dues collected by the State. In addition every port has their unique facilities based on the trade of the region it serves. (Stopford 2009, 81-82) As ports earn income by charging ships for the use of the facilities provided by the port, the quantity and quality of these facilities besides the location are among the facts that determine the pricing decisions of ports and average price that should a long run exceed the total costs. This means that the average price is different in every port. This formula is nevertheless applicable for every port in the Baltic Sea as the average price is variable also.

The challenge of the differentiation is that it could create competitive disadvantage for ports that will introduce differentiated port fees. According to Mellin & Rydher (2011) and representative of Port of Turku (interview in 7.2.2013) the system has not create an insurmountable economic disadvantage so war. The current system that gives discount for both  $SO_x$  and  $NO_x$  reduction will have to reform after 2015 as new sulphur directive will be introduced and this would create an opportunity to increase the discount granted for  $NO_x$  reduction as presented above. Also concerning existing differentiated fairway and port fees it has been stated that the system does not take into account the distance travelled. (Kågeson, 2009) Despite the concerns, the system advantage lies in the fact that the investments for decreasing of emission will be executed by those with lowest cost. When thinking economically the reduction should be conducted by optimizing the resource allocation.

### 4. Conclusions

Port fees as an economic incentive is a fairly new approach to sustainable marine management. Port fees are currently tested in different ports in the Baltic Sea area. Pricing is a complex process, which is based on ports profitability. Pricing must always be examined through the eyes of the customers. An increase in price may cause customers to reject company or in this case port. (Bhimani & al. 2012) In Swedish ports this is solved by the fact that all major ports in Sweden have introduced environmentally differentiated port fees so it does not create competitive disadvantage for ports. In case of Pan-Baltic port fee system or worldwide system, this should be applicable.

Research has revealed that there is no preferred solid environmentally differentiated port fee system in the Baltic Sea. During the process it was noticed that there is both challenges and possibilities with this system. As the ports are commercial operators, it is impossible to introduce a solid port fee system without giving port owners a large degree of flexibility to their pricing decisions. Based on this study it is clear that the amount of granted discount has an important effect as an economic incentive to emission reduction and the system is possible to introduce so that it would not create an economic disadvantage to a specific port. For a successful application of market-based port fee system, it is essential that the given incentive reflects the market's perception of an accurate amount of discount. Another caution in the practical use of this system is that market especially the high volatile markets of maritime transport and the knowledge about environmental performance may rapidly change over time.

Implications for further research derive from the limitations related to this study. The analysis of the incentive-reaction mechanism in this case is a difficult issue to investigate. Future research would focus on systematic market research about the needs and responses of the shipping companies. For example considering applicability of the possible Scenario to the real life it would be interesting to examine the rate of the possible incentive; how big the incentive should be to create an actual investment decision. Also as this study indicates only port authority fees (e.g berthing fees), the state fees (e.g navigational fee) would also be interesting aspect to study further as these together would create even bigger incentives for NO<sub>x</sub> reduction.

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# Comparative Analysis of Shipping Center Competitiveness in Chinese Major Port Cities

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### Abstract

International shipping centers adopt a different development strategy models. The choice of each center depends on its status of international routes, the scope of the hinterland, the economic development level, and the conditions of its own and those of its supporting cities, and so on. It is of important significance to establish a competitiveness evaluation index system that caters to the characteristics of a shipping center and use scientific methods to evaluate those characteristics. Hierarchical analysis, principal component analysis and cluster analysis are applied to classify Chinese main ports, including Shanghai, Nanjing, Tianjin, Wuhan, Guangzhou, Dalian, Chongqing, Qingdao. They are ranked according to their soft environments as well as hard environments. The main influencing factors are investigated as well. A shipping center competitiveness evaluation index system is established.

Keywords: shipping center; hierarchical analysis; principal component analysis; cluster analysis

### 1. Introduction

The construction of international shipping centers in China is going-on rapidly proceeding. In 1996, it was proposed to construct the Shanghai international shipping center and all initial goals were achieved. The strategic focus has been shifted to the construction of the soft environment. In recent years, Tianjin, Dalian, Qingdao and some other cities have also taken strategic measures to establish shipping center. It is necessary to adjust the development direction and position of the shipping center timely and reasonably. Therefore, the competitiveness of these shipping centers needs to be evaluated. It is of great significance to establish competitiveness evaluation index system that caters to the shipping center's characteristics, and to use scientific methods to evaluate them.

The research activities were mainly focused on the competitiveness of a port. A systematic study of the competitiveness of shipping centers is in need. Before the 1960s, the number of articles on port competitiveness abroad is relatively small, and most research activities were towards the relationship between the port and shipping. Since the 1960s, some studies studying port development have emerged. Gradually port competitiveness becomes a major topic.

Related scholars studying the ports of Europe and North America present the factors affecting the competitiveness of ports, mainly on the side of shipping companies, exporters, shippers, freight forwarders and so on. Since the 1990s, Peters (1990) studied the competitiveness of European ports; Murphy, et al (1992) researched the competitiveness of Canadian ports from different analytical dimensions and the main factors; UNCTAD (1992) studied the competitiveness of world's major ports based on the perspective of the international traders; Starry (1994) proposed that the factors influencing port competitiveness also include the port location, inland railway transport, investment in port facilities and port labor stability; Mahmud (1995) studied Malaysian ports competitiveness, emphasizing the importance of port freight, safe handling of cargo, port scheduling and services confidence; Klink and Berg (1998) indicated that the key factor of the port competitiveness is an efficient multimodal transport service connecting the port and hinterland by studying European ports; Bichou and Gray (2005) pointed that ports are complex and dynamic entities, so port systems have different operational, organizational and strategic methods and that logistics and supply chain

management are the factors most affecting the competitiveness of port. Acosta, Coronado, et al (2007) found that the port infrastructure, superstructure and communication technology are three main factors determining the competitiveness of the container transport, by analyzing the competition in container transport between the port of Algeciras Bay and the Mediterranean port's under the same port geographical background; the previous does not make sense Yeo. Roe and Dinwoodie (2008) identifies the components influencing their competitiveness and presents a structure for evaluating China and South Korea, including port service, hinterland condition, availability, convenience, logistics cost, regional centre and connectivity are the determining factors in these regions; Notteboom (2008) indicated that, in addition to traditional factors affecting the port competitiveness, another increasingly important key factor is the performance of the logistics chain including ports, which means providing better service for customers at lower costs; Jose et al. (2009) combined different influencing factors of port competitiveness to rank the competitiveness of port for Spanish port authorities; Hwang et al. (2010) studied that the cooperation of Taiwan ports would produce positive influences to the competitiveness of neighboring ports in the same area, while the competitive intensity of regional ports and the strategy of shipping companies and terminal operators would create an indirect effect on the competitiveness. Yeo, Roe and Dinwoodie (2011) present an approach to measure container port competitiveness, a key but neglected element of channel management in a complex and dynamic logistics environment underpinned by commercial confidence and trust in European supply chains fed with goods from container ports in Northeast Asia. Neringa et al. (2012) disclosed the preconditions for competitiveness in Lithuanian freight transport services market. Statistical data analysis, as well as opinion of president of association 'Linava' and suppliers of freight transport services are discussed.

In summary, the research of many scholars focuses on the study of a port's competitiveness, not on the systematic research of international shipping center competitiveness. There are many factors influencing the competitiveness of the shipping center, which are difficult to measure directly due to the large scope. At present, the academic evaluation of competitiveness uses fuzzy math and gray theory in the evaluation process. Determining the weight of an evaluation index is an important step to make authentic evaluation results. There are three general methods to determine the weights, i.e. Delphi method, expert evaluation method and the analytic hierarchy process method. For shipping centers, a complex system involving society, economy and infrastructure, existing systematic evaluation methods are subjective, lack of sufficient scientificity, and therefore not very practical.

Considering little lack of systematic evaluation of the shipping center competitiveness of Chinese major port cities, this paper applies AHP and sets up the competitiveness evaluation index system based on an expert questionnaire we have send out. For the Competitiveness of the soft environment as well as hard environment of shipping center in the major Chinese port cities, Shanghai, Nanjing, Tianjin, Wuhan, Guangzhou, Dalian, Chongqing, Qingdao, the principal component analysis is used to study the main factors affecting the shipping centers; secondly, clustering methods are used to classify and rank the major shipping centers and analyze the strengths and weaknesses of each shipping center together with its causes.

### 2. Research Methods and Data Sources

### 2.1 The basic approach and step of analytic hierarchy process

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. Users of the AHP first divide their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about each element's relative meaning and importance.

### 2.2 PCA (Principal Component Analysis)

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. It is mostly used as a tool in exploratory data analysis and for making predictive models. PCA can be done by eigen value decomposition of a data covariance (or correlation) matrix or singular value decomposition of a data matrix, usually after mean centering (and normalizing or using Z-scores) the data matrix for each attribute. The results of a PCA are usually discussed in terms of component scores, sometimes called factor scores. Its operation can be thought of as revealing the internal structure of the data in a way that best explains the variance in the data. PCA can supply the user with a lower-dimensional picture, a "shadow" of this object when viewed from its (in some sense) most informative viewpoint. This is done by using only the first few principal components so that the dimensionality of the transformed data is reduced.

### 2.3 Cluster analysis

Cluster analysis is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters). Cluster analysis as such is not an automatic task, but an iterative process of knowledge discovery or interactive multi-objective optimization that involves trial and failure. It will often be necessary to modify preprocessing and parameters until the result achieves the desired properties. Clustering can therefore be formulated as a multi-objective optimization problem. It will often be necessary to modify preprocessing and parameters until the result achieves the desired properties.

There is no objectively "correct" clustering algorithm, but as it was noted, "clustering is in the eye of the beholder." The most appropriate clustering algorithm for a particular problem often needs to be chosen experimentally, unless there is a mathematical reason to prefer one cluster model over another. It should be noted that an algorithm that is designed for one kind of models has no chance on a data set that contains a radically different kind of models.

It takes a sample as a point of P dimensional space, and defines the distance in space, classifies the samples with closer distance for one category and the samples with further distance for another category. But there are many kinds of definitions for similarity coefficients and distances, and the definitions affect the type of the variables greatly. This paper uses the shortest distance, the longest distance and class average method to carry on the analysis.

### 2.4 Data sources

This project distributed questionnaires to 30 prestigious experts and scholars in the shipping fields to evaluate shipping center competitiveness. The recovery rate of questionnaires was 100%. The expert investigation method as used to score qualitative indexes of shipping center competitiveness. Quantitative data was derived from China statistical yearbook and China city yearbook.

## 3. Empirical Analysis

## 3.1 Determination of evaluating index of shipping center competiveness

In this part, both the expert investigation method and analytic hierarchy process (AHP) are used to estimate the weight of this index. The first step is to consult 11 prestigious experts and scholars in the shipping industry using the relevant questionnaires with 100% recovery. The indices include two levels: the first class indices consist of port natural conditions and infrastructure index, port external conditions index, port operation and management ability index, shipping center service environment index and hinterland economy and trade situation. Using the data from the questionnaires, we determine the mean, get information such as mean, mode, and median of the various indicators, and then formulate the corresponding judgment matrix to set the weight of each index with AHP.

### 3.2 Shipping center competitiveness evaluation

### 3.2.1 Weight of influencing factor based on AHP

### 3.2.1.1 Determine the evaluation object set

P = Influencing factor on shipping center competitiveness

### 3.2.1.2 Construct the evaluation factor set

 $u = \{u_1, u_2, \dots, u_6\} = \{$  port natural conditions and infrastructure index, port external conditions index, port operation and management ability index, shipping center service environment index as well as hinterland economy and trade situation}

### 3.2.1.3 Determine the reviews level domain

Establish the evaluation set v={excellent, good, average, poor }

### 3.2.1.4 Calculate the weight of first index

Formulate corresponding judgment matrix  $S = (u_{ij})_{n \times n}$ :

	x1	x2	x3	x4	x5		
x1	1	2	3	1	3		
x2	0.5	1	2	0.5	1		
x3	0.3333	0.5	1	0.3333	0.3333		
x4	1	2	3	1	3		

**Table 1: Judgment Matrix** 

Excel software is used to calculate the maximum Eigen value S = 5.12772 and count coincidence indicator CI=0.03193, average random coincidence indicator RI= 1.24 and average random coincidence rate CR=0.028509. When CR<0.1, the results of AHP have absolute consistency and the distribution of the weight coefficient is very reasonable. Relevant weight is listed as follows:

(0.310, 0.151, 0.082, 0.310, 0.147)

### 3.2.1.5 Calculate the weight of second index

Likewise, AHP is used to set the weight of each index: Formulate corresponding judgment matrix separately, and count the maximum Eigen value and coincidence indicator with excel software to get the weight coefficient indices for evaluating the port natural conditions and infrastructure include port location (location advantage), waterline length (km), port operating days, port's throughput capacity (mt), water depth of port main channel (m), storage yard area (sq.m). The weights of these indices are calculated as follow: (0.281, 0.135, 0.131, 0.117, 0.300, 0.055)

The weight of three indices evaluating port external conditions including foreign trade import and export volume of port (Billion dollars), GDP of port city (Billion yuan) and port transport convenient conditions is listed below:

(0.35 0.172222 0.477778)

The weight of six indices evaluating port operation and management ability including cargo throughput, foreign trade cargo throughput, container cargo throughput, port efficiency, International voyage density and domestic voyage density is listed below:

(0.058, 0.088, 0.176, 0.176, 0.373, 0.129)

The weight of five indexes evaluating shipping center service environment including port information, shipping policy environment, ship port costs, advanced shipping service industry and shipping service efficiency is listed below:

(0.129, 0.356, 0.97, 0.205, 0.205)

The weight of five indices evaluating hinterland economy and trade situation including hinterland economy GDP, foreign trade volume, industrial structure, Traffic network density and port hinterland connection strength is listed below:

(0.139, 0.210, 0.111, 0.371, 0.169)

3.2.1.6 Establish shipping center competitiveness comprehensive evaluation system based on AHP

First class index competiveness score = total weight multiply second class index value; Aggregative indices score = total weigh multiply first class index value

3.2.1.7 Second class index of competiveness scores

Table	2: Port Natural Condit	ions and Infrastructur	e Competitiveness Eval	uation
	City	Score	Rank	
	Shanghai	0.739769	2	

Shanghai	0.739769	2
Qingdao	0.146927	4
Dalian	0.019539	5
Chongqing	-1.26595	8
Nanjing	-0.41177	7
Guangzhou	0.268756	3
Tianjin	0.823891	1
Wuhan	-0.32116	6

### Table 3: Port External Conditions Competitiveness Evaluation

City	Score	Rank
Shanghai	1.132438	1
Qingdao	0.517358	2
Dalian	0.139159	3
Chongqing	-0.10797	6
Nanjing	-0.71448	7
Guangzhou	-0.04253	5
Tianjin	0.071217	4
Wuhan	-0.99519	8

### Table 4: Port Operation and Management Ability Competitiveness Evaluation

City	Score	Rank
Shanghai	1.459711	1
Qingdao	-0.29542	6
Dalian	-0.43105	8
Chongqing	-0.3266	7
Nanjing	0.35707	2
Guangzhou	-0.24981	4
Tianjin	-0.26608	5
Wuhan	-0.24782	3

City	Score	Rank
Shanghai	1.314748	1
Qingdao	0.714133	3
Dalian	-0.11087	5
Chongqing	-0.79483	6
Nanjing	-0.87673	7
Guangzhou	-0.07596	4
Tianjin	0.809552	2
Wuhan	-0.98004	8

### **Table 5: Shipping Center Service Environment Competitiveness Evaluation**

### Table 6: Hinterland Economy and Trade Situation Competitiveness Evaluation

City	Score	Rank
Shanghai	1.288654	1
Qingdao	0.672119	2
Dalian	-0.01786	5
Chongqing	-0.72827	7
Nanjing	-0.59349	6
Guangzhou	0.231355	4
Tianjin	0.552052	3
Wuhan	-1.40456	8

### 3.1.8 First class index of competitiveness score

### Table 7: Shipping Center Competence Comprehensive Score

City	Score	Rank
Shanghai	1.11708916	1
Qingdao	0.419504894	3
Dalian	-0.045286989	5
Chongqing	-0.58877933	7
Nanjing	-0.565152224	6
Guangzhou	0.066761947	4
Tianjin	0.576123323	2
Wuhan	-0.980258847	8

From the data, the top three cities are Shanghai, Tianjin and Chongqing. Shanghai ranks first in all factors except port natural conditions and infrastructure (4th) with much higher scores than those cities that rank the second. But its natural conditions and infrastructure score is a little less than Tianjin port, which means Shanghai has been ranked the best in all factors. The competitiveness of Shanghai shipping center will remain invincible if it continues to keep the advantage.

# 3.2.2 Influencing factors of shipping center competitiveness based on the principal component analysis method

In consideration of the uncertainties and the reverse of some factors, 18 indicators affecting the competitiveness of international shipping center are chosen to do the principal component analysis, through which major factors are determined and eight ports are ranked. These 18 variables are correlative to some degrees and correlation degree of 19 pairs of variables are more than 0.9 , which imply that the explanatory variables are not independent of each other.

In this case, the overlapping information can be extracted to synthesize a factor with principal component analysis and factor analysis to minimize the number and the influence of variable auto-correlation on the analysis results.

Extraction principle of principal component analysis is one that its characteristic root is equal or greater than one. Principal component characteristic root and its variance can be found in the Table 8.

3.2.2.1 Variable selection	
X1container cargo throughput in 2010	X2 cargo throughput in 2010
X3 waterline length	X4 water depth of port main channel
X5 Port operating days	X6 Port's throughput capacity
X7 Storage yard area	X8 foreign trade cargo throughputs
X9 GDP in 2010	X10 hinterland economy GDP in 2010
X11foreign trade import and export volume in 2010	X12foreign trade volume in 2010
X13 Port hinterland connection strength	X14 Traffic network density
X15 location advantage	X16 port information
X17 Policy environment	X18 Shipping service efficiency

Four principal component characteristic roots in total are greater than one in the table, so these four components will be extracted. As the total variance ratio of y1, y2, y3 and y4 is 92.3%, we choose these components as new indexes. The linear combination of y1, y2, y3 and y4 is as follow:

$$\begin{split} y_1 &= 0.757x_1 + 0.957x_2 + 0.613x_3 + 0.591x_4 - 0.591x_5 + 0.034x_6 + 0.167x_7 - 0.658x_8 + 0.751x_9 + 0.634x_{10} \\ &+ 0.793x_{11} + 0.849x_{12} + 0.920x_{13} + 0.878x_{14} + 0.975x_{15} + 0.985x_{16} + 0.926x_{17} + 0.943x_{18} \\ y_2 &= 0.546x_1 + 0.042x_2 + 0.651x_3 - 0.389x_4 + 0.059x_5 + 0.745x_6 + 0.379x_7 + 0.125x_8 + 0.405x_9 - 0.382x_{10} \\ &+ 0.509x_{11} + 0.385x_{12} - 0.355x_{13} - 0.412x_{14} - 0.126x_{15} - 0.124x_{16} - 0.173x_{17} - 0.312x_{18} \\ y_3 &= -0.334x_1 - 0.058x_2 + 0.093x_3 + 0.361x_4 + 0.300x_5 + 0.617x_6 + 0.818x_7 - 0.384x_8 - 0.220x_9 + 0.511x_{10} \\ &- 0.313x_{11} - 0.248x_{12} - 0.150x_{13} - 0.221x_{14} + 0.060x_{15} + 0.096x_{16} + 0.259x_{17} + 0.050x_{18} \\ y_4 &= 0.038x_1 + 0.145x_2 - 0.416x_3 + 0.035x_4 + 0.745x_5 - 0.044x_6 - 0.112x_7 - 0.090x_8 + 0.453x_9 + 0.143x_{10} \\ &+ 0.068x_{11} + 0.209x_{12} - 0.035x_{13} - 0.044x_{14} - 0.107x_{15} + 0.027x_{16} - 0.005x_{17} - 0.043x_{18} \end{split}$$

y1 is the aggregate variable of x1, x2, x4, x8, x9, x10, x11, x12, x13, x14, x15, x16, x17, x18, which reflects the port macroscopic benefit. We can conclude that objective conditions such as port location, environment, traffic, informatization and services on ports are more important while considering their higher proportions of y1, mostly more than 90%.y2 implicates the port shoreline and port through capacity, y3 implicates port storage yard area and y4 relates to port operating days. A linear equation from the linear regression can be obtained as follows:

$$F = 0.59028 \times y_1 + 0.15360 \times y_2 + 0.12019 \times y_3 + 0.05921 \times y_4$$

Each port's composite score is calculated and ranked in Table 9.

City	<i>y</i> <sub>1</sub>	ran k	<i>y</i> <sub>2</sub>	rank	<i>y</i> <sub>3</sub>	rank	<i>y</i> <sub>4</sub>	rank	Total score	rank
Shanghai	1.797	1	1.419	2	-0.867	6	0.074	4	1.179	1
Qingdao	0.454	3	-1.116	8	0.149	4	-0.510	7	0.084	4
Dalian	0.054	5	-0.309	5	0.058	5	-1.821	8	-0.117	5
Chongqing	-1.057	7	-0.129	3	-1.089	7	0.934	2	-0.720	7
Nanjing	-0.867	6	-0.317	6	-1.139	8	-0.450	6	-0.724	8
Guangzhou	0.120	4	-0.255	4	0.162	3	1.389	1	0.133	3
Tianjin	0.631	2	-0.913	7	1.368	1	0.603	3	0.433	2
Wuhan	-1.131	8	1.621	1	1.358	2	-0.219	5	-0.268	6

Table 8: The Principal Component and Port Score

In Table 9, Shanghai port has the best comprehensive benefit, Tianjin ranks the second, while Nanjing has the worst benefit. Considering the four component scores, those of Nanjing are nearly the worst for all components. Only by improving the quality in all the fields with defects, can Nanjing change its position and gain a higher comprehensive benefit.

Shanghai is not always the best. Its port storage yard area is very weak. If the conditions in port storage yard area and port operating days can be improved, Shanghai can get more comprehensive benefit and will be the ahead of all national ports.

### 3.3 Shipping center competitiveness cluster analysis

Group average method, minimum distance method and the longest distance method are used to classify main shipping centers in China.

### Figure 1: Group Average Method



Figure 1 demonstrates the result for group average method. Figure 1 shows that three groups are differentiated. The first group includes Shanghai alone. The second group includes Chongjin, Nanjing and Wuhan, and the third group consists of Qingdao, Tianjin, Guangzhou and Dalian.

In general, according to the geographic location, Qingdao, Guangzhou, Dalian, Tianjin are coastal cities and it is suitable to classify them into one class. Chongqing, Nanjing, Wuhan are not coastal, it is reasonable to classify them into another one group. It is appropriate to classify shanghai alone for the fact that Shanghai, as an international metropolis, is the only one to have the advantage in foreign trade.

### 4. Conclusions and Directions for Further Research

Based on the above analysis, both the principal component analysis and hierarchical analysis methods indicate that of Shanghai international shipping center always maintains the first position and Tianjin the second. Shanghai is classified alone in the cluster analysis. As an international shipping center, Shanghai has the unique advantage unequalled by anyone else. However, in terms of natural conditions and infrastructure competitiveness, Shanghai does not show a particular advantage. It is closely related to the reality that Shanghai port is not a natural good harbor.

Due to the world's changing environment, the status as well as the function of shipping center will also change. It is necessary to establish an evaluation system that can continuously update the dynamic shipping center competitiveness. The determination of the weight, the selection of indicators and the longitudinal study are worthy of further research.

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# An Approach for Baltic Dry Index Analysis Based on Empirical Mode Decomposition

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### Abstract

Bulk shipping market has the characteristics of seasonality, cyclicality, high volatility etc. Due to the non-stationary and nonlinear of price series and the complexity of influencing factors, it is difficult to analyse the fluctuation of bulk shipping market. In this study, a method based on empirical mode decomposition (EMD) is proposed to investigate the volatility characteristics of Baltic Dry Index (BDI). In this method, the original freight price series is decomposed into several independent intrinsic modes using EMD first. Then the intrinsic modes are composed into three components (time series), namely, short term fluctuations caused by normal market activities, the effect of extreme events, and a long term trend. Numerical experiments indicate that the proposed method can effectively reveal the characteristics of bulk freight price series with different economical meanings, and decrease the error accumulation. Meanwhile, by the composition of intrinsic modes, the complexity of model formulation can be controlled and the operability of the model can be improved.

Keywords: Bulk shipping market, empirical mode decomposition, BDI

### 1. Introduction

Being influenced by multiple factors, such as supply and demand, international political and economic situation, bulk shipping market has the characteristics of high volatility and cyclicality. The volatility of bulk shipping market has received increasing attention, not only by ship owners and charterers, but also by other participants such as shippers and financial companies. Understanding the dynamics and trend of freight rate is helpful for risk control and resource deployment.

Issues related to the volatility of shipping market have gained increasing attention and have been extensively studied. Methods such as vector autoregression model (VAR), generalized autoregressive conditional heteroscedasticity model (GARCH) an auto-regressive moving average model (ARMA) are widely used to analyze and forecast the volatility of bulk shipping market. These methods are helpful to understanding the volatility feature of bulk shipping market. However, due to the non-stationary and nonlinear of the volatility (Goulielmos and Psifia, 2009), it is difficult to grasp the complex volatility constitution of the bulk shipping market. It is a great challenge to analyze the non-stationary and nonlinear time series by the econometrics models.

To reflect the non-stationary and nonlinear of price series (Baltic Dry Index, BDI), a method based on empirical mode decomposition (EMD) is proposed. The original freight price series is decomposed into several independent intrinsic modes first. And then the intrinsic modes are composed into three components (time series), namely, short term fluctuations caused by normal market activities, the effect of extreme events, and a long term trend. Finally, the features of the three components are defined and some forecasting strategies for BDI are also discussed.

The rest of the paper is organized as follows. In section 2, a brief review of previous works is given. Section 2 gives the methodology formulation based on EMD. Detailed experimental results based on decomposition and composition is presented in Section 4. Conclusions are given in Section 5.

### 2. Literature Review

The volatility of bulk shipping market has gained wide attention and much research has done on it. In the past decades, traditional econometric and statistical methods, such as vector auto-regression (VAR), GARCH models and VECM models have been widely used in shipping market analysis and forecasting. For example, Kavussanos and Alizadeh-M (2001) analyzed the seasonal volatility at the aspects of ship type, lease term and market environment etc. Veenstra and Franses (1997) found that cointegration relations exist between several freight rates time series and there is an economically meaningful structure exists in a set of dry bulk shipping freight rates. Duru and Yoshida (2011) studied the lag nature and price elasticity of bulk shipping market, through the long term freight index. Results indicate that the log-linear model is not a significant model for forecasting the bulk shipping market freight time series into long term trend component and temporary particular component with random model.

Usually, the above methods can give good analysis and forecasting results when the price series is linear. However, in real world BDI series, nonlinearity exists, which make the forecasting a challenge task. Some nonlinear and artificial intelligent method such as artificial neural networks (ANN), support vector machines (SVM) and nonlinear regression begin to be used in bulk freight market analysis. For example, Leonova and Nikolov, V. (2012) proposed a model based on wavelet and neural network for the prediction of dry bulk shipping indices, Duru et al. (2012) developed a multivariate model of fuzzy integrated logical forecasting method for analyzing bulk shipping market. Goulielmos and Psifia (2009) developed a nonlinear method in which the nonlinear dynamic and chaotic deterministic modeling theory was tested.

EMD is a nonlinear, non-stationary data analysis method developed by Huang et al. (1998). By decomposing a time series into several independent intrinsic modes based on scale separation method, EMD can explain the time series from a new perspective. The decomposition can be achieved according to the characteristics of time scale, without setting any basis function in advance. Then, the model can be applied to any type of signal decomposition in theory.

Currently, EMD is well applied in the field of machinery fault diagnosis (Yu et al. 2005; Qi et al. 2007), medical science (Rojas et al. 2012), petroleum price forecasting (Zhang et al. 2009), financial market analysis (Guhathakurta et al. 2008; Lei 2011) etc. In fault diagnosis, EMD method does well in extracting fault message, reducing interference of vibration signal by external factors, diminishing energy diffusion and leakage, improving the signal accuracy. For the image of physiological signal, the decomposition could obviously reduce the boundary distortion of image. Furthermore, the method works well in the forecasting of crude oil price (Yu et.al.2008), exchange rates (Premanode and Toumazou, 2013) and metro passenger flow (Wei and Chen, 2012) etc.

The bulk shipping market is similar to the financial market in many respects such as the non-stationary and nonlinear of the volatility. Existing studies on financial market price series based on EMD method provide some reference. In this paper, an improved EMD model, which is called Ensemble EMD (Wu and Huang, 2004) is developed considering the characteristics of bulk shipping freight market. This method has been used in certain field such as crude oil market analysis (Zhang et al. 2008), and its efficiency has been proved.

### 3. Methodology Formulation

In this section, the overall process of EMD-based method for the analysis of BDI time series is presented. First of all, a brief description of EMD technique is provided. Then the improved EMD model for BDI time series is proposed, and the overall steps of the EMD-based method are surmarized.

### 3.1 The Basic Theory of EMD

EMD is a nonlinear, non-stationary data processing technique proposed by Hang et al. (1998). The basic principle of EMD is decomposing a time series into several intrinsic mode functions (IMFs) based on the following assumptions: a) there are at least two extrema in the whole time series, one maximum and one

minimum; b) the local time-domain characteristic of the data is only determined by the time scale in the extrema; c) if there is no extrema but inflection points, the extrema can be acquired by once or several times differential of the data, then decomposition results are obtained through integration. The IMFs must satisfy the following conditions:

- 1) The number of extrema (including maxima and minima) must be equal to the number of zero crossings throughout the whole time series, or differ at most by one;
- 2) At any point, the mean value of local maximum envelope and local minimum envelope must be zero.

The essence of EMD method is to obtain the intrinsic pattern of fluctuation through time scale features of the data, then decompose the data to get IMFs. This self-adaptive decomposition process is called "sifting process". The specific process is as follows:

- 1) Identify all the local maxima and minima of the time series x(t);
- 2) Connect all the local maxima by the cubic spline to generate upper envelope line h(t); similarly, use the local minima to generate lower envelope line l(t);
- 3) Calculate the point-by-point mean value of the upper and lower envelopes m(t),

$$m(t) = \frac{1}{2}[h(t) + l(t)];$$

- 4) Obtain a new series a(t), a(t) = x(t) m(t);
- 5) If a(t) satisfies the characteristics of IMFs, then a(t) is regarded as a IMF, and replace the x(t) in step 1) with r(t) = x(t) a(t); Otherwise, replace the x(t) in step 1) with a(t).

The whole process means to separate the volatility of highest frequency in the time series step by step, and leave the remaining part as a new time series to repeat the sifting process. The process is repeated until the stop criterion appears, namely, there is only one local extrema or a monotone function in the time series r(t). At the end of the sifting process, the original time series is decomposed into several IMFs and a residue, which can be expressed by

$$x(t) = \sum_{i=1}^{n} a_i(t) + r(t)$$
(1)

Then, obtain the Hilbert spectrum with IMFs by Hilbert transform. Hilbert transform of a real-valued function refers to convolve the system input f(t) with the pulse response  $1/\pi t$  as follows.

$$H[f(t)] = h(t) \times f(t) = \int_{-\infty}^{\infty} f(\tau) \times h(t-\tau) d\tau = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{f(\tau)}{t-\tau} d\tau$$
(2)

Hilbert transform is always expressed by Eq. 3.

$$\hat{f}(t) = H[f(t)] = f(t) \times \frac{1}{\pi t}$$
(3)

Where H is the Hilbert transform. Thus, Hilbert transform is equivalent to the pulse response of a linear network being  $1/\pi t$ .

EMD can be used as an effective decomposition method in the sense that it is easy to be understood and implemented. It can reduce a time series into simple independent IMFs, and suitable for nonlinear and non-stationary time series. Furthermore, fluctuations within a time series can be selected from the time series automatically and adaptively, and the IMFs and residue represent the linear and nonlinear behavior depend only on the characteristics of the time series being studied.

### 3.2 Improved EMD Model for BDI time series

BDI is composite index published by London's Baltic Exchange. Now, the index is widely used by

practitioners as a general market indicator reflecting the movements in the dry bulk market. It is the 'barometer' of the dry bulk shipping market. Therefore, by the analysis of BDI time series, the volatility characteristics and mechanism of dry bulk market can be reflected. In this paper, BDI series is decomposes based on EMD, and the IMFs conforming to the characteristics of time scale can be obtained.

For the non-stationary time series of BDI index, the original economic nature of the data may be lost to a large extent by Hilbert transform. Thus, an improved EMD model is established, namely, classifying and reconstituting the IMFs based on the decomposition results of EMD model. The improved EMD model aims at retaining the original economic nature of BDI index.

In this paper, the IMFs are sequenced according to the frequency in Hilbert spectrum, and the economic nature of time series are kept through classifying and reconstituting. The process is:

- 1) Sequence  $a_i(t)$  according to the frequency, and then calculate the mean value and variance of each  $a_i(t)$ ;
- 2) Classify  $a_i(t)$  on the basis of whether the results of z-test deviating from zero significantly. Then, several  $a_i(t)$  are divided into high and low frequency components;
- 3) Add all the  $a_i(t)$  in each component respectively, and get the new time series by composition.

The overall process of improved EMD method is shown in Fig.1.



### Fig.1: The Process of Improved EMD Model

### 4. Experimental Results

### 4.1 Data sets

The BDI was first introduced on 1 November 1999 to replace the Baltic Freight Index (BFI) which was the first shipping index published by Baltic Exchange. In this paper, BDI from November 1, 1999 to December 21, 2012 is selected as the sample data. Fig.2 presents the graph of the selected BDI data. The maximum value of the sample data is 11,793 points, and the minimum is 647 points.



Fig. 2 depicts the overall trend of BDI index. The fluctuation of BDI index time series present the

characteristics of large amplitude, irregularity, and non-stationary (Goulielmos and Psifia, 2009). From November, 1999 to early 2003, the curve fluctuates gently. And the market volatility increase from 2003. BID reaches the peak 11793 points in May 20, 2008. In the following six months, it descends sharply to about 700 points, and then maintains a low level.

### 4.2 Decomposition

Based on EMD, BDI time series is decomposed into eight IMFs and one residue. Fig.3 shows the decomposition results with IMFs are sorted by fluctuation frequency from high to low. Furthermore, the statistics of IMFs is shown in Table 1.



### Fig.3: The Decomposition of BDI Time Series

 Table 1: Measures of IMFs and the Residue for BDI from Nov.1<sup>st</sup> 1999 to Dec.21<sup>st</sup> 2012

	Mean period(day)	Variance as % of observed	
IMF1	4.801	0.025	0.053
IMF2	12.476	0.037	0.104
IMF3	22.665	0.049	0.477
IMF4	25.796	0.059	2.090
IMF5	43.041	0.316	5.408
IMF6	89.067	0.272	17.471
IMF7	603.084	0.537	9.741
IMF8	177.569	0.695	64.647
Residue		-0.121	0.008

Results indicate that the eight IMFs have different linear relationship with the original sequence. IMF8 is in

the dominant position of IMFs, mainly due to the correlation between IMF8 and the original sequence is the most significant, and the percentage of variance is the highest. Furthermore, there is almost no fluctuation of residue series, which demonstrates dry bulk freight rates maintain a level of relative stabilization without interference factors. At this level, the normal profit of all market participants can be maintained.

### 4.3 Composition

Based on the decomposition results in above section, composition process is implemented. Firstly, the z-test is used to classify the IMFs. Results are shown in Table 2. From Table 2, the mean value of IMF6 deviates significantly from zero firstly. Therefore, IMF6 is regarded as the boundary of classifying IMFs. The 8 IMFs are composed into two parts, the high frequency component which includes the first five IMFs, and the low frequency component which includes IMF6 to IMF8.

Secondly, the original BDI time series is composed into three components based on the results of z-test, namely, high frequency component caused by normal market activities, low frequency component caused by the effect of extreme events, and residue component representing the long term trend. Fig.4 shows the graph of the three components and the original BDI time series. Detail illustrations of the three components are given as follows:

Table 2: Results of Z-Test for IMFs								
IMF	1	2	3	4	5	6	7	8
z-test result	-0.124	-0.495	-0.494	-0.947	0.272	-13.54	-0.914	-16.76



### 4.4 Long Term Trend

The residue obtained by the decomposition of BDI index reflects the long term trend of BDI. In other words, it represents the basic dry bulk freight level determined by the long term supply-demand relationship. The curve of long term trend in Fig.5 shows that the basic freight rate maintains about 3800 points from 1999 to 2012.



### Fig.5: The Curve of Long Term Trend

The viewpoints some of some industrial practitioners illustrate the reasonability of long term trend curve in Fig.5. For example, an industry research report published in 2009 by Changjiang Securities demonstrated that shipping operators are profitable, even though they purchase a second-hand ship with the highest price in 2008, if BDI exceeds 3000 points. On condition that the BDI index achieves 3500 point, the rent of Capesize is 70000 USD/day, and the second-hand ship price is regarded as the highest price in 2008, the rate of return could exceed 30%. Meanwhile, as shown in the information provided by Bloomberg, when the BDI index exceeds 4000 points in the history, the bulk shipping market is in its prosperity phase. Therefore, the level of 3800 points is sufficient to ensure the normal profitability for market participants.

Moreover, the long term trend curve decreased slightly from 3850 to 3780. This is also can be explained by existing studies. For example, although the bunker price increases greatly (the 380cst is 152USD/ton in 2003 and 700USD/ton in July 2008), technical innovations improve the ship design and operation efficiency (Chen e al. 2011) which helps to decease the operation cost. Therefore, the long term equilibrium of dry bulk market is relatively stable.

### 4.5 High Frequency Component

The high frequency component represents the normal fluctuation of bulk shipping market. The normal fluctuation may be caused by many reasons, such as short term fluctuations of international trade volume, economic policies influencing market demand, the speculative of FFA market and the expectation of market participants etc. Fig. 6 shows the high frequency component of BDI.



### **Fig.6: The Curve of High Frequency Component**

As shown in Fig.6, the curve of high frequency component fluctuates around a baseline. The high frequency component is influenced by the supply-demand fluctuation of dry bulk market, which can be illustrated as follows.

At aspect of demand, bulk shipping market demand derives from the international bulk trade, and the demand of bulk trade is influenced by world economy and global trade. Iron ore, coal and grain are regarded as the main commodities in bulk trade. Factors affecting world trade will have an indirect impact on the dry bulk market. For example, unpredictable climate change will cause frequent fluctuation of the grain trade demand, and the steel production affects the demand for iron ore and coal etc.

At the aspect of supply, the fleet scale expands gradually with the development of shipbuilding technology, and the trend of large-scale vessel develops rapidly. The bulk market supply develops with the increase of maritime trade volume. Because of the long shipbuilding period, the fluctuation of shipping supply lags behind the maritime trade volume. The activity of shipbuilding market, chartering market, demolition market, and second-hand ship market are influenced by expectations of market participants. Furthermore, shipping costs is the theoretical basis for shipping enterprises to make capacity planning, such as handling costs, labor costs and fuel costs etc, which affects the supply of dry bulk market.

#### 4.6 Low Frequency Component

The effects of extreme events (shown in Fig.7) are mainly illustrated by IMF6 to IMF8. Considering that the trend curve changes slowly and normal fluctuation (high frequency curve) is small, large fluctuations in medium period results from extreme events. The fluctuation rate of low frequency component is more slowly because the effects of high frequency factors are excluded. Therefore, the curve of low frequency component is smooth.

With the development of world economic globalization, the local extreme events will spread worldwide. The reconstructed low frequency component presents the impact of extreme events on the bulk freight rate, such as epidemic diseases, terrorist attacks, bad weather, local military conflicts, trade war, major changes in international relations and international politics etc. Detail affects of the extreme event are illustrated as follows.



Fig.7: The Curve of Low Frequency Component

American 9/11 attacks happened in September 11, 2001 aggravates the economic contraction. The impact on American economy of 911 spreads worldwide through various channels of trade, capital flows, exchange rates and international financial markets. 911 has an indirect impact on the bulk shipping market. The curve drops sharply due to the affect of 911, and then low frequency component reaches the historic lows at spot A. Moreover, the curve remains a relatively low level until the rebounds at the end of 2002.

In the two years from the end of 2003, extreme events occur frequently and continual fluctuations emerge near the spot B. This is because that the global epidemic diseases influence international community in all respects, such as SARS and avian influenza. Also, the Iraq War of 2003 impacts on the stock market, the world oil market and the Middle East trade. The Doha trade talks are interrupted without the agreement on agriculture between developed and developing members.

The world economy develops rapidly from the end of 2005. The low frequency curve ascends substantially, and achieves an extreme spot C in early 2008. Then the American subprime mortgage crisis makes BDI nosedive after reaching spot C. As the credit crisis deepens, American subprime mortgage crisis evolves into global financial crisis gradually. The global economy is in the recession, and shocks the international dry bulk trade. Without the dissipation of subprime mortgage crisis, the frequent appearance of Somali pirate accelerates the downtrend of low frequency curve.

Owing to the first round of QE by FED in September, 2008, the low frequency component rises from spot D. However, descending happens from spot E due to the swine flu outbreak around the world. Furthermore, Grecian debt crisis from December, 2009 to May, 2010 generates contagion effects, and the credit crisis happens successively in Spain, Ireland, Portugal and Italy which restrains the uptrend of BDI. The published national emergency policies accelerate the lowering speed at spot F. For example, as Russian conflagration severe losses in agricultural production in July, 2010, Russia promulgates export bans on wheat. And India promulgates export bans on iron ore in August, 2010.

The low frequency component curve begins to ascend at spot G due to events with positive promotions to bulk shipping market. For example, FED promulgates the second round of QE, and a reform scheme of the "quotas" has been passed by the International Monetary Fund (IMF).

The bulk shipping market is influenced greatly by Libya war occurred in February, 2011. It causes the low frequency series descending from spot H, so far the volatility of the series is at a low level.

Therefore, the low frequency curve demonstrates the influence of extreme event on BDI time series, which proves the efficiency of the improve EMD method.

### 5. Conclusions

In this paper, a method based on improved EMD is proposed to investigate the volatility characteristics of BDI. The BDI time series is decomposed into several IMFs and residue by EMD, and then the IMFs and residue are composed into three components, namely, short term fluctuations caused by normal market activities, the effect of extreme events, and a long term trend. Results indicate that the proposed method can effectively reveal the characteristics of bulk freight price series with different economical meanings.

The proposed EMD-based model realizes the stationarity of the non-stationary BDI time series, and retains the economic meanings of the series simultaneously. It is a potential efficient method to BDI forecasting. Thus, it is worthy of further study to combine the improved EMD model with typical forecasting methods, such as exponential smoothing, artificial neural networks and support vector machine to improve the forecasting accuracy of bulk shipping market volatility.

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# **Corporate Responsibility in the Port Sector: The Institutional Theory Perspective**

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### Abstract

Corporate responsibility is not a new concept in seaports, as a result of the important role that ports play in local communities. In the last decades, however, ports have increasingly undertaken costly efforts to improve their image, as part of their corporate responsibility profile. The most discernible characteristic of this new image is that ports aim at appearing environmentally aware and sustainable. Nevertheless, the degree of adoption of green practices varies substantially among ports and globally, as some limit their efforts to respond to local community pressure or normative requirements, while others actively pursue green strategies. Corporate responsibility, and in particular its environmental dimension, however, appears to be likely to keep on increasing in importance over time.

This manuscript offers an explanation of the drivers behind such renewed interest in green strategies and corporate responsibility for ports, making use of the arguments developed in the context of institutional theory. Institutional theory focuses on the processes by which certain social structures are accepted as defining recommended social behaviours by firms. Such structures include of course norms, but also unwritten rules, routines or social constructs. Although there is an emerging literature on corporate responsibility and environmental sustainability in the port sector, institutional theory has never been applied to investigate the motivational forces behind the endorsement of such concepts in port authorities' strategies.

The paper develops a conceptual model that explains the sources of pressure that shape the corporate responsibility and environmental strategies of ports. The deriving conceptual framework is accompanied and empirically validated through several examples drawn from major ports around the world. The paper argues that the processes of vertical integration along supply chains, and the increasing competitive focus on port-centric logistics tend to strengthen the importance of corporate responsibility and in particular of environmental performance in ports. Furthermore, the paper argues in favour of a correspondence between the degree of port agility and the corporate responsibility profile of the port. Managerial and policy implication are also discussed.

*Keywords: port management; institutional theory; corporate social responsibility; green ports; environmental management.* 

### 1. Introduction

Ports are characterised by substantial external effects (Dinwoodie, Tuck, and Knowles 2012, 263) and it is not surprising that they are concerned with their environmental and social impacts. On the one side the increasing societal attention on the impacts of port operations, has induced port authorities naturally to take action to protect local communities and society in general from the negative external effects of the port. Port authorities have thus been entrusted with the task of managing port development and balancing the benefits and costs deriving from port activities (Verhoeven 2010, 247-270). On the other side, this renewed interest in the environmental and societal impacts of ports exerts pressure on port authorities also in other ways.

Firstly, port authorities are entrusted, as public bodies and as maritime authorities, to translate national, regional and global (environmental) regulation(Chlomoudis and Pallis 2002, xiv, 231; Verhoeven 2010, 247-270). As such, port authorities themselves are subjected to increasing regulatory pressure, as they need to comply with regulation and ensure that adequate facilities, procedures and other requirements are available to the firms operating in the ports to ensure compliance. In addition, in many parts of the world, port authorities,

as governmental agencies, are under the scrutiny of the media and the public opinion. They are, in fact, expected to operate in the public interest and ensure transparency of decision-making.

Secondly, neglecting to account for the external costs of port operations and developments can have dramatic consequences for the port as operations are interrupted and port developments are delayed, in some cased for years. Furthermore ports often benefit from public resources, and port investments often transfer external costs to local communities (Benacchio et al. 2001). When developments are privately funded, adequate risk management strategies are a necessity in order to ensure viability of the project (Meersman 2005; Ho and Ho 2006; Yap and Lam 2013). Overlooking the external impacts of port infrastructure development can substantially delay port projects (as in the case of the Deurganckdock in Antwerp) with substantial cost overruns, or even result in project abandonment. This in turn may affect the competitiveness of the port (Van de Voorde and Winkelmans 2002) and have required port authorities to learn to carefully manage stakeholder relations (Dooms and Verbeke 2007), and ensure that environmental and social matters are addressed, and when necessary compensation measures put in place.

A third issues is related to competitiveness, the enhancement of which could be considered one of the main objectives of port authorities (Meersman and Van de Voorde 2010). Since port competitiveness increasingly depends on the competitiveness of the chain where the port operates (Goss 1990), it is advisable for port authorities to stimulate the development of logistics activities that can favour the port (Heaver 1995). A paradigm has been proposed that places ports as elements in value driven chain systems (Robinson 2002) and has been the origin of prolific research in the area of port-centric logistics (Mangan, Lalwani, and Fynes 2008). But as correctly pointed out by some authors (Adams et al. 2009), this paradigm implies the necessity for ports and in particular container terminals to actively promote environmental sustainability and green management practices (Lun 2011).

Finally, given the deregulation trends that have characterised the sector since the 1980s (Baird 2000), port authorities have been increasingly acquiring the characteristics of private enterprises, and, in some cases, they operate and behave as such (Brooks 2004). Deregulation has an important consequence on port authorities, as they need to become more accountable of their decision and of their corporate image. Such accountability, together with increasing competition among ports, makes port marketing a compelling issue (Cahoon 2007). In this respect port authorities have to behave similarly to private enterprises, and even more as multinationals as some of them are active globally as terminal operators and investors.

As a result of these various forms of pressure, in the last decades it can be observe that ports have increasingly undertaken costly efforts to improve their image as part of their corporate responsibility (CR) profile. The degree of adoption of CR practices varies substantially among ports and globally, as some ports limit themselves to respond to local community pressure or normative requirements, while others actively pursue CR actions. There have been few references to environmental sustainability in ports and terminals (Denktas-Sakar and Karatas-Cetin 2012; Lun 2011; Lam and Van de Voorde 2012) that are discussed more in detail in the next section. Some authors have discussed CR in the context of ports (Dooms and Verbeke 2007)or have investigated the role of environmental performance for the competitive positioning of ports (Haezendonck 2000, 69-81)This is surprising as corporate responsibility appears to be likely to keep on increasing in importance over time and has been the subject of extensive research in other areas.

Most research efforts in studying CR can be found in the areas of strategic management, supply chain management and sustainability (Carbone, Moatti, and Vinzi 2012; Aguinis and Glavas 2012; Peloza and Shang 2011). In a recent survey (Aguinis and Glavas 2012, 932-968), the authors surveyed 588 journal articles and 102 books on CR, and highlight the extent to which CR literature have advanced, but also notice the need for research to focus on the processes and underlying mechanisms through which CSR actions and policies lead to particular outcomes. The authors also highlight the importance of multilevel analysis that encompasses how CR affects industries, organisations and individuals.

One way of looking at these issues is by making use of the paradigms developed by institutional theory (Brammer, Jackson, and Matten 2012). Institutional theory focuses on the processes by which certain social structures are accepted as defining recommended social behaviours by firms (DiMaggio and Powell 1983;

Dacin, Goodstein, and Scott 2002). Such structures include of course norms, but also unwritten rules, routines or social constructs. In particular institutional theory enables research to account for the diversity of CR, i.e. how it is implemented across countries, and the dynamics of CR, how its implementation changes from country to country (Brammer, Jackson, and Matten 2012).

The use of institutional theory allows also contributing to another issue highlighted by Auguinis and Glavas (2012, 932-968): the lack of the research investigating CR at the individual level, or, as the authors call it, *the microfoundation* of CR. Institutional theory, in fact, with its focus on the legitimation acknowledges that organisations and individuals within organisations seek recognition and are shaped invariably by habits and traditions. CR attitudes are deeply rooted in individual upbringing, organisation cultures and national epics and role models. These themes can only marginally find space in this manuscript, but the port authorities are strongly characterised by the culture of the country where the port is located, and are traditionally being rooted in the local community, the port city and the close port hinterland.

Although this study is not the first to look at the use of institutional theory in the area of CR (Matten and Moon 2008; Bondy, Moon, and Matten 2012), and is not the first to apply institutional theory to ports (Lu and Koufteros 2013; Lun et al. 2008) it is the first to look at CR in seaports using institutional theory. Seaports are an interesting example, not only for their dual nature of public bodies with private firm characteristics, but also as they are deeply rooted in the local normative and social context, but at the same time need to maintain an international focus. Many port authorities are active internationally and differ on how environmental and social imperatives are implemented in different parts of the world.

A full appreciation of how ports implement CR globally would require a cross-sectional approach and could provide the basis for interesting research. Before such approach can be applied, however, port management research needs to further develop the conceptual constructs on which to base quantitative analysis. As ports differ among each other and comparisons need to be made carefully, more research is needed on case studies and conceptual models. This paper represents a first step towards such conceptualisation. Its main contribution resides in combining institutional theory and CR in the port sector in the hope to stimulate further research in this area. The paper also contributes to the existing theory of port as logistics service providers, highlighting how if ports aim at strengthening the competitive position of the chains where they operate, a CR orientation is critical.

The paper is structured in four sections. This introduction outlined the relevance of corporate responsibility in ports and introduced the conceptualisations that will be dealt with in more detail in the other sections. Section two analyses the emerging literature on CR in the port sector, highlighting how the analysis so far has focused on the environmental dimension of CR. Section three introduces institutional theory and develops a set of hypotheses linked to the applicability of CR to the port sector. Section four summarises the major findings of the paper, indicates areas for further research and concludes.

### 2. CR in the Port Sector: Definitions and Literature Review

### 2.1. The green port and the sustainable port concepts

CR is not a new concept in seaports, as a result of the important role that they play in shaping the developments and sustainability of local communities. In the last decades, however, ports have increasingly undertaken costly efforts to improve their image, as part of their CR profile. Since port authorities are typically public bodies, they are traditionally not seen as falling within the scope of CR studies. CR is, in fact, generally defined as voluntary (Carroll 1999), and given the public nature of most port authorities(Brooks 2004; Verhoeven 2010) it would be expected that CR should be part of their nature.

Port governance reforms and port competition, however, are modifying the nature of port authorities, that are required to pursue growth, efficiency and financial independence along traditional public functions and interests (Juhel 2001; Brooks 2004). As private capitals increasingly play a role in ports, and as ports around the world become corporatized, ports need to supplement their public task, such as the provision of infrastructure as a public good, with financial and managerial considerations typical of the private sector

(Baird 2004). As competition increases and hinterlands become contestable (Ng 2006; Notteboom, Ducruet, and De Langen 2009), ports try to attract new customers and have to make larger efforts to main the old ones. Moreover, the need to convince the public of the need for new infrastructure and the increasing attention paid by society to the negative external effects of ports and shipping, calls for ports to become better stakeholders' managers (Dooms and Verbeke 2007).

As a result ports need to look for legitimacy from the local communities and the public opinion, and at the same time from their customers and users. In this respect ports behave as private companies and it is not surprising that then they need to engage in marketing, promotion (Cahoon 2007) and, as we argue, improve their CR profile. This has resulted in a large set of initiatives aiming at bringing the local communities closer to the harbour, such as the popular *Hafengerburtstag* (port birthday) in Hamburg, or the *Haven Dagen* in Rotterdam. This image is strengthened by marketing and communication efforts and by the improvements that port waterfronts have been going through in Amsterdam (Wiegmans and Louw 2011), Hamburg (Grossmann 2008), the USA (Hoyle, Pinder, and Husain 1988) and many other ports in Asia and Europe (Ducruet 2007).

The most discernible characteristic of this new image is that ports aim at appearing environmentally aware and sustainable. Being identified as a *green port* is clearly a valuable strategy as ports need to counteract the negative effects of pollution from vessel and cargo handling operations, congestion from the use of hinterland transport network and the negative impacts of infrastructure developments (Lam and Van de Voorde 2012). Nevertheless, the degree of adoption of green practices varies substantially among ports and globally, as some limit their efforts to respond to local community pressure or normative requirements, while others actively pursue green strategies. Corporate responsibility, and in particular its environmental dimension, however, appears to be likely to keep on increasing in importance over time.

Notwithstanding this increasing importance the literature in the area of sustainability in the port sector is at most scant and *green port* definitions are rather ambiguous (Lam and Van de Voorde 2012; Acciaro, Ghiara, and Cusano 2013; Adams et al. 2009). The magazine and event organisers *GreenPorts* indicate as part of the scope of green ports that of "balancing environmental challenges with economic demands" (GreenPorts 2013). The ESPO initiative called *EcoPorts* (ESPO 2012), aims at creating a "level playing field on port environmental management in Europe through the sharing of knowledge and experience between port professionals [...] in line with the principles of voluntary self regulation" (EcoPorts 2013).

From these statements we can infer that the concept of green port is rooted in the triple bottom line principle, that entails the inclusion of social, economics and environmental goals from a microeconomic standpoint (Elkington 1997; Henriques and Richardson 2012). We can also infer that green ports go beyond regulation as voluntary action is encouraged, and that environmental management has the potential of distorting the level playing field, favouring some players with respect to others as the implementation of stringent environmental practices may disadvantage the port. It is interesting to observe that this last statement is supported in some CR literature, which identifies CR practices as costly and therefore detrimental to the firm competitiveness<sup>i</sup>.

We can define green ports as those ports engaging in the proactive development, implementation and monitoring of practices aiming at reducing the environmental impacts of the port at a local, regional and global level beyond regulatory compliance. They engage in innovation and research with the objective of balancing environmental challenges with economic performance. Green ports are concerned, among other issues, with resource preservation, air/water/soil pollution reduction and control, limitation on the impacts on the fauna and flora, as well as climate change mitigation and adaptation.

The green port concept stems primarily from the need for ports to improve their environmental performance as a result of local communities and port users increasing demand for environmental accountability. Logistics service providers are more and more concerned with the sustainability and performance of their supply chains, and have been requiring transport providers and ports to collect information related to their environmental key performance indicators (EKPI), most notably, green-house gas emissions, but also water and sediment quality (Darbra et al. 2005b; ESPO 2012).

But the green port concept is also related to the demand from the side of local communities to be informed on

the types of cargo that go through the port and the environmental risks associated with port operations. This increased attention to the environmental performance of the port is also often motivated by the necessity of the port to protect some of its economic activities, as ports redevelop their waterfronts for tourism (Bauriedl and Wissen 2002) or residential areas and as the relationship between the port and the city becomes more symbiotic (Hoyle, Pinder, and Husain 1988). Ports are increasingly focusing on tourism, real estate management and the environmental profile of the port has consequences on the port image and their development.

It appears then that the green port concept is invariably linked to the societal perception of environmental priorities for the port, and can be considered as an integral part of a broader concept that accounts also for sustainability and CR. This concept, that can be referred to as, *sustainable port*, incorporates the green port concept, but stresses the role of societal impacts and economic viability of port strategies. The sustainable port concept require ports to account for economic, environmental and societal considerations in their strategy definition, in line with the triple bottom line approach advocated by sustainability scholars (Elkington 1997).

### 2.2. *Literature review*

Academic literature initially focused on ecological issues (Bateman 1996; Dinwoodie, Tuck, and Knowles 2012; Liao et al. 2010; Berechman and Tseng 2012; OECD 2011), and monitoring port environmental impacts (Darbra et al. 2004; Darbra et al. 2009; Darbra et al. 2005a; Wooldridge, McMullen, and Howe 1999; ESPO 2012). Some literature has focused on the environmental impacts deriving from shipping activities (Goulielmos, Lun, and Lai 2012; OECD 2011; Berechman and Tseng 2012; Dinwoodie, Tuck, and Knowles 2012), while others have focused on hinterland-based emissions (Roso 2008; Roso 2007; Bergqvist and Egels-Zandén 2012; Liao, Tseng, and Lu 2009).

There is also an emerging literature that from the seminal works of Haezendonk (Haezendonck 2001; Haezendonck, Coeck, and Verbeke 2000; Haezendonck et al. 2006) aimed at identifying the value added that environmental performance in particular, and CR in general, might bring to ports. Lam and Van de Voorde (2012) provide a review of the extant literature on green ports and sustainable supply chain management and provide one of the first frameworks for sustainable port strategies. They develop five propositions that address the role of stakeholders involvement in green market development and green policy effectiveness and in turn the impact that green market development and policy effectiveness have on sustainable port operations and development. In their framework they postulate that 'a green port will lead to positive outcome on port's customer retention and economic performance' (Lam and Van de Voorde 2012).

Limited literature has looked explicitly at the social and economic dimensions of sustainability (Denktas-Sakar and Karatas-Cetin 2012). In this paper the authors highlight the role of resource dependence theory in port sustainability and stakeholder management. Through a literature review of the use of resource dependence theory in supply chain management they develop a conceptual framework, that suggests that ports should adopt strategies as '*insertion, integration and dominance for the management of interdependencies through the adoption of strategic tools to enhance effective stakeholder relations management and port sustainability*'. These strategies look at strengthening the interdependence with shipping lines and terminal operators though dedicated terminal concessions, transaction costs reduction and the objective of capturing supply chain value (Jacobs and Hall 2007), and by doing so also strengthening stakeholder interdependencies and ensuring sustainable growth for the port. The authors intend to extend their framework to better account for the environmental aspects of the analysis.

As correctly pointed out by Robinson (2002) and by others more recently (Jacobs and Hall 2007), summarising the value-delivery framework developed by Porter, one of the key focus that companies and transport service providers should consider is the creation of value for their costumers. In terms of CR strategies for ports and in general for logistics service providers, such focus becomes relevant in the moment in which port customers, but also port stakeholders, and the supply chain parties in which the port is inserted, assign value to CR. In other words CR practices make sense when they add value to the chain where the port operates.

The resource dependence analysis highlights the role that supply chain management plays in port environmental management and CR strategy definition. Sustainable supply chain management, intended as the strategic integration of economic, environmental and social goals for the improvement of the economic performance of a company and its supply chain (Carter and Rogers 2008), has become and established concept in the supply chain management literature and recently it has started being applied to maritime logistics and ports (Pawlik, Gaffron, and Drewes 2012; Acciaro 2011; Lam and Van de Voorde 2012).

To similar results arrives the work of Adams, et al. (2009). From their study of eight world ports, they conclude that going beyond environmental compliance does not appear to be directly beneficial for market share increase, but they argue that a business case exists as port operators and port authorities that invest in improving environmental compliance are likely to gain a competitive edge. Their results arise from the observation that as regulation increases, as port developments are more dependent on adequately addressing societal environmental concerns, and in general environmental imperatives for ports becomes more compelling, by not thinking in terms of competitive advantage ports are missing a business opportunity to improve their competitive position.

It is not simply a matter of dealing with environmental regulation, that has always played an important role in ports as the economic benefits of port activities tend to fall on the larger port hinterland while external costs are born in the proximity of the port (Benacchio et al. 2001). Port authorities, in fact, are increasingly realising that good environmental performance is a necessary requirement to maintain good relations with local communities, and can become a source of competitive advantage (Wiegmans and Geerlings 2010; Adams et al. 2009). The attractiveness of the port in terms of its green image can be interpreted as the port being able to gain competitive advantage through sustainability, as cleaner ports are likely to be more attractive for cruise passengers and tourism activities.

Much more controversial is sustainability as a source of competitive advantage for those ports whose portfolio of activities is geared more towards cargo loading and unloading operations or the heavy industry. Little investigation has been carried out on how sustainability impacts port competitiveness and how such relationship actually unfolds. If ports are seen as elements in value-driven chain systems, as described above, (Robinson 2002), then the supply chain management literature on corporate social responsibility can offer guidance on how green ports, as logistics service providers, can be competitively superior (McKinnon 2010).

On the basis of these observations and of the emerging literature described above it can be argued that CR improves port competitiveness for the following reasons:

- Favours the identification of inefficiencies and business opportunities that otherwise could have remained unknown
- CR allows for better stake-holder management
- CR allows the port to be identified as green and therefore more innovative
- Sustainable supply chains are more difficult to replicate
- Sustainable ports have a higher possibility of influencing or pre-empting environmental regulation or regulation aiming at reducing societal negative impacts

The characteristics of sustainable ports are particularly suited to an approach to port management that is in line with the agile port concept(Marlow and Paixão Casaca 2003; Paixão and Marlow 2003; Mangan, Lalwani, and Fynes 2008) and the definition of fourth generation ports as outlined in UNCTAD (1999). Agility calls for a stronger link between external and internal business environments and allows ports to respond rapidly to economic changes (Paixão and Marlow 2003). Considering that sustainability constitutes an important challenge to modern port operations (ESPO 2012), the ability of the port to adapt to and influence upcoming regulation and to respond to customer demands, need to be an integral part of agile port strategies.

An agile sustainable port strategy needs to be articulated on various fronts and is by definition multifaceted and flexible, and therefore prioritisation systems are particularly relevant. Typical environmental themes relevant for ports are discussed for example in OECD (2011) and ESPO (2012), which offers guidance on how to prioritise those issues. There is instead less focus on societal priorities, although interesting insights can be obtained from the literature on stakeholder management(Dooms and Verbeke 2007) and port supply
chain value creation(Jacobs and Hall 2007; Denktas-Sakar and Karatas-Cetin 2012; Robinson 2002). There is also emerging literature on the innovative potential of green ports (Acciaro et al. 2013) and the role of ports as energy managers (Acciaro, Ghiara, and Cusano 2013).

## 3. The Institutional Theory Perspective on CR in the Port Sector

## 3.1. Institutional theory

Social behaviours of economic organisations and individuals are shaped by rules, norms and routines (*structures*) (Scott 2004). Institutional theory deals with how these structures influence behaviours, spread over time and space and are adopted or abandoned. A definition of institutional theory is provided by Morgan et al. (2012):

The field in which we are interested can be defined in how the forms, outcomes, and dynamics of economic organisation (firms, networks, markets) are influenced and shaped by other social institutions (e.g. training systems, legal systems, political systems, educational systems, etc.) and with what consequences for economic growth, innovation, employment, and inequality. Institutions are usually defined [...] as formal or informal rules, regulations, norms, and understandings that constrain and enable behaviour.

(Morgan et al. 2012, p. 2)

In the specific context of this paper we are interested in looking at port authorities as a special form of economic organisation. This assumption is reasonable since port authorities combine institutional roles with typical functions of private firms in various degrees(Brooks 2004), and as such they are subjected to the influences of structures. Institutional theory has already been used for various type of economic organisations (Zucker 1987).

Port authorities and the individuals that operate within them are assumed to seek social recognition and are then exposed to habits, traditions and other social influences, which are not only the result of rational optimisation behaviours. A central concept in institutional theory is that of *legitimacy*, that is conformity to social expectations (Zucker 1987). Legitimacy contributes to the organisation success and survival (DiMaggio and Powell 1983), and as such provides an incentive for organisation to adopt behaviours and practices that are similar to those adopted by other comparable organisations. In doing so they become similar to each other adopting certain common practices, refereed to as *isomorphism*, in order to gain societal acceptance and benefit from legitimacy (Scott 2004).

The processes that lead to isomorphism are of four types (DiMaggio and Powell 1983): coercive, mimetic, normative, and competitive. Coercive isomorphism is the result of pressure from governments or customers. Mimetic isomorphism stems from business uncertainty and is the result of the imitative practices that organisations put in place when they are uncertain of their efficacy, but feel peer pressure in adopting them. Normative isomorphism derives from norms that are set by the way people are trained and educated, or by rules that are used for obtaining standards and certifications. Finally competitive isomorphism is the result of the preference for those practices that do benefit the organisation by improving operational efficiency (DiMaggio and Powell 1983; Lun et al. 2008).

The suitability of institutional theory in the context of CR is quite striking. Nonetheless its application to CR highlights that CR practices are not entirely voluntary (Brammer, Jackson, and Matten 2012). This is not a trivial point, and, as Brammen et al. suggest, it shakes the foundations of CR. In their insightful paper, the authors also highlight the deriving *contested and contingent nature* of CR. This analysis is also particularly suited for the application of CR to the port sector, with the contested and contingent definition for example of *green port*.

## 3.2. Coercive structures

Governments are typically associated with the type of pressure that coercive structures exert on organisations.

It has been mentioned already how governments and governmental agencies have to adhere to specific code of conducts developed at a national or international level. These could refer to accident prevention practices within the port authority or the port areas as well as structures aiming at eliminating corruption from public offices. Also port governance reform, if seen as the attempt of government to increase organisational efficiency within the port, can be interpreted as a coercive structure.

But coercive structures are also imposed by the agencies from which the organisation depends upon. In the case of port authorities these are clearly port customers, such as shipping lines and transport service provides, terminal operators and, last but not least, cargo interests. Consumers increasingly take into account in their purchasing decisions the conditions under which products are manufactured and transported(Pickett-Baker and Ozaki 2008). *Bio* labels for products, *Fairtrade*, as well as of powerful shippers' initiatives such as the *Wall-Mart green label* or the *IKEA Eco Score cards* are all forms of coercive pressure for logistics providers and as a result for ports. CR becomes a necessary requirement for engaging in certain types of trades.

Regulation and consumer pressure are in the end two sides of the same trend, as governments, tend to respond, or at least need to take into account, changes in population tastes and values. On the basis of these considerations a first proposition can be put forward:

Proposition 1: As national, regional and international regulation and the societal valuation of environmental and social management practices increase, the more port authorities will engage in CR.

## 3.3. Mimetic structures

Mimetic structures are the result of behaviours that port authorities acquire from examples that have been developed elsewhere. The CR profiles of many ports are surprisingly similar as ports tend to apply the same technologies, or engage in the same type of CR activities. On the one side it is true that many of the social and environmental issues that port authorities have to face are similar, and that organisations in general tend to benchmark to learn from competitors best practices. On the other side a mimetic component is an integral part on how port authorities select environmental and social practices as many of them are characterised by uncertainty. Ports monitor the developments in other ports and take inspiration from the most successful strategies implemented elsewhere. An example is the similar response that ports have been providing to the developments of onshore power supply or the investment in LNG bunkering activities. Several ports have engaged in waterfront redevelopment and try to exploit waterfront locations for urban redevelopments.

In an uncertain environment, in line with the hypothesis of bounded rationality, port authorities may feel that is a certain practice revealed successful for a competitor, there is a high chance that it might be appropriate also for the port. Especially if the costs associated with adoption of certain practices, ports might adopt CR behaviours simply as a result of mimetic pressure. A related example could be linked to the adoption of the landlord port model by many port authorities in the world. While clearly the port governance reform is not initiated by the port authority alone, and in the case of developing countries a certain coercive pressure has been exercised by the World Bank and the International Monetary Fund, it is also likely that a certain degree of mimetic pressure has played a role in the global adoption of the landlord governance model.

The more certain practices are accepted and implemented among various ports, whether they are related to environment, stakeholder management or governance, the more it is likely that sch practices will be adopted by other port authorities. We can then formulate the a second proposition:

Proposition 2: The implementation of CR practices by port authorities will increase as the number of port authorities engaging in CR practices within a competing range increases.

## 3.4. Normative structures

Normative structures are related to the way organisations acquire their professional skills and how certain specialisations are shared among consultants, advisors and surveyors. Most of the people that deal with CR

participate to the same training programmes and are advised by a limited pool of consultants. These professionals are likely to have similar opinions and follow similar approaches to CR. Furthermore certain practices associated for example with ISO certifications, ensure that normative structures are reproduced and repeated among organisations. We can then formulate the following proposition:

Proposition 3: As CR norms become more codified through certifications and standards, and as the profession CR officials becomes better established, the more port authorities will implement CR practices.

## 3.5. *Competitive Structures*

Competitive isomorphism is particularly interesting in the case of CR as it stems from the search for operational efficiency. CR has often been identified as a source of cost increase (Walley and Whitehead 1994) and although this might not always be the case, it has generally not been associated with operational efficiency. CR is not implemented identically among all firms, and isomorphic strategies allow for competitive differentiation. Competitive structures are those that arise because of performance pressure and CR can grant an advantage to firms that put an effort in implementing it.

In the value delivery framework (Robinson 2002) outlined in the previous section emerges clearly how CR, and in particular its environmental dimension, can represent superior practices as long as port authorities engage in those practices that are required by their customers. Since isomorphism is likely to arise also in firms upstream and downstream the focal firm, i.e. the port authority in this case, CR is likely to benefit the competitiveness of ports. Such relationship is strengthened by the correlation between innovativeness and CR (Kibbeling 2010) therefore favouring those port authorities that engage in CR practices.

Several examples can be used to associate CR with better performance. The attempt to reduce emissions, by increasing energy efficiency, may stimulate port authorities to investigate electrification of port equipment and often substantially reduce energy costs. The use of alternative fuels, such as LNG or biofuels for port operations, can also substantially reduce the port fuel bill. The necessity to redevelop obsolete port areas has allowed port authorities to capitalise on prime real estate and increase revenue from port waterfront redevelopments. These considerations can be summarised in the following proposition:

Proposition 4: CR practices can arise as a consequence of competitive pressure and result in operational efficiency gains for port authorities and port operators.

Port authorities are likely then to adopt CR practices to increase their legitimacy and at the same time to increase operational efficiency and performance. They will be perceived as trustworthy and more innovative and as such will be preferred by their customers and be favoured by other agencies.

## 4. Concluding Remarks

This paper has highlighted a set of drivers behind the renewed interest in CR in ports. The arguments used in the paper explain why ports show an interest in CR. On the basis of extant literature we define the concept of green port concept arguing how it should be integrated in the broader perspective of sustainable ports. The main drivers fro CR are then discussed in view of the existing research on the concept of green port. The contribution of the paper is identifying the interest of port authorities in CR not only in the traditional rationale of promoting environmental awareness, but also as a source of competitive advantage through the supply chain value creation.

The paper also argues that a CR attitude is in line with concepts of agility and port-centric logistics. The processes of vertical integration along supply chains, in fact, as well as the increasing competitive focus on port-centric logistics, tend to strengthen the importance of CR and in particular of environmental performance in ports. There is therefore a correspondence between the degree of port agility and the corporate social responsibility profile of the port.

Furthermore the paper proposes an alternative view on CR in ports making use of the lenses developed in the context of institutional theory. Institutional theory focuses on the processes by which certain social structures are accepted as defining recommended social behaviours by firms. Such structures include of course norms, but also unwritten rules, routines or social constructs. This analysis shows that CR developments in the port sector have a reinforcing effect through mimetic and normative structures. As environmental regulation will increase, ports will need to increase CR practices. Finally the existence of competitive pressure allows for diverse approaches for the implementation of CR practices in ports, in line with the main literature findings on environmental performance for ports.

The increasing role of CR in the port sector has major implications on port management and policy. A successful implementation of CR practices requires a broader understanding of such practices at an organisational level. Furthermore sustainable ports are likely to be selected in the future a preferred supply chain partners and therefore will acquire stronger dominance on the chain. This increases the range of strategic options that ports have to compete, where CR will become one of the competing battlegrounds, together with ports, infrastructure, innovation and hinterland accessibility. Competition will extend along the supply chain, with different chain parties struggling to capture the value generated in the sustainable chain. This requires business to find adequate mechanisms to share value as supply chain cooperation will remain critical.

From a policy perspective this changes the role that environmental regulation plays in the port industry. As sustainable ports become better skilled at influencing regulation, governments have to ensure that the level playing fields are maintained. Furthermore financial support aiming at fostering sustainability might become unnecessary, as port authorities, and the chains where they operate, learn to capitalise on their superior CR performance. Clearly national governments have interest in favouring the development of sustainable supply chains that include their ports, and therefore an adequate balance between chain competition and cooperation should be found.

These implications call for further research in the area of CR in the port sector. Empirical validation of the propositions and concepts outlined in this paper would be beneficial for a better understanding of how the port sector perceives CR. It is likely that CR is perceived differently in different locations around the world, and understanding such differences is a necessary part of understanding the value creation through CR in ports. There is a lack of studies on the societal impacts of ports and how they are affecting the local communities in manners other than the environment. This area would be complementary to the existing research on CR. Finally, more attention should be paid by port researchers on the managerial implications of CR in the port sector in particular and for maritime chains in general.

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<sup>&</sup>lt;sup>i</sup> This attitude is observed also in the container shipping industry (see Michele Acciaro, "Pricing in Sustainable Global Container Transport," *International Journal of Decision Sciences, Risk and Management* 3, no. 3, 2011) where, while on the one side CR practices are well established, on the other side are perceived as adding costs and thus making offers less attractive to those shippers more sensitive to price differentials.

# Does Chinese Port Industry Need More Regulation? – A Game Theory Analysis of Port Specialization

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#### Abstract

The fast growth of the Chinese economy and its international seaborne trade has escalated the demand for high quality and efficient port services. "Decentralization" of the port management regime has given local government greater freedom in port development and operational decision-making. However, major port capacity expansion in coastal areas, coupled with the slowing down of both the economy and trade growth over recent years, has led to over-capacity and excessive competition. Although both port specialization and government regulations are called for to address these issues, few studies have investigated the formation mechanism and economic implications of port specialization. This paper uses alternative duopoly games, namely a Stackelberg game and a simultaneous game, to model port competition where ports provide differentiated services in the sectors of containerized cargo and dry-bulk cargo. Our analytical results reveal that inter-port competition can lead to port specialization in the following three ways. A port can specialize in a type of cargo (1) for which there is relatively high demand, (2) where it has established capacity first, or (3) for services which require prohibitively high capacity costs. Also, it is seen that over-capacity is likely if strategic port decisions are made simultaneously instead of sequentially. These results suggest that if there is a clear market leader, policy intervention may not be necessary. However, if no port has clear market power, then government coordination and intervention may be needed in order to prevent overcapacity and to encourage specialization.

Keywords: Port specialization, Competition games, Port industry in China

## 1. Introduction

The fast growth of the Chinese economy and its international seaborne trade has escalated the demand for high quality and efficient port services. To capitalize on this opportunity and promote their local economy, many coastal cities have been investing heavily in expanding existing port capacity or in developing new facilities. This has led to a sharp increase in handling capacity. As of the year 2000, there were a total of 784 deep-water berths in mainland China capable of handling ships with a deadweight tonnage above 10,000. However, between 2008 and 2012 alone, 602 more such berths were added (State Council 2013a). There has been no sign of slowing investments. In 2012, 96 deep-water berths were completed, with another 100 to be added in 2013 (National Development and Reform Commission 2013). However, the trade growth rate in China has been slowing down over recent years, due to the long lasting impact of the 2008 financial crisis in the U.S., the economic recession in Europe, and the appreciation of Chinese currency, namely Renminbi (RMB). As a result, much of the newly added port capacity is underutilized, which often triggers fierce competition among nearby ports. Sun and He (2008) conclude that lack of cooperation among the ports in the city of Tianjin and the Hebei provinces has led to a tremendous waste of resources. The increasing need for cooperation among ports in southern China has also been well-recognized (for instance: Song 2002, Sit 2009, Wang and Olivier 2007, Homsombat et al. 2013). This has stirred up debate as to whether the Chinese government should adopt appropriate policies with respect to port development and management so as to encourage cooperation and coordination between neighboring ports. In particular, should the government introduce more regulations in the port sector? Or should it even revert back to the previous centralized planning regime?

There appears to be general agreement that coordination and cooperation among ports could lead to substantial benefits. Song (2003, 2004) argued that the relationship between ports in a region should be Coopetition. That is, ports must cooperate and compete at the same time. With the on-going trend towards port privatization, devolution and deregulation, however, coming up with policies that at the same time ensure both sufficient competition and sufficient cooperation is not a straightforward matter. Some Chinese government officials and researchers have proposed that the government should coordinate or promote port specialization. Xiao (2005) suggested that ports in the Bohai rim should specialize based on their respective competitive advantages. For example, there can be port specialization with regard to the handling of coal, iron ore, petroleum and chemicals, and agricultural products. He argued that specialization would provide a foundation for cooperation, leading to a win-win situation for all ports in the region. The Ministry of Transport (2011) and State Council (2013b) called for coordinated and balanced growth in regional ports. The State Council suggested that in the Bohai rim priority should be given to capacity for handling coal and iron ore. The Yangze River Delta region should further invest in container transport systems, bulk goods and sea-river transshipments. The government would also support cruise service development as a team in Tianjin, Shanghai, Guangdong province and Hong Kong. Similar initiatives are also proposed by local governments. For example, the Guangdong provincial government clearly stated that to foster port cluster development in southern China, the ports of Shenzhen, Guangzhou and Zhuhai should form clear specialization so that there can be better coordination among these ports, which would then allow them to better cooperate with the port of Hong Kong (Guangdong Provincial Department of Transport 2012).

Intuitively prompting port specialization as a means to discourage excessive investment and cut-throat competition appears to be a good policy. It is well known in the economics literature that product differentiation reduces price competition (Shaked and Sutton 1982, Moorthy 1988). This intuition should also apply within the maritime industry. For example, the average ship size for bulk cargo has been increasing. As a result, ports need to invest in purpose-built bulk-handling terminals that allow them to load and discharge large bulk ships timely and efficiently. World-class coal and iron ore terminals load Panamax and Cape size ships at 4,000 to 5,000 tonnes per hour, compared to a normal handling rate of 1,000 tonnes per hour for handy-size vessels. However, it clearly doesn't make sense for every port in a region to invest in and keep upgrading such expensive equipment. Instead, specialization would allow ports to achieve economies of scale by building dedicated equipment, and subsequently to fully utilize the infrastructures invested in. Therefore, specialized ports would have little incentive to invest in the same type of handling capacity as rival ports, thus avoiding excessive competition.

However, it remains unclear as to how port specialization could be introduced in the first place, and as to whether a government should mandate or plan for port specialization. As a general principle, regulation should be introduced only if there is a market failure. Therefore, if ports specialize as a result of competition, then governments can just serve to safeguard a free economy, rather than actually planning for and imposing specialization upon ports. Few studies, though, have analyzed the formation process and economic implications of port specialization. Hilling (1975) noted that there was clear port specialization and traffic division in Ghana due to hinterland linkage and distribution of economic activity. Talley (2009) proposed that competition is likely to promote port specialization and innovation. However, he didn't identify the conditions and mechanisms leading to specialization. Wang et al. (2012) investigated the conditions affecting regional port governance. They concluded that the likelihood of port alliance and cooperation is dependent on factors such as port service differentiation, relative cost efficiency and market potential. Although inter-port competition and port specialization/differentiation are explicitly modeled in their alliance formation analysis, they haven't investigated the effects of competition on port specialization. Instead, port specialization and service differentiation are treated as exogenous. Therefore, there is a need to investigate the formation mechanism and economic implications of port specialization. This will allow appropriate government policies to be designed and introduced, and will also provide valuable insight and guidance on the development strategies that ports use as the industry becomes increasingly competitive and dynamic.

This paper aims to fill such research gap by investigating the driving factors and market conditions influencing port specialization, as well as the economic implications of port specialization on port operators,

traffic throughout and market outcomes. This is achieved by constructing an analytical economic model, in which competing ports choose the types of cargo they will handle. Alternative types of competition between ports, namely a Stackelberg game vs. a simultaneous game, are investigated.

Our analytical results suggest the following: (1) Without coordination, ports may choose to invest in the same type of infrastructures even if there is insufficient demand for multiple ports; as a result, there may be excessive investment that is not sustainable; such outcome is likely to happen when ports make strategic decisions simultaneously, and when market demand is moderate. (2) Inter-port competition can lead to port specialization in three ways: A port can specialize in a type of cargo for which there is relatively high demand, in one where it has established capacity first, or for services which require prohibitively high capacity costs. (3) Leader ports enjoy substantial first-mover advantages in terms of higher profit and larger traffic volume.

This makes it difficult for a central government to coordinate or mandate capacity investment and port specialization. In summary, our analytical results suggest that a government should be prudent about introducing more regulation and central planning in order to promote port specialization. If there is a clear market leader, policy intervention may not be necessary. However, if no port has clear market power, then government coordination and intervention may be needed so as to prevent overcapacity and to encourage specialization.

This paper is organized as follows: Section 2 provides an overview of port investment and competition in China, as well as the on-going process of port specialization. Section 3 introduces the economic model. Section 4 reports on the modeling results and their interpretation. The last section summarizes and concludes the paper.

# 2. Port Development in China

The fast growth in China's national economy, especially seaborne trade, would not have been possible without China's rapid port development over the past 20 years. One of the most important driving forces behind this fast development has been the decentralization of China's port management regime. Before 1984, all portworks in China, including those of planning, construction and operation, were managed by the Ministry of Transportation (MOT) under the State Council. After that, this centrally-planned system was replaced by the so-called "dual-track" system in which local governments had more freedom in the planning, financing and operation of ports, with central government (MOT) only retaining the right of approval for major port development projects. This "dual-track" system was further reformed in 2001, since when local governments have become the sole decision maker for port development and management, although decisions still need to be endorsed by the MOT (Li, Luo and Yang, 2012). This "decentralization" process, coupled with China's booming seaborne trade, has led to a surge of competition in port development among all the coastal provinces and/or municipalities. As a result, port capacity has increased at an unprecedented rate.

The most remarkable increase is in the container sector. As shown in Figure 1, the number of container ports increased from only 4 ports in 1979 to 45 in 2011, while in the same period the total throughput increased from almost nothing to 160 million TEUs (Li, Luo and Yang, 2012). The year 2001, when China's entry into the World Trade Organization (WTO) was endorsed, marked a turning point in container port throughput, as evidenced by a much steeper growth curve in the years that followed.

Figure 1: Number of Container Ports and Container throughputs in China between 1979 and 2011



Compared with container cargo, the demand for bulk cargoes has not experienced the same rapid expansion, with the exception of coal and iron ore (MOT, 2011). As shown in Figure 2, these two categories have noticeably faster growth rates than those of the other four. This may be ascribed to the increasing domestic demand for steel and energy, two of the most important inputs for infrastructure development. In 2011, China's total coal imports amounted to 182 million tons (Meng, 2012), yet although this accounted for 28.2% of the global coal trade (Meng, 2012), it was only 13% of the coal throughout handled by the major Chinese coastal ports, which underscores the magnitude of the domestic coal shipping volume in China. In addition, China has become the dominant consumer of iron ore. In the same year, 2011, the global trade for iron ore was 970 million tons, with 686 million tons, or about 71%, being shipped to China. This accounted for about 68% of the iron ore throughput at Chinese coastal ports, indicating that domestic shipping of iron ore plays only a minor role.





Although it is not feasible to handle container and bulk cargo at the same terminal, many ports have both container and bulk terminals. For example, among seven major ports in northern China in terms of coal throughput, 6 also handle containers (Figure 3). The northern provinces are the traditional coal output regions in China. Among them, Tianjin and Qingdao are two highly populated coastal municipalities. Therefore, compared with other ports, these two have a higher demand for container services.





With the slowdown in Chinese manufacturing exports due to the appreciation of the RMB since 2006, the 2008 financial crisis, and the recent EU economic depression, together with the huge investment in port development during this period (State Council 2013a; National Development and Reform Commission 2013), there is great concern about over-capacity and excessive competition among neighboring ports (Liu 2011; Xu and Yin 2008). Many proposals have been made to merge smaller ports, or to reduce the level of competition through government regulation. With the ongoing trend of port privatization, decentralization and deregulation, however, coming up with policies that at the same time ensure both sufficient competition and sufficient cooperation is not a straightforward matter. If specialization is possible with free market competition, then government intervention is not necessary. This calls for a formal investigation, and is what motivates this study.

#### **3.** The Economic Model

In this section, we construct an analytical model for port service choice and specialization. Consider the case when two ports in a region, port 1 and port 2, face two types of demand, namely container cargo and bulk cargo. The demand for container port services can be specified as the following system of equations, where subscript 1 denotes Port 1, and subscript c denotes the container sector. Let p be the port service charge, and q be the port output/traffic volume. Finally, intercept a is the reservation price for a port's service (i.e. the highest valuation of the port's service when traffic volume is zero). This parameter can also be regarded as an indicator of the levels of (potential) port demand; *ceteris paribus*, a larger intercept a implies higher demand/output at the port. The latter interpretation is mostly used in the following analysis.

That is, for Port 1 the container port charge  $p_{1c}$  is determined by reservation price /demand level  $a_1$ , its own traffic/output volume port  $q_{1c}$ , and the traffic volume at the competing port  $q_{2c}$ . This demand specification for container port services corresponds to a representative shipper maximizing a quadratic and strictly concave utility function  $U_c(q_{1c}, q_{2c}) = a_1q_{1c} + a_2q_{2c} - \frac{1}{2}\left[b(q_{1c}^2 + q_{2c}^2) + 2kq_{1c}q_{2c}\right] + q_0$ , where  $q_0$  represents the numeraire goods (money). The concavity condition implies  $b^2 - k^2 > 0$ . The condition of positive output quantities for both ports implies  $a_1b - a_2k > 0$  and  $a_2b - a_1k > 0$ . Since a port's demand is more sensitive to its own price than a competing port's price, we have  $b \ge k$ . When b = k, the two ports provide perfectly homogenous services. When b > k > 0, the two ports provide differentiated services.

Similarly, the demand for bulk cargo port services can be specified as the following system of equations, where subscript *b* stands for bulk cargo. As is the case with the container sector, it is assumed that  $\beta^2 - \gamma^2 > 0$ ,  $\alpha_1\beta - \alpha_2\gamma > 0$ , and  $\alpha_2\beta - \alpha_1\gamma > 0$ .

$$\begin{cases} p_{1b} = \alpha_1 - \beta q_{1b} - \gamma q_{2b} \\ p_{2b} = \alpha_2 - \gamma q_{1b} - \beta q_{2b} \end{cases}$$
(2)

The total cost for container port services and bulk goods port services are specified as in (3).  $K_c$  and  $K_b$  represent fixed costs related to port investment and operation. Variable costs are proportional to port throughputs  $q_{ic}$  and  $q_{ib}$ , and constant marginal costs  $m_c$  and  $m_b$ . Without loss of generality, we assume that  $a_1, a_2 > m_c$  and  $\alpha_1, \alpha_2 > m_b$ .

$$\begin{cases} T_{ic} = K_c + m_c q_{ic}, \ i = 1,2 \\ T_{ib} = K_b + m_b q_{ib}, \ i = 1,2 \end{cases}$$
(3)

In practice, ports use many different measures to compete with each other. In theoretical analysis, short term measures can be represented by price competition, while long term ones can be modeled using capacity investment, such as the two stage game theory model by Luo, Liu and Gao (2012). In theory, such a two-stage game can be approximated by a one-shot Cournot game (for an example, see Kreps and Scheinkman 1983, Boccard and Wauthy 2000, Moreno and Ubeda 2006, and Yin and Ng 2008). Therefore, in our analysis, quantity competition is used. A port's objective function is specified as in (4), so that a port maximizes its profit by choosing the output volumes for container and bulk cargo sectors.

$$\max \pi_i(q_{ic}, q_{jb}) = (p_{ic} - m_c)q_{ic} - K_c + (p_{jb} - m_b)q_{jb} - K_b$$
(4)

Clearly, a port has two possible strategies: (I) to specialize in either container or bulk services, or (II) to provide both container and bulk cargo services. In our model, if the port decides to specialize in only one type of service then the volume and costs associated with the other service will be zero. For example, if Port 1 decides to offer only a container service, then  $q_{1b} = 0$  and  $T_{1b} = 0$ . Otherwise, this port's output volumes for both container and bulk cargo will be positive.

The equilibrium results will depend on many factors, such as market demand (as measured by  $a_i$  and  $\alpha_i$ ), exchangeability (and thus degree of competition between the two ports, as measured by k and  $\gamma$ ), and the costs of providing port services. In addition, the type of competition between the two ports plays an important role. When a large port competes with a small port in a particular region (or when a port in a large city competes with a port in a small city), the larger port usually has dominant market power, which is more likely to lead to capacity investments in the region. In such a case, port competition may be best described as a leader-follower game. When two ports are of similar sizes, port competition may be better modeled as a simultaneous game. Given that there are numerous ports along the Chinese coastal areas, both types of competition may be possible. Therefore, we will consider the following two types of competition in our analysis:

## Case I: Stackelberg game

In this case, competition between the two ports is modeled on the following sequential game:

- Stage One: The leader port (say Port 1) decides on its output volumes in both container and bulk cargo operations.
- Stage Two: The other port (Port 2 in this case) decides on its output volumes in container and bulk cargo operations based on Port 1's output volumes as chosen in Stage One.

## Case II: Simultaneous game

In this case, two ports make their output decisions simultaneously.

For major investments, such as investing in a port, a mixed strategy is in practice probably not an option. Therefore, we will keep our analysis restricted to pure Nash equilibrium. The usual approach in solving a simultaneous game is to jointly solve both ports' reaction functions for equilibrium outputs, and this is the method adopted in this paper. However, with simultaneous moves, and no coordination between the two ports, the competition results of a one-shot game may not be sustainable. For example, if both ports choose to specialize in bulk cargo but there is insufficient demand, then both ports may earn negative profits. Such possible outcomes will be evaluated in our analysis, and the implications will be discussed.

In solving the two types of games, we focus on the market outcomes where at least one port provides at least one type of service (bulk or container). This leads to 12 possible outcomes, as summarized in Table 1. For example, market outcome (b, -) refers to the case when Port 1 specializes in bulk cargo service and Port 2 offers no service; (bc, bc) refers to the case when each port provides both container and bulk cargo services.

Ports		Port 2								
	Strategy	<b>S</b> 1	S2	<b>S</b> 3	S4					
Port 1	<b>S</b> 1	(b, -)	(b, b)	(b, c)	(b, bc)					
	S2	(c, -)	(c, b)	(c, c)	(c, bc)					
	S3	(bc, -)	(bc, b)	(bc, c)	(bc, bc)					

Table 1: Ports' Strategies of Service Offering

Without loss of generality, in this paper we assume in the Stackelberg case that Port 1 is the leader and Port 2 is the follower, in which case the above 12 possible outcomes can be further classified into the following four scenarios:

- Scenario I: Port 1 offers service (either one or two types of service) and Port 2 offers no service (i.e., outcomes (b, -), (c, -), (bc, -)), or each port specializes in a mutually exclusive service (i.e. outcomes (b, c), (c, b)). In this scenario, Port 1 is a monopoly in either one or both services; otherwise, each port is a monopoly in its own specialized service.
- Scenario II: Both ports specialize in the same service (i.e., outcomes (b, b), (c, c)).
- Scenario III: One port offers both services and the other port specializes in one type of service (i.e., outcomes (bc, b), (bc, c), (b, bc), (c, bc)). In this scenario, there is inter-port competition in one type of service and monopoly in the other type of service.
- Scenario IV: Both ports provide two types of service (i.e. neither port chooses to specialize), and this includes outcomes (bc, bc). In this scenario, there is inter-port competition in both services.

Using the above classification, both the Stackelberg game and simultaneous game can be fully solved if the above four scenarios can be solved. The following section solves these four scenarios.

## 4. Model Analytical Solution and Results Comparison

In this section, we will first solve the four scenarios summarized above for the Stackelberg game and simultaneous game respectively, and then benchmark the outcomes across different scenarios.

#### 4.1 Stackelberg game

Consider <u>Scenario I</u>, which includes outcomes (b, -), (c, -), (bc, -), (b, c) and (c, b). Since there is no competition between port services with respect to bulk cargo vs. container cargo, we only need to obtain a solution for one outcome, say (bc, -). The solutions for other outcomes will have similar mathematical expressions. For the outcome of (bc, -), the service charges of ports are given by  $p_{1c} = a_1 - bq_{1c}$  and  $p_{1b} = \alpha_1 - \beta q$ . The profit maximization problem of Port 1 can be expressed as  $\max_{q_{1c},q_{1b}} \pi_1 = (p_{1c} - m_c)q_{1c} - K_c + (p_{1b} - m_b)q_{1b} - K_b$ . Therefore, the First Order Conditions (FOC) are given by

$$\begin{cases} \frac{\partial \pi_1}{\partial q_{lc}} = a_1 - m_c - 2bq_{lc} = 0, \\ \frac{\partial \pi_1}{\partial q_{lb}} = \alpha_1 - m_b - 2\beta q_{lb} = 0. \end{cases}$$
(5)

which lead to the following equilibrium outputs and port profit:

$$q_{1c} = \frac{a_1 - m_c}{2b}, \ q_{1b} = \frac{\alpha_1 - m_b}{2\beta},$$
(6)

$$\pi_1 = \frac{(a_1 - m_c)^2}{4b} + \frac{(a_1 - m_b)^2}{4\beta} - K_b - K_c.$$
(7)

<u>Scenario II</u> includes outcomes (b, b) and (c, c). Without loss of generality, consider the case of (c, c). The port charges are defined in equation (1). For Port 2, its profit maximization problem is given by  $\max_{q_{2c}} \pi_2 = (p_{2c} - m_c)q_{2c} - K_c$ . This leads to FOC of  $\frac{\partial \pi_2}{\partial q_{2c}} = a_2 - m_c - kq_{1c} - 2bq_{2c} = 0$ , which gives this port's reaction function, conditional on Port 1's output volume, as

$$q_{2e}(q_{1e}) = \frac{a_2 - m_e - kq_{1e}}{2b}$$

$$\tag{8}$$

Therefore, Port 1's profit maximization problem is specified as

$$\max_{q_{1c}} \pi_{1} = (p_{1c} - m_{c})q_{1c} - K_{c} = \left(a_{1} - m_{c} - bq_{1c} - k \cdot \frac{a_{2} - m_{c} - kq_{1c}}{2b}\right)q_{1c} - K_{c}$$
(9)

Which further leads to the following equilibrium outputs and port profits

$$\begin{cases} q_{1c} = \frac{1}{4b^2 - 2k^2} [(2a_1b - a_2k) - (2b - k)m_c], \\ q_{2c} = \frac{1}{2b(4b^2 - 2k^2)} [(4a_2b^2 - 2a_1bk - a_2k^2) - (4b^2 - 2bk - k^2)m_c], \\ \\ \pi_1 = \frac{1}{4b(4b^2 - 2k^2)} [(2a_1b - a_2k) - (2b - k)m_c]^2 - K_c, \\ \\ \pi_2 = \frac{1}{4b(4b^2 - 2k^2)^2} [(4a_2b^2 - 2a_1bk - a_2k^2) - (4b^2 - 2bk - k^2)m_c]^2 - K_c. \end{cases}$$
(11)

<u>Scenario III</u> includes outcomes (bc, b), (bc, c), (b, bc), (c, bc). Without loss of generality, consider the case of (bc, c). Since there is no competition between the bulk cargo sector and the container sector, it is straightforward to show that the equilibrium traffic throughputs of each port in this scenario are mathematically identical to the outcomes of (c, c) and (b,-). <u>Scenario VI</u> includes outcomes (bc, bc). In a similar way, the equilibrium throughputs of each port in this scenario are mathematically identical to the port in this scenario are mathematically identical to the port throughputs of each port in the cases of (c, c) and (b,b).

#### 4.2 Simultaneous game

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For a one-shot static game in which two ports make simultaneous decisions, without coordination between the two ports the market outcomes may lead to negative profits. Such equilibria are not sustainable, and in the long term the ports will have to pursue other strategies. They may either merge with each other or leave the market. We will first solve non-trivial outcomes when each port provides at least one type of service (otherwise, this port doesn't need to be considered in our static game). We will then evaluate whether the ports' profits are positive, and the implications for policy makers. Since we keep to non-trivial outcomes where both ports have positive output/traffic volumes, in the simultaneous game only Scenarios II, III and IV need to be solved.

To solve Scenario II in a simultaneous game, without loss of generality consider the case of (c, c). Port charges are  $\tilde{p}_{1c} = a_1 - b\tilde{q}_{1c} - k\tilde{q}_{2c}$  and  $\tilde{p}_{2c} = a_2 - k\tilde{q}_{1c} - b\tilde{q}_{2c}$  respectively. The objective function of port *i* is  $\max_{\tilde{q}_{z}} \tilde{\pi}_{i} = (\tilde{p}_{ic} - m_{c})\tilde{q}_{ic} - K_{c}$ , i = 1, 2. The corresponding FOCs are thus  $\frac{\partial \tilde{\pi}_{i}}{\partial \tilde{q}_{ic}} = a_{i} - m_{c} - 2b\tilde{q}_{ic} - k\tilde{q}_{jc} = 0$ ,  $i, j = 1, 2; i \neq j$ , solving which lead to the following equilibrium traffic volumes

and port profits:

$$\tilde{q}_{1c} = \frac{1}{4b^2 - k^2} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big],$$

$$\tilde{q}_{2c} = \frac{1}{4b^2 - k^2} \Big[ (2a_2b - a_1k) - (2b - k)m_c \Big],$$
(12)

and

$$\tilde{\pi}_{1} = \frac{b}{(4b^{2} - k^{2})^{2}} \Big[ (2a_{1}b - a_{2}k) - (2b - k)m_{c} \Big]^{2} - K_{c},$$

$$\tilde{\pi}_{2} = \frac{b}{(4b^{2} - k^{2})^{2}} \Big[ (2a_{2}b - a_{1}k) - (2b - k)m_{c} \Big]^{2} - K_{c}.$$
(13)

Scenario 3 and Scenario 4 can be solved similarly. Since the solution process is straightforward, details are omitted in this section.

#### 4.3 Comparison across scenarios and competition games

Mathematically it is sufficient to benchmark traffic volumes and port profits for one sector, say the container market. The same conclusions can then be generalized to the bulk cargo market. Table 1 summarizes and benchmarks the representative two outcomes when only the container sector is considered.

				e ontainer istarnet
		Stackelberg Game		Simultaneous Game
	$q_{1c}$	$rac{a_1 - m_c}{2b}$	${ ilde q}_{{\scriptscriptstyle 1}c}$	
(bc, -)	<i>q</i> <sub>1b</sub>	$\frac{\alpha_1 - m_{\theta}}{2\beta}$	${ ilde q}_{_{1b}}$	
	$\pi_{_1}$	$\frac{(a_1-m_c)^2}{4b}+\frac{(a_1-m_b)^2}{4\beta}-K_b-K_c$	$ ilde{\pmb{\pi}}_1$	
	$q_{_{1c}}$	$\frac{1}{4b^2 - 2k^2} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big]$	${ ilde q}_{{\scriptscriptstyle 1}c}$	$\frac{1}{4b^2-k^2} \Big[ (2a_1b-a_2k)-(2b-k)m_c \Big]$
	$q_{2c}$	$\frac{1}{2b(4b^2-2k^2)} \left[ (4a_2b^2-2a_1bk-a_2k^2)-(4b^2-2bk-k^2)m_c \right]$	$ ilde{q}_{_{2c}}$	$\frac{1}{4b^2-k^2} \Big[ (2a_2b-a_1k) - (2b-k)m_c \Big]$
(c, c)	$\pi_{_{1c}}$	$\frac{1}{4b(4b^2-2k^2)} \left[ (2a_1b-a_2k) - (2b-k)m_c \right]^2 - K_c$	$ ilde{\pmb{\pi}}_{_{1c}}$	$\frac{b}{(4b^2-k^2)^2} \Big[ (2a_1b-a_2k) - (2b-k)m_c \Big]^2 - K_c$
	$\pi_{_{2c}}$	$\frac{1}{4b(4b^2-2k^2)^2} \left[ (4a_2b-2a_1bk-a_2k^2)-(4b^2-2bk-k^2)m_c \right]^2 - K_c$	${\tilde \pi}_{_{2c}}$	$\frac{b}{(4b^2-k^2)^2} \Big[ (2a_2b-a_1k) - (2b-k)m_c \Big]^2 - K_c$

Table 2: Comparison across Scenarios/Games for Container Mari
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Benchmarking market equilibria across different scenarios and competition games, the following propositions can be obtained. In particular, comparing market equilibria under the two different types of games, we have:

**Proposition 1.** If the "relative demand" of the leader port (say Port 1) and the follower port (say Port 2) satisfies  $a_2 < \frac{2b}{k}a_1 + (1 - \frac{2b}{k})m_c$  and/or  $\alpha_2 < \frac{2\beta}{\gamma}\alpha_1 + (1 - \frac{2\beta}{\gamma})m_b$ , then the leader port's output quantity and

profit under the Stackelberg game are higher than those under the simultaneous game, whereas the follower port's output quantity and profit are lower under the Stackelberg game than those under the simultaneous game. In a Stackelberg competition, the leader port has a higher output quantity and profit than that of the follower.

**Proof.** Since, in the simultaneous game, we restrict it to the case of positive traffic volumes, we only need to compare the Stackelberg and simultaneous outcomes when both ports provide the same type of services, such as (c, c) or (b, b). For j = c, b, we need to show that (a)  $q_{1j} > \tilde{q}_{1j} > \tilde{q}_{2j} > q_{2j}$  and  $q_{1j} > \tilde{q}_{1j} > 0$ ; (b)

 $\pi_{1j} > \tilde{\pi}_{2j} > \pi_{2j} > \pi_{2j}$ . Consider outcome (c, c), and outcome (b, b) follows analogously. By (10) and (11) we have

$$q_{1c} - \tilde{q}_{1c} = \frac{k^2}{(4b^2 - 2k^2)(4b^2 - k^2)} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big] > 0,$$
(14)

$$\pi_{1c} - \tilde{\pi}_{1c} = \frac{k^4}{4b(4b^2 - 2k^2)(4b^2 - k^2)^2} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big]^2 > 0.$$
<sup>(15)</sup>

Similarly, we have

$$\tilde{q}_{2c} - q_{2c} = \frac{k^3}{2b(4b^2 - 2k^2)(4b^2 - k^2)} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big] > 0, \tag{16}$$

$$\tilde{p}_{2c} - p_{2c} = \frac{k^3}{2(4b^2 - 2k^2)(4b^2 - k^2)} \Big[ (2a_1b - a_2k) - (2b - k)m_c \Big] > 0,$$
(17)

thus  $\tilde{\pi}_{2c} > \pi_{2c}$ . It is straightforward to show that  $\tilde{q}_{1c} > \tilde{q}_{2c}$  and  $\tilde{\pi}_{1c} > \tilde{\pi}_{2c}$ . Therefore we have shown that  $q_{1j} > \tilde{q}_{1j} > \tilde{q}_{2j} > q_{2j}$ ,  $q_{1j} > \tilde{q}_{1j} > 0$  and  $\pi_{1j} > \tilde{\pi}_{1j} > \tilde{\pi}_{2j} > \pi_{2j}$ .

Proposition 1 confirms that where port competition is possible and when the market is large enough for both ports to have positive outputs, there is a clear first-mover advantage. A Stackelberg leader's profit and traffic volume are not only higher than the Stackelberg follower, but also higher than the payoffs when two firms engage in a simultaneous game. The worst possible outcome for a port is to be a follower in Stackelberg competition. This probably explains the aggressive port investments witnessed in China. With high growth in both trade and economy, the port sector has been a promising industry in which to invest. However, with many potential entrants into this growth market, an early investment will give a port a great competitive advantage over its rivals. As a result, many cities invest in new port facilities without making any careful evaluation of the market potential and industry development pattern. This implies that even if the government attempts to regulate the port sector, ports will still have a strong incentive to deviate from or bypass such regulation.

Whereas Proposition 1 describes market equilibria when both ports handle positive traffic volumes, one also needs to consider whether it is sustainable for both ports to provide such service. With respect to this issue, the following Proposition 2 can be obtained. Since the same results hold for both the container and bulk sectors, we only report below the case for the bulk sector, assuming that Port 1 is the market leader in the case of the Stackelberg game.

**Proposition 2.** In the presence of inter-port competition, a port will provide port service if its demand is sufficiently large compared to the demand of the other port. For the bulk cargo sector, denote  $\underline{\delta}_{b}(\alpha_{1}) = \frac{\gamma}{2\beta} \alpha_{1} + (1 - \frac{\gamma}{2\beta}) m_{b}, \ \overline{\delta}_{b}(\alpha_{1}) = \frac{2\beta\gamma}{4\beta^{2} - \gamma^{2}} \alpha_{1} + (1 - \frac{2\beta\gamma}{4\beta^{2} - \gamma^{2}}) m_{b} \text{ and } \widehat{\delta}_{b}(\alpha_{1}) = \frac{2\beta}{\gamma} \alpha_{1} + (1 - \frac{2\beta}{\gamma}) m_{b},$ 

then we have

- i) If  $\alpha_2 \leq \underline{\delta}_b(\alpha_1)$  then  $q_{2b} < \tilde{q}_{2b} \leq 0$ . This implies that if the demand for Port 2 is much smaller than that of Port 1, then Port 2 will not provide any service at all.
- ii) If  $\underline{\delta}_b(\alpha_1) < \alpha_2 \le \overline{\delta}_b(\alpha_1)$  then  $q_{2b} \le 0 < \tilde{q}_{2b}$ . This implies that if the demand for Port 2 is moderate, then Port 2 will provide service in a simultaneous game but not in a Stackelberg game.
- iii) If  $\alpha_2 > \overline{\delta}_b(\alpha_1)$  then  $0 < q_{2b} < \tilde{q}_{2b}$ . This implies that if demand for Port 2 is sufficiently large, then Port 2 will provide bulk services in both types of competition games.
- iv) If  $\alpha_2 > \hat{\delta}_b(\alpha_1)$  then  $q_{2b} < 0$ ,  $\tilde{q}_{2b} \le 0$ . This implies that if demand for Port 2 is very large relative to the demand for Port 1, then Port 1 will be driven out of the market.

Note that Proposition 2 suggests that whether a port will provide service in a particular sector not only depends on market demand (i.e.  $\alpha_i$ ), but more importantly on the "relative demand" between the two ports, since different "relative demands" (as defined in the above four cases) will lead to different outcomes. The

proof for Proposition 2 follows directly on from the market equilibrium solution, and thus is omitted here. The market outcome zones described in Proposition 2 are illustrated in Figure 1 below, where "+" is used to denote positive output and "-" for no output.



**Figure 4: Market Outcome Zones for Different Potential Demands** 

Figure 4 depicts the relationships between the output quantity of Port 2 as its relative demand (i.e.  $\alpha_2$  as a function of  $\alpha_1$ ) increases. The Figure also suggests that whereas the market outcomes are in most cases similar in the case of both Stackelberg and simultaneous games, they are different when  $\delta_{i}(\alpha_{1}) < \alpha_{2} \leq \overline{\delta}_{i}(\alpha_{2})$ . The differences in the case of the bulk cargo sector are highlighted in Figure 5. As shown in the Figure, when  $\underline{\delta}_b(\alpha_1) < \alpha_2 \le \overline{\delta}_b(\alpha_1)$ , Port 2 provides port services in a simultaneous game but not in a Stackelberg game. That is, where the competitor's demand is not too large, a leader port can deter the entry of a potential competing port, but this is not the case in a simultaneous game.

Figure 5: Differences in Market Outcomes — Stackelberg Game vs Simultaneous Game



Note that in a simultaneous game a port will provide service so long as its marginal revenue is higher than its marginal cost, but this, however, doesn't guarantee that a port can earn positive profit. Clearly, if a port earns negative profit it is not sustainable. This has important implications for the strategies of ports in the long term. We summarize the key conclusion as the following Proposition 3. The proof follows directly on from the equilibria solutions and thus is omitted here.

**Proposition 3:** If the relative demand for Port 2 is moderate then Port 2 will not provide service under Stackelberg competition. It will provide port service in a simultaneous game, but will earn negative profit if the fixed cost is large. Using bulk cargo as an example, mathematically this implies that when

$$\overline{\delta}_{b}(\alpha_{1}) < \alpha_{2} \leq \underline{\delta}_{b}(\alpha_{1}) \text{ , then } \overline{\pi}_{ib} \leq 0 \text{ if } K_{b} \geq \overline{K}_{b} \text{ where } \overline{K}_{b} = \frac{\beta}{(4\beta^{2} - \gamma^{2})^{2}} \left[ (2\alpha_{i}\beta - \alpha_{j}\gamma) - (2\beta - \gamma)m_{b} \right]^{2} \text{ for } i, j = 1, 2, i \neq j.$$

Proposition 3 has important implications for port specialization. Capacity investments for container and bulk cargo can be of a different nature. Efficient bulk cargo operations often require a dedicated rail network that links to a port's catchment area, as well as specialized port handling equipment and storage facilities. That is, investments for bulk operations tend to be lumpy, or capacity can only be added in large volumes. This implies that there is a high fixed cost, irrespective of the subsequent traffic volume. For container services, port capacity can often be added progressively by installing more cranes and allocating larger container yards. Also, even for large container ports, much of the ground transportation is handled by trucks, so there is no need for dedicated / lumpy investment on a rail network. This means that in the medium or long run, most of the total cost<sup>1</sup>. Since we are analyzing port specialization, which is a not a short term decision, it appears reasonable to assume that  $K_c << K_b$  for most practical issues.

Assume that the fixed cost of providing a container service accounts for a small proportion of the total cost, whereas the fixed cost of providing a bulk service can be either low (i.e.  $K_b < \overline{K}_b$ ) or high (i.e.  $K_b \ge \overline{K}_b$ ). Then the competition outcome matrix for different combinations of relative demands can be obtained, as in Table 3. The notation follows that used in Table 1. Note that by assuming a low fixed cost for a container operation, but a high fixed cost for a bulk operation, then, in the case of the simultaneous game, a port (say Port 2) can make a positive profit from the container service even if the relative demand for it is only moderate (i.e. when  $\underline{\delta}_c(a_1) < a_2 \le \overline{\delta}_c(a_1)$ ). However, if the relative demand for its bulk service is only moderate (i.e. when  $\underline{\delta}_b(\alpha_1) < \alpha_2 \le \overline{\delta}_b(\alpha_1)$ ), then it is not sustainable for it to provide a bulk service at all (i.e. with both ports providing a bulk service but earning negative profits). For example, when  $a_2 \le \underline{\delta}_c(a_1)$  and  $\underline{\delta}_b(\alpha_1) < \alpha_2 \le \overline{\delta}_b(\alpha_1)$  market equilibrium in the case of a simultaneous game is (bc,b). However, there is insufficient demand to accommodate two bulk ports. In the long term, at least one port's bulk service needs to be either abandoned or merged with the other port. This would lead to an outcome of either (bc,-) or (c,b). We report such long term likely outcomes in the "Simultaneous – Sustainable" column.

As summarized in Table 3, there are a few cases where two ports engage in complete specialization so that the outcomes are either (b,c) or (c,b). These cases are highlighted in gray. It is clear that such complete specialization is only possible in the following cases:

<u>Natural Specialization</u>: Each port has a high relative demand for one exclusive type of cargo. For example, when [a<sub>2</sub> ≤ δ<sub>c</sub>(a<sub>1</sub>), α<sub>2</sub> > δ<sub>b</sub>(α<sub>1</sub>)], so that Port 2 has a very low relative demand for container cargo but a high relative demand for bulk cargo, then in all the scenarios we considered the market outcomes are always (c,b). Such types of "natural specialization" are highlighted with a '^' sign in the table.

Relative	Demand	Low Fixed C	Cost of Bulk Service $K_b < \overline{K}_b$	High Fixed Cost of Bulk Service $K_b \ge \overline{K}_b$		
		Stackelberg	Simultaneous	Simultaneous – Sustainable		
	$\alpha_2 \leq \underline{\delta}_b(\alpha_1)$	(bc, -)	(bc, -)	(bc, -)		
$a_2 \leq \underline{\delta}_c(a_1)$	$\underline{\delta}_{\boldsymbol{b}}(\boldsymbol{\alpha}_1) < \boldsymbol{\alpha}_2 \leq \overline{\delta}_{\boldsymbol{b}}(\boldsymbol{\alpha}_1)$	(bc, -)	(bc, b)	(bc, -) / (c,b)**		
	$\overline{\delta}_b(\alpha_1) < \alpha_2 \le \widehat{\delta}_b(\alpha_1)$	(bc, b)	(bc, b)	(bc, b)		
	$\alpha_2 > \widehat{\delta}_b(\alpha_1)$	(c,b) ^	(c,b) ^	(c,b) ^		
	$\alpha_2 \leq \underline{\delta}_b(\alpha_1)$	(bc, -)	(bc, c)	(bc, c)		
$\underline{\delta}_c(a_1) < a_2 \le \overline{\delta}_c(a_1)$	$\underline{\delta}_b(\alpha_1) < \alpha_2 \le \overline{\delta}_b(\alpha_1)$	(bc, -)	(bc, bc)	(bc, c) / (c,bc)		
	$\overline{\delta}_b(\alpha_1) < \alpha_2 \le \widehat{\delta}_b(\alpha_1)$	(bc, b)	(bc, bc)	(bc, bc)		

 Table 3: Competition Outcome Matrix – Conditional on Relative Demand
 (Fixed Cost of Container Service is Assumed to be Low)

	$\alpha_2 > \widehat{\delta}_b(\alpha_1)$	(c,b) *	(c,bc)	(c,bc)
	$\alpha_2 \leq \underline{\delta}_b(\alpha_1)$	(bc, c)	(bc, c)	(bc, c)
$\overline{\delta}_c(a_1) < a_2 \le \widehat{\delta}_c(a_1)$	$\underline{\delta}_{\boldsymbol{j}}(\boldsymbol{\alpha}_1) < \boldsymbol{\alpha}_2 \leq \overline{\delta}_{\boldsymbol{j}}(\boldsymbol{\alpha}_1)$	(bc, c)	(bc, bc)	(bc, c) / (c,bc)
	$\overline{\delta}_b(\alpha_1) < \alpha_2 \le \widehat{\delta}_b(\alpha_1)$	(bc, bc)	(bc, bc)	(bc, bc)
	$\alpha_2 > \widehat{\delta}_b(\alpha_1)$	(c,bc)	(c,bc)	(c,bc)
	$\alpha_2 \leq \underline{\delta}_b(\alpha_1)$	(b, c) ^	(b, c) ^	(b, c) ^
	$\underline{\delta}_{\boldsymbol{b}}(\boldsymbol{\alpha}_1) < \boldsymbol{\alpha}_2 \leq \overline{\delta}_{\boldsymbol{b}}(\boldsymbol{\alpha}_1)$	(b, c) *	(b, bc)	(b, c) / (-,bc)**
$a_2 > \hat{\delta}_c(a_1)$	$\overline{\delta}_b(\alpha_1) < \alpha_2 \le \widehat{\delta}_b(\alpha_1)$	(b, bc)	(b, bc)	(b,bc)
	$\alpha_2 > \widehat{\delta}_b(\alpha_1)$	(-,bc)	(-,bc)	(-,bc)

\*In a Stackelberg game, equilibrium outcomes are the same regardless of whether the fixed cost related to a bulk cargo service is high or low.

- <u>First-mover Specialization</u>: In a Stackelberg game, if the follower Port 2's relative demand for one type of cargo (say a container service) is moderate (i.e.  $\underline{\delta}_c(a_1) < a_2 \leq \overline{\delta}_c(a_1)$ ), but its relative demand for the other type of cargo is high (bulk cargo in this case, since  $\alpha_2 > \widehat{\delta}_b(\alpha_1)$ ), then Port 2 will specialize only in the sector for which it has a high relative demand. It will not provide the other type of service, since Port 1 has already achieved a first-mover advantage. Such types of "first-mover specialization" are highlighted with an '\*' sign in the table.
- (Long-term) Specialization Due to Excess Capacity: As explained in the discussions earlier, if a port's relative demand is moderate (i.e. in the case of bulk service  $\underline{\delta}_b(\alpha_1) < \alpha_2 \leq \overline{\delta}_b(\alpha_1)$ ), but its fixed cost is high, then the market outcome may naturally lead to an unsustainable outcome: Both ports provide services, but earn negative profits. In the long term, at least one port will either have to leave the market or merge with the other port. This could, but not always, lead to port specialization. Such cases are highlighted with a '\*\*' sign.

Even though each of the above three cases could lead to complete specialization, only the last case, under certain circumstances, warrants government intervention. In the first two cases of natural specialization and first-mover specialization, no additional benefits can be achieved if the government recommendation / policy is the same as the (would be) market equilibrium in a free market. On the other hand, if government recommendations / policies deviate from a free market outcome, such policies may not take full effect, or the market outcomes will be distorted and lead to unexpected results. Either way, with inappropriate and/or unnecessary government intervention, social welfare will be reduced.

## 4. Discussion and Conclusions

The fast growth of the Chinese economy and its international seaborne trade has escalated the demand for high quality and efficient port services. This has led to a sharp increase in port investment, which in many cases has resulted in excess handling capacity and destructive competition. Many economists and government officials suggest that the Chinese government should encourage cooperation and coordination between neighboring ports. In particular, many propose that the government should coordinate or promote port specialization. However, it is far from clear what the correct government policy ought to be, and whether or not more regulation and government intervention is needed. For example, it remains unclear as to how port specialization can be introduced, and whether a government should mandate or at least plan for port specialization.

This paper proposes an economic model for port service choice and specialization, so that the driving factors and market conditions influencing port specialization, as well as the economic implications of port specialization, are examined. Our analytical results suggest the following: that (1) Without proper coordination, ports may choose to invest in the same type of infrastructures even if there is insufficient demand for multiple ports; as a result, there may be excessive investment in that sector, which is not sustainable; such outcome is likely to happen when ports make strategic decisions simultaneously, and when market demand is moderate. However, over-investments are less likely when ports make sequential decisions, or when one port's demand is clearly higher than the other's. (2) Without government intervention, port specialization might be achieved, but at the expense of over-capacity investment and excessive competition. However, competition alone will lead to port specialization if each port enjoys a high demand in a sector different from that of its competitors, or when ports make sequential strategic decisions. (3) Leader ports enjoy substantial first-mover advantages in terms of greater profit and larger traffic volume. A follower port, however, will be seriously disadvantaged in the competition. This makes it difficult for a central government to coordinate or mandate capacity investment and port specialization. In summary, our analytical results suggest that government intervention in port specialization is neither necessary nor effective in most cases. Therefore, instead of resorting to more regulation and central planning, the government may be better positioned to assist ports in making the right decisions. For example, the government may provide better demand forecasts; compile and publish port investment and capacity expansion plans; and promote port consolidation and mergers in cases of excess capacity investment.

In view of the fact that our results have been obtained under fairly general assumptions, we have not taken into consideration historical development paths, geographical differences and current market outcomes, which could vary substantially across different regions / ports. Historical development and geographical factors could play important roles in shaping a port's pattern of specialization. Todd (1993) noted that, in the very early days, Kaohsiung developed into a key coal handling port in Taiwan, since there were coal deposits in a bay close to the harbor, and the Japanese used it for coal shipping during their period of occupation in World War II. Since the 1970s, major export processing zones (EPZs) have been established both inside and adjacent to the port area as part of the overall government economic development plan. As a result, Kaohsiung has come to handle an increasing share of manufactured goods. Such an example clearly demonstrates the importance of both historical development and geographical factors. Therefore, it is important that researchers explicitly consider such issues when evaluating a particular market, although such objectives are beyond the scope of the analytical model we propose in this paper.

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<sup>1</sup>Clearly, there are cases where container operations may also involve substantial sunk costs and lumpy investment. For example, investments on ship route dredging and hinterland transport networks could be lumpy.

# **Empty Container Reposition Optimization Model with the Feeder Transportation**

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#### Abstract

In this paper, under the condition that the demand of empty containers must be satisfied and the empty container reposition must obey to a certain port calling rule, empty container reposition optimization model for a complex transportation system with multiple hub ports and multiple feeders in one direct ship route is developed which aims at minimize the total cost of the ship route system with multiple hub ports and multiple feeders. Finally, a numerical example is provided to illustrate the effectiveness of the proposed model, and analyzed the impact of container lease cost, transport capacity on the total cost of a complex transportation system.

Key words: Waterway transportation, Feeder, Direct ship route, Empty container reposition

## 1. Introduction

Empty container reposition is a popular topic in container position industry, and many scholars have different theories about this topic.

Some papers focus on the empty container repositioning. For instance, Wang and Meng(2012a) assumed that the empty containers could be repositioned between different ports in any time, and used the integer linear programming to develop a empty container reposition optimization model in the liner shipping. Wang and Wang (2007) considered the multi-mode transport system in inland, with both container demand and supply need to be met, developed an optimal integer program model for the different ports and inland transport stations. Cao et al. (2012) considered the container shipping in the railway system with the random empty container demand, developed an optimal model for the container reposition. Song and Dong (2012) evaluated the effectiveness of the empty container reposition policy under flexible destination ports and the result showed that new policy is better than the conventional policy. Song and Dong(2012) developed a model about joint cargo route and empty container reposition for a shipping network, and proposed two methods to solve the problem including two-stage shortest-path method and two-stage heuristic-rules method. Wang and Wang (2012) considering the demand from the customer must be satisfied, and constraint of storage and load ability of the ports, developed an integer programming model about the empty container reposition in the land-carriage system. Bandeira et al. (2009) focused on the unbalanced export/import containers trading, a integrated distribution model was developed to optimize the total cost.

Some papers analyze the empty container reposition in consideration of ships allocation and ship route designing. For instances, Dong and Song (2009) under the assumption that the empty container demand is uncertain, developed the model to decide the optimal quantity of ship and empty container in different ports and voyages. Wang and Meng (2012b) developed a mixed-integer non-linear stochastic programming model about tactical-level liner ship route schedule design problem, and obtained the optimal arrival time of a ship at each calling port in a ship route and optimal speed of the ships. Meng et al. (2012) assumed that container transshipment is allowed and container shipment demand is uncertain, and then developed a two-stage stochastic integer programming model to determine the optimal number and type of the ships for a ship route.

Furthermore, there are some other related researches. Lei and Church (2011) presented three strategic-level models for locating away-from-port storage yards for empty shipping containers , which aimed to reduce the

mileage involved in repositioning empty containers. Shintani et al. (2007) took the empty container reposition into consideration, and developed a two-stage model to decide the optimal container liner shipping service network. Li et al. (2007) assumed that the demand and supply of the empty container is uncertain, and the empty container reposition is allowed, firstly developed a model to determine the optimal empty container inventory, and then proposed a method to obtain the optimal empty container reposition strategy.

In this paper, simultaneously considering the empty container demand, capacity of the ships and a ship portcalling rule in the ship routes, the empty container reposition optimization model for a complex ship route system with multi-feeders in one direct ship route is developed.

# 2. Assumptions and Parameters

We assume that the shipping system only consists of one direct ship route. The empty container demand must be met, and once the demand can't be satisfied, leasing empty container is allowed. The parameters used in the empty container reposition model are shown as follows:

Param	eters
t the time period	reposition at time t
$T_k$ cycle time for one voyage for ship k	$R_m^t$ quantity of empty container in port <i>m</i> after
$ au_{ij}$ transportation time from port <i>i</i> to <i>j</i>	reposition at time t
k ship index on the direct ship route,	N the hub port $a = 1 2$
k =1,2,3,,K	g = simp match on the direct simp route, $g = 1, 2,$
<i>m</i> port index in the direct ship route, $m = 1, 2, 3,$	$i$ port index in the feeder, $i=1, 2, 3, \dots, F$
$l_{m}$ order of the port <i>m</i> in direct ship route	$H_i$ hub port index. $i=1,2,\ldots,a$ .
$U_{mm}^{k}$ capacity of ship k on the direct ship route m	$g_i$ ship index in the feeder $f_i$ , $g_i = 1, 2, 3, \dots, G_i$
to n	$h_i$ ports index on the feeder of hub port
$D_m^t$ the demand for empty container in port <i>m</i> at	$H_i, h_i = 1, 2, \dots, J_i$
time <i>t</i>	At time $t$ , if the ship $k$ calls port $m$ in the direct
$S_m^t$ , the supply of empty container in port <i>m</i> at	ship route, then $\alpha_m^{kt} = 1$ , or $\alpha_m^{kt} = 0$ ; According to the
time <i>t</i>	order of the calling port, if port $n$ follows port $m$ ,
$C_m^r$ unit leasing cost in port <i>m</i>	$\beta_{mn}^{\ \ k} = 1$ , or $\beta_{mn}^{\ \ k} = 0$ .
$C_m^s$ unit holding cost in port <i>m</i>	$x^+ = \max\{0, x\}, \ x^- = \min\{0, x\}.$
$C_{mn}^{t}$ unit transportation cost on the direct ship route	Decision variable
from port $m$ to $n$ at time $t$	$X_{mn}^{kt}$ quantity of empty container transshipped by
$Z_{mn}^{kt}$ quantity of the full container shipped by ship	ship $k$ from port $m$ to $n$ at time $t$
k from port $m$ to $n$ at time $t$	$X_{h_ih_j}^{g_it}$ quantity of empty container transshipped by
$O_m^t$ quantity of leased empty container in port <i>m</i> at	ship $g_i$ from port $h_i$ to $h_j$ at time t
time t	
$Q_m^t$ quantity of empty container in port <i>m</i> before	

# 3. Model

On a global voyage, there may be only one hub port, or several hub ports, the later is very common, such as Euro-Asia ship route, which almost every port is the hub port. In this section, the complex ship route system with multi-hub ports and multiple feeders in one direct ship route is considered. The empty container reposition optimization model for this case can be formulated as follows.

$$\min \left\{ \sum_{T} \sum_{k=1}^{K} \sum_{m=1}^{M} \sum_{n=1}^{M} X_{mn}^{kt} C_{mn}^{k} \alpha_{m}^{kt} \beta_{mn}^{k} + \sum_{T} \sum_{m=1}^{M} O_{m}^{t} C_{m}^{r} + \sum_{T} \sum_{m=1}^{M} R_{m}^{t} C_{m}^{s} + \sum_{i=1}^{K} \sum_{m=1}^{K} R_{i}^{t} C_{m}^{s} + \sum_{m=1}^{K} \sum_{m=1}^{K} \sum_{m=1}^{K} R_{i}^{t} C_{m}^{s} + \sum_{m=1}^{K} \sum_{m=1}^{K} \sum_{m=1}^{K} R_{i}^{t} C_{m}^{s} + \sum_{m=1}^{K} \sum_{m=1}^$$

The objective function (1) defines the total cost including empty container reposition cost, leasing cost and holding cost on the direct ship route and feeder, respectively.

Subject to

$$\sum_{k=1}^{K} \sum_{l_m < l_n} X_{mn}^{kt} \alpha_m^{kt} \beta_{mn}^k \le Q_m^t, (Q_m^t > 0, \text{ and } m \ne H_i)$$

$$\tag{2}$$

$$\sum_{g_i=1}^{G_i} \sum_{h_i < l_{h_i}} X_{h_i h_j}^{g_i t} \alpha_i^{g_i t} \beta_{h_i h_j}^{g_i} \le Q_{h_i}^t, (Q_{h_i}^t > 0, \text{ and } h_i \neq H_i)$$
(3)

$$\sum_{k=1}^{K} \sum_{m=1}^{M} X_{H_{i}m}^{t} + \sum_{g_{i}=1}^{G_{i}} \sum_{h_{i}=1}^{J_{i}} X_{H_{i}h_{i}}^{t} \le Q_{H_{i}}^{t}, (Q_{H_{i}}^{t} > 0)$$
(4)

Constraints (2), (3) and (4) demonstrate that the empty container transshipped out from the port should not exceed the available empty container in the ports of direct ship route, feeders and the hub port, respectively.

$$Q_{m}^{t} = R_{m}^{t-1} + \sum_{k=1}^{K} \sum_{l_{m} < l_{n}} X_{nm}^{kt'} \beta_{nm}^{k} + S_{m}^{t} - D_{m}^{t}, (m \neq H_{i});$$
(5)

$$Q_{h_{i}}^{t} = R_{h_{i}}^{t-1} + \sum_{g_{i}=1}^{G} \sum_{l_{h_{i}} < l_{h_{j}}} X_{h_{j}h_{i}}^{gt''} \alpha_{h_{j}}^{gt''} \beta_{h_{j}h_{i}}^{g} + S_{h_{i}}^{t} - D_{h_{i}}^{t}, (h_{i} \neq H_{i});$$

$$K \qquad G_{i}$$
(6)

$$Q_{H_{i}}^{t} = R_{H_{i}}^{t-1} + \sum_{k=1}^{K} \sum_{l_{H_{i}} < l_{n}} X_{nH_{i}}^{kt'} \alpha_{n}^{kt'} \beta_{nH_{i}}^{k} + \sum_{g_{i}=1}^{G_{i}} \sum_{l_{H_{i}} < l_{j}} X_{h_{j}H_{i}}^{g_{i}t_{i}} \alpha_{h_{j}}^{g_{i}t_{j}} \beta_{h_{j}H_{i}}^{g_{i}} + S_{H_{i}}^{t} - D_{H_{i}}^{t};$$

$$(7)$$

Constraints (5), (6) and (7) impose the available empty container in the ports, including the hub ports, and the ports in the direct ship line or feeders, should be the total of the empty container stored, the empty container transshipped from other ports, the empty container supply minus the empty container demand.

$$\sum_{p=1}^{l_m} \sum_{q=l_m}^{M} X_{pq}^{kt'} \alpha_p^{kt'} \beta_{pq}^k + \sum_{p=1}^{l_m} \sum_{q=l_m}^{M} Z_{pq}^{kt'} \alpha_p^{kt'} \beta_{pq}^k \le U_{mn}^k$$
(8)

$$\sum_{p=1}^{l_{h_i}} \sum_{l_{h_j}}^{J_i} X_{h_i h_j}^{g_i t} \alpha_{h_i}^{g_i t} \beta_{h_i h_j}^{g_i} + \sum_{p=1}^{l_{h_i}} \sum_{l_{h_j}}^{H} Z_{h_i h_j}^{g_i l_i} \alpha_{h_i}^{g_j l_i} \beta_{h_i h_j}^{g_i} \le U_{h_i h_j}^{g_i}$$
(9)

Constraints (8) and (9) impose the capacity limit of the ship route. The full container and empty container from one port to another port should not exceed the capacity of the ship.

$$t - T_k < t' < t - \tau_{ji}; t - T_{g_i} < t_i < t - \tau_{nm}$$
<sup>(10)</sup>

Constraint (10) represents the time limit. The time of the empty container transported from other ports to one port should be after the former voyage, and before the ship goes by this port.

$$O_{\rm m}^{\rm t} = -\left(Q_{\rm m}^{\rm t}\right), \left(m \neq H_{\rm i}\right) \tag{11}$$

$$O_{h_i}^t = -\left(Q_{h_i}^t\right)^-, (h_i \neq H_i)$$
(12)

$$O_{S_i}^t = -\left(\mathcal{Q}_{S_i}^t\right)^- \tag{13}$$

Equitation (11), (12) and (13) define the rented container,

$$R_{m}^{t} = \left(Q_{m}^{t} - \sum_{k=1}^{K} \sum_{n=1}^{M} X_{mn}^{kt} \alpha_{m}^{kt} \beta_{mn}^{k}\right)^{+}, (m \neq H_{i}, Q_{m}^{t} > 0)$$
(14)

$$R_{h_{i}}^{t} = \left(Q_{h_{i}}^{t} - \sum_{g_{i}=1}^{G_{i}} \sum_{h_{j}=1}^{J_{i}} X_{h_{i}h_{j}}^{g_{i}t} \alpha_{h_{i}h}^{g_{i}t} \beta_{h_{i}h_{j}}^{g_{i}}\right)^{+}, (h_{i} \neq H_{i}, Q_{i}^{t} > 0)$$
(15)

$$R_{H_{i}}^{t} = \left(Q_{H_{i}}^{t} - \sum_{k=1}^{K} \sum_{n=1}^{M} X_{H_{i}n}^{kt} \alpha_{H_{i}}^{kt} \beta_{H_{i}n}^{k} - \sum_{g_{i}=1}^{G_{i}} \sum_{h_{j}=1}^{H_{i}} X_{H_{i}h_{j}}^{g_{i}t} \alpha_{H_{i}}^{g_{i}t} \beta_{S_{i}H_{i}}^{g_{i}}\right)^{+}, (Q_{H_{i}}^{t} > 0)$$

$$(16)$$

Equitation (14), (15) and (16) define the stored containers in the ports.  $X_{h_ih_j}^{g_i t} \ge 0, X_{mn}^{kt} \ge 0, i = 1, 2, ..., a.$ 

(17)

Constraint (17) means that the decision variables should not be negative.

## 4. Numerical Example

In this section, a simple numerical example is introduced to evaluate the model in the paper, and then the sensitivity analysis is performed.

#### 4.1 Date description

There is only one ship in the direct ship route and feeder, respectively. There are 7 ports in the direct ship route, which are Port 1, Port 2, Port 3, Port 4, Port 5, Port 6, Port 7. There are 3 ports in the feeder, which are Port a, Port b, Port c. Port 4 is the hub port. The ships call every port. It is shown as Fig.1. and detailed parameters are shown in Table 1, Table 2, Table 3 and Table 4.

#### Fig.1: The Diagram of Ship Route



Table 1: Tr	ansportation	Cost and C	<b>Duantity</b>	of Full	Container in	n Direct	Ship	Route
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	Por	t 1	Por	rt 2	Por	rt 3	Por	t 4	Por	t 5	Por	t 6	Por	t 7
	Quan.	Cost												
Port 1	-	10	-	10	-	20	-	35	60	50	30	55	60	70
Port 2	-	20	-	-	10	10	-	25	40	40	30	45	30	60
Port 3	-	35	-	10	-	-	-	10	130	20	70	30	100	50
Port 4	150	50	130	25	170	10	-	-	-	10	20	20	30	40
Port 5	100	55	150	40	150	20	200	10	-	-	-	10	-	30
Port 6	50	70	40	45	10	30	50	20	-	10	-	-	-	20
Port 7	30	-	20	60	30	50	70	40	-	30	-	20		

	Port a		Port	b	Port	c	Port 4		
	Quan.	Cost	Quan.	Cost	Quan.	Cost	Quan.	Cost	
Port a	-	-	-	10	-	20	50	5	
Port b	-	5	-	5	-	15	40	10	
Port c	-	15	-	-	-	20	70	20	
Port 4	30	5	40	10	60	-	-	-	

## Table 2: Transportation Cost and Quantity of Full Container in Feeder

## Table 3: The Transportation Capacity of Direct Ship Route and Feeder

Port 1-2	Port 2-3	Port 3-4	Port 4-5	Port 5-6	Port 6-7	Port 4-a	Port a-b	Port b-c
500	800	1500	1500	500	500	300	150	300

#### Table 4 The holding cost and leasing cost in direct ship route and feeder

	Port 1	Port 2	Port 3	Port 5	Port 4	Port 6	Port 7	Port a	Port b	Port c
Holding cost	30	20	25	25	35	30	25	25	35	25
Leasing cost	15	30	20	25	30	25	25	25	25	20

## 4.2 *Computation Results*

The results are shown as Table 5, Table 6 and Table 7. The total cost for empty container reposition model (RM) and no empty container reposition model (NRM) are shown as Table 8 and Table 9, respectively.

It can be found that the total cost with empty container reposition has the advantage, although the empty container reposition cost is added, but the leasing cost and holding cost decrease.

Because the shortage of the empty container shouldn't exist, any demand of the empty containers should be met. When the port is in short of empty containers, it will have two choices, including transshipping empty containers from other ports, or leasing containers from the leasing market. Which choice should be the optimal choice, it depends on the leasing cost of leasing market, the empty container transportation cost and the capacity of the ship route. If the capacity of the ship route is enough to satisfy the demand of the empty containers reposition, and the transportation cost is lower than the leasing cost, empty container repositioning is the optimal choice. If there is no enough capacity, or the transportation cost is high, leasing empty container will be the only choice.

	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6	Port 7	Port a	Port b	Port c
Port 1	0	0	200	0	0	0	0	-	-	-
Port 2	0	0	90	0	0	0	0	-	-	-
Port 3	0	0	0	220	100	0	0	-	-	-
Port 4	0	0	0	0	0	0	0	0	0	0
Port 5	0	0	0	0	0	0	0	-	-	-
Port 6	0	0	0	0	0	0	0	-	-	-
Port 7	0	0	0	0	0	30	0	-	-	-
Port a	-	-	-	110	-	-	-	0	0	0
Port b	-	-	-	0	-	-	-	0	0	0
Port c	-	-	-	0	-	-	-	10	5	0

Table 5: The Quantity of Empty Containers to be Repositioned in Direct Ship Route and Feeder

## Table 6: The Quantity of Rented and Stored Container in the Direct Ship Route and Feeder

ý				1			-			
	Port 1	Port 2	Port 3	Port 5	Port 6	Port 7	Port a	Port b	Port c	Port 4
Quan. of rented container	0	0	0	150	30	0	0	0	0	0
Quan. of stored container	0	0	0	0	0	0	0	0	0	0

Tuble 7. The Optimal Total Cost of RM								
Reposition c	ost	Leasing cost			Holding cost			
Direct ship route	Feeder	Direct ship route	Feeder	Hub port	Direct ship route	Feeder	Hub port	Sum
10425	225	1950	0	3000	0	0	0	15600

Table 8: The Optimal Total Cost of NRM								
Reposition of	cost	Leasing cost			Holding cost			
Direct ship	Foodor	Direct ship	Foodor	Hub	Direct ship route	Feede	Hub	Sum
route	recuei	route	recuei	port	Direct ship toute	r	port	

4875

6450

2800

0

27475

175

# Table 7: The Optimal Total Cost of RM

# 4.3 Sensitivity Analysis

0

7052

0

In this Section, we perform the sensitivity analysis on the effects of changes in the model parameters on the result. The sensitivity analysis is performed by changing each of the parameters and keeping the other parameters unchanged. According to the practice, the leasing cost, capacity of the ship route, and the empty container transportation cost have the great effect on the total cost. So in this paper, the sensibility analysis is mainly about the leasing cost, capacity of the ship route, and the empty container transportation cost.

# 4.3.1 The impact of leasing cost

According to the result showed in the former tables, only Port 4, Port 5 and Port 6 lease empty containers, so change the leasing cost of these ports will have a big effect on the total cost. The total cost in table 9 is based on the leasing cost of others ports have no change, for example, the leasing cost of Port 4 will change from 20 to 40, but the cost of other ports including port 5, and port 6 keep unchanged.

According the Table 9, when the leasing cost of Port 4, Port 5 and Port 6 increases, the total cost of the two models including RM and NRM both increase, but the increasing of the NRM is higher than RM, it's because under RM, empty container reposition is allowed, and once the leasing cost of one port increase, the empty container will be transshipped from other ports, if there are no available empty containers in other ports, leasing empty container from leasing market with lower price is also allowed.

Leasing Change of Port 4'		4's leasing cost	Change of Port 5's leasing cost		Change of Port 6's leasing cost	
Leasing	Total cost of	Total cost of	Total cost of	Total cost of	Total cost of	Total cost of
cost	RM	NRM	RM	NRM	RM	NRM
20	14850	26325	12350	23725	14550	26875
25	15600	27475	13600	24975	15450	27175
30	15600	28625	14850	26225	15600	27475
35	15600	29775	15600	27475	15750	27775
40	15600	30925	15600	28725	15900	28075

Table 9: The Effect of the Leasing Cost Change on the Total Cost on Ship Route

# 4.3.2 The impact of ship transportation capacity

In order to analyze the impact of ship transportation capacity in the direct ship route and feeder on the optimal results, the paper takes ship route from Port 4 to Port 5 in the direct ship route and from Port 4 to Port a in the feeder as examples. According to Table 10, when the capacity of ship route Port 4 to Port 5 and Port 4 to Port a is changed from 600 to 725, the total cost of RM become lower, and because there's no empty container repositioning is allowed in NRM, so the total cost of NRM keeps the same. It shows that the capacity of the ship route will have a big influence on the total cost of RM, and if the capacity of the ship route can't meet the demand of empty container reposition, it will weaken the effect of the RM.

Direct ship route (Port 4 to Port 5)			Feeder(Port 4 to Port a)			
Capacity	Total cost of RM	Cost of NRM	Capacity	Total cost of RM	Total cost of NRM	
600	16100	27475	170	19850	27475	
625	15975	27475	195	18725	27475	
650	15850	27475	220	17600	27475	
675	15725	27475	245	16475	27475	
700	15600	27475	260	15850	27475	
725	15600	27475	285	15600	27475	

## Table 10: The Effect of the Ship Route's Capacity Change on the Total Cost on Ship Route

## 4.3.3 The impact of transportation cost

In order to analyze the sensibility of transportation cost in direct ship route and feeder, respectively, the paper takes ship route Port 4 to Port 5 in the direct ship route and Port 4 to Port a in the feeder for instance. The result is showed in Table 11. From Table 11, we can find that as the transportation cost of ship route Port 4 to Port 5 and Port 4 to Port a increases, the total cost of RM and NRM increases. But it is the change the transportation cost of ship route Port 4 to Port a brings a bigger change to the total cost of RM and NRM. That is because there are less ports in the feeder than the direct ship route.

Table 11: The Effect of the Empty Container Transportation Cost Ch	ange
on the Total Cost on Ship Route	

Dir	ect ship route (Port 4	to Port 5)	Feeder (Port 4 to Port a)			
Trans. Cost	Total cost of RM.	Total cost of NRM	Trans. Cost	Total cost of RM	Total cost of NRM	
10	15600	27475	5	15600	27475	
15	16100	27475	10	16100	27475	
20	16100	27475	15	16100	27475	
25	16100	27475	20	16600	27475	
30	16100	27475	25	16950	27475	
35	16100	27475	30	17300	27475	

# 5. Conclusions

In this paper, under the assumption that empty container shortage is not allowed, the empty container reposition is permitted between any port, the capacity of the ship is limited. A complex shipping system with multiple hub ports and multiple feeders in one direct ship route is considered. Finally, the numerical example shows that the total cost after empty container reposition is much lower. As the leasing cost becomes lower, the quantity of rented empty container increases, but the quantity of empty container decrease; as the capacity of ships becomes lower, the transshipped empty container decreases.

There are some future research fields based on this paper. This paper is based on the fixed allocation of the feeder ports to the hub ports, in the future work, the allocation decision of the feeder port to hub port can be considered. In this paper, the parameters used in the models (such as empty container demand, empty container supply, ship transportation time, ship transportation capacity, etc) are considered as certain parameters. The uncertainty of these parameters should be considered in the future.

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# Investigating the Impacts of Introducing Emission Trading Scheme to Shipping Industry

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## Abstract

Although international shipping is the most energy efficient means of transportation in terms of unit  $CO_2$ emission per tone-mile cargo shipped, due to enormous cargo volume and continuous growth, it still contributes a significant part of global emissions. In order to reduce the CO<sub>2</sub> emission from the international shipping industry, International Maritime Organization (IMO) is considering possible market-based measures (MBM). One of the most promising alternatives is the Emission trading Scheme (ETS). Our study thus proposes an economic model to theoretically analyze and benchmarks two different ETS mechanisms for international maritime transport industry, namely an open ETS scheme and a Maritime only ETS (METS) scheme. The model is also calibrated using maritime industry real operational data in year 2007. Our study quantifies the differential impacts of ETS on container shipping and dry bulk shipping sectors. It is suggested that ETS scheme, whether open or maritime only, will decrease ship's cruising speed, throughput and fuel consumption for both container and bulk sectors. Under open ETS scheme, we find that dry-bulk sector will have higher proportional output reduction and sell more (or use less) emission permits. Under maritime only ETS, the emission permit trading price is endogenously determined, and the emission reduction objective will definitely be reached. Container carriers will buy emission permits from the dry-bulk side. The collusiveness of one sector will only affect itself in open ETS, while it will affect the other less colluded sector in the METS. Specifically, when the sector that sells (buys) permits in METS is more collusive (competitive), the permit price will rise.

Keyword: Shipping industry, open and closed Emission Trading Scheme (ETS), economic modeling

## 1. Introduction and Background

Due to the perceived serious consequences of global warming and the scientific evidence on the link between the trend of global temperature and the CO<sub>2</sub> concentration in the atmosphere, reducing CO<sub>2</sub> emission has become an common effort of human beings in this planet. International shipping is the most energy efficient means of transportation in terms of units of emission per tome-mile cargo shipped. However, due to the enormous cargo volume, it still contributes a significant part of the global CO<sub>2</sub> emission. According to International Maritime Organization (IMO), international shipping emitted 870 million tons of CO<sub>2</sub> in year 2007, or about 2.7 percent of global CO<sub>2</sub> emissions from fuel consumption. Considering the growth of maritime transport due to world economic development, CO<sub>2</sub> emissions from this sector is expected to triple by 2050. From this perspective, emission reduction from shipping can also have significant contribution to the global CO<sub>2</sub> reduction. Therefore, Marine Environment Protection Committee (MEPC) of IMO identified and developed policy options to reduce Green-House-Gas (GHG) emissions from ships. Many technical and operational measures have been formulated by MEPC, such as Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), and Energy Efficiency Operational Indicator (EEOI). To motivate the shipping industries in adopting most efficient methods, IMO is also considering possible marketbased measures (MBM) in international shipping, and one of the most promising alternatives in this category is the Emission Trading Scheme (ETS) (Kageson, 2007; Miola et al, 2011)

Even though, there are still many issues that need to be considered in design and implementation of the ETS. First, an ETS can be "open" or "closed". In an open system, shipping companies can trade emission permits with other sectors, while in closed ETS they can only trade among themselves. The implication of applying different ETS on the realization of emission reduction objectives in the shipping industry has be to taken into account. Second, the shipping industry is not homogeneous. Different types of cargo are carried in specialized ships with different costs, energy efficiency, have different market price and market structure. For example, compared with container ships, on average, dry-bulk ships are older, less expensive and less energy efficient. The cargo it carried has lower value, thus the ship speed is generally lower. In terms of market structure, container shipping market is believe to be more colluded because of its high concentration, and the existence of liner conferences and alliances. It is necessary to take into account the differences in different shipping sectors, and understand the different impacts of ETS implementation on the operation of individual sector, as well as the resulted changes in the production and consumption pattern, and the shift of international trade.

Many existing studies in ETS in shipping focused on the advantages and flexibility of regional or sub-global scheme (Gilbert and Bows, 2012), allocation mechanism of emission permits (Haites, 2009; Kageson, 2007; Hepbrun et al, 2006). In general ETS, there are also studies that focusing on the impact of ETS on firm performance (Montomery, 1972; Bode, 2006; Demailly & Quirion, 2006), and many found that ETS may benefit companies (Sijm et al, 2006; Smale et al, 2006; Veith et al, 2009; Oberndorfer, 2009; Kim et al, 2009) as a result of the "Windfall Profit" in free allocation of excessive permits.

In this paper, we analytically investigate and benchmark two different ETS mechanisms for international maritime transport sector, namely an open ETS scheme and a closed Maritime only scheme (METS). The analytical results can shed light on the effectiveness of ETS to achieve emission reduction objectives in international shipping sector. More importantly, our study quantifies the differential impacts of ETS on maritime sectors, such as container shipping and dry bulk shipping, and examined the differential impacts on shipping quantity, speed, fuel consumption, and their profits.

Our modeling results suggest that ETS scheme, whether open or closed, will decrease ship's cruising speed, throughput and fuel consumption for both container and bulk groups. The level of reduction has negative relationship with permit prices. Under open ETS scheme, the emission reduction requirement is not binding, because shipping company can always buy permits if the allocated permits are not enough. In addition, we find that dry-bulk sectors will have higher proportional output reduction and sell more (or use less) permits. The profit of container shipping sector is less sensitive to the increase of permit price due to its low competitiveness. Under maritime only ETS, the emission reduction objective will definitely be reached. The permit price will have the same impact on the shipping quantity, speed and fuel consumption as in the open ETS case. The only difference is that market structure will have more significant impact than the open case. The collusiveness of one sector will only affect itself in open ETS, while it will affect the other less colluded sector in the closed ETS, as the other sector has to face the high permit price in the closed market. The economic model is calibrated with real shipping industry data. The empirical findings confirm the analytical results and also predict that container sector will buy the emission permits from dry-bulk side under maritime only ETS.

This paper is organized as follows. Section 2 sets up basic model and solves the equilibrium for benchmark case without ETS scheme. In Section 3 we solve the equilibrium for an open ETS scheme case and compare the results with benchmark case. Section 4 considers a Closed Maritime Only ETS scheme consisting of container and bulk shipping sectors. Equilibrium of the emission trading behavior between the two sectors are derived and compared with other cases. Section 5 will illustrate the model's calibration and discuss the empirical results. Section 6 provides concluding remarks.

#### 2. Economic Model and Benchmark Case

Among all the international maritime transport groups, dry bulk sector<sup>i</sup> has the largest share in tonnage of cargo shipped, and container sector has the fastest growth rate (Figure 1). To simplify the analysis, we consider these two sectors only in this study<sup>ii</sup>. Since these two sectors use different ships, carry different goods and have different operation costs, the impacts of ETS on them are different. In addition, our analysis is general, but can be applied to analyze route specific problem, since maritime ETS might be regional or multi-regional.



Figure 1: Share of Three Major Cargo Categories (measured in weight) and Their Growth Indices (Year 1980=100)

Source: Review of Maritime Transport 2011, UNCTAD

We consider the case where there are  $N_1$  ( $N_2$ ) carriers providing homogenous container (bulk) shipping services between Europe and Asia. Before ETS is introduced, the annual demands for container shipping and bulking shipping are independent (not substitutable), which can be modeled with the following demand functions.

$$P_1 = a_1 - b_1 \sum_{i=1}^{N_1} q_{1,i} \qquad i = 1, \dots N_1 \text{ and } N_1 \ge 1$$
(1.1)

$$P_2 = a_2 - b_2 \sum_{i=1}^{N_2} q_{2,i} \qquad i = 1, \dots N_2 \text{ and } N_2 \ge 1$$
(1.2)

where  $q_{r,i}$  is carrier *i*'s outputs / traffic volumes (r = 1 for container carrier; r = 2 for bulk carrier), while  $P_r$  is the market shipping price.  $t_{r,i}$  is the transport/shipping time for carrier *i*. If the average distance travelled by a ship is  $D_r$ , the average cruising speed is  $S_{r,i}$  for carrier *i*, then we have  $t_{r,i} = D_r/S_{r,i}$ .

Before ETS scheme is introduced, a carrier's cost for one ship per year is the sum of fuel cost  $f_{r,i}$  and capital cost of the ship  $\gamma_{r,i}$ .<sup>iii</sup> Following Psaraftis (2008, 2009), fuel cost can be expressed as a cubic function of ship cruising speed as specified in equation (2), where  $\lambda_r$  is a coefficient representing a ship's energy efficiency which depends on ship operation. And  $\eta$  is fuel price.  $f_{r,i} = \eta \lambda_r S_{r,i}^3$  (2)

The lower the value of  $\lambda_r$ , the higher the energy efficiency, because it requires lower cost for given  $S_{r,i}$ . The annualized fixed cost of a ship,  $\gamma_r$ , is assumed to be fixed, which includes the capital and financial costs, periodical maintenance cost, and operation cost.

Further we assume that the objective of the carrier is to maximize profit by choosing the optimal quantity and cruising speed. Then the problem of the carrier can be written as:

$$max_{q_{r,i},S_{r,i}} \pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r) \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r}$$
(3)

Where  $U_r$  is the average capacity of a ship and  $\rho$  is a ship's average proportion of working days in a year.  $P_r q_{r,i}$  is the yearly total revenue.  $f_{r,i} + \gamma_r$  is the total operating cost per ship in one year, equaling fuel cost plus the ship capital cost.  $\frac{q_{r,i}}{U_r S_{r,i} \rho/D_r}$  is the total number of ships utilized per year<sup>iv</sup>. The corresponding first order conditions (FOCs) for (3) are:

$$\frac{\partial \pi_{r,i}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j \neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j \neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{1}{U_r S_{r,i} \rho/D_r} [\eta \lambda_r S_{r,i}^3 + \gamma_r] = 0$$
(4.1)

$$\frac{\partial \pi_{r,i}}{\partial S_{r,i}} = -\frac{q_{r,i}}{U_r \rho/D_r} \left[ 2 \eta \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2} \right] = 0$$
(4.2)

Referring to Brander and Zhang (1990, 1993), Fu et al (2006), Basso and Zhang (2008), we introduce Conduct parameter  $v_{ri,i}$  in FOC (4.1), and we assume  $v_{ri,i}$  is a constant value<sup>v</sup>.

$$u_{ri,j} = \sum_{j \neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}}, \quad -1 \le \nu_{ri,j} \le N_r - 1$$

This conduct parameter  $v_{ri,j}$  measures how aggressively one firm competes with each other in the same market. When  $-1 \le v_{ri,j} \le 0$ , the more negative the  $v_{ri,j}$ , the more fierce the competition is between two firms. While, when  $0 \le v_{ri,j} \le N_r - 1$ , the more positive the  $v_{ri,j}$ , the more cooperative the two firms are. Specifically,  $v_{ri,j} = 0$  corresponds to Cournot competition;  $v_{ri,j} = -1$  corresponds to Bertrend competition;  $v_{ri,j} = N_r - 1$  corresponds to Perfect collusion to maximize joint profit. (See Appendix 1 for detailed illustration). As well, the second order condition (SOC) for (3) is also checked and proves to satisfy (see Appendix 2).

As we assume non-negative optimal traffic quantity, the FOC (4.2) can be transformed as (4.3)  $2\eta\lambda_r S_{r,i}^3 - \gamma_r = 0$ (4.3)

Imposing symmetry so that  $q_{r,1} = q_{r,2} = \cdots = q_{r,N_r} = q_r$ ;  $S_{r,1} = S_{r,2} = \cdots = S_{r,N_r} = S_r$ ;  $v_{ri,j} = v_{ri,g} = v_{r,i}$ ,  $i \neq j \neq g$ ; and further  $v_{r,1} = v_{r,2} = \cdots v_{r,N_r} = v_r$ , then the equilibrium speed and quantity for a carrier can be solved as:

$$\tilde{S}_r = \sqrt[3]{\frac{\gamma_r}{2\eta\lambda_r}} > 0 \tag{5.1}$$

$$\tilde{q}_r = \frac{2a_r U_r \rho - 3D_r \sqrt[3]{2\eta \lambda_r \gamma_r^2}}{2U_r \rho b_r [(N_r + 1) + \nu_r]}$$
(5.2)

From (5.1), it is clear that the optimal speed is a function of the fixed cost and energy efficiency of the ship, as well as the fuel price. From this, one can see that ship speed is lower if a ship has lower fixed cost, lower efficiency (higher  $\lambda_r$ ), and higher fuel price.

The fuel consumption volume at equilibrium can be obtained as

$$\tilde{F}_{r} = \lambda_{r} \tilde{S}_{r}^{3} \frac{\tilde{q}_{r}}{U_{r} \rho \tilde{S}_{r}/D_{r}} = \frac{\sqrt[3]{2\lambda_{r} \gamma_{r}^{2} D_{r} (2a_{r} U_{r} \rho - 3D_{r} \sqrt[3]{2\eta \lambda_{r} \gamma_{r}^{2}})}{4\sqrt[3]{\eta^{2}} U_{r}^{2} \rho^{2} b_{r} [(N_{r}+1)+\nu_{r}]}$$
(5.3)

(6)

The non-negativity of shipping quantity  $\tilde{q}_r$  and fuel consumption  $\tilde{F}_r$  implies that  $2a_r U_r \rho > 3D_r \sqrt[3]{2\eta \lambda_r \gamma_r^2}$ 

In addition, it is direct to show following comparative statics results (see Appendix 3)  $\frac{\partial \tilde{q}_r}{\partial \eta} < 0, \frac{\partial \tilde{q}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{q}_r}{\partial D_r} < 0, \frac{\partial \tilde{q}_r}{\partial \nu_r} < 0, \frac{\partial \tilde{q}_r}{\partial U_r} > 0, \frac{\partial \tilde{q}_r}{\partial \gamma_r} < 0; \frac{\partial \tilde{s}_r}{\partial \eta} < 0, \frac{\partial \tilde{s}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{s}_r}{\partial \gamma_r} > 0; \frac{\partial \tilde{s}_r}{\partial \gamma_r} < 0$ (7)

The signs for  $\frac{\partial \tilde{F}_r}{\partial \lambda_r}$ ,  $\frac{\partial \tilde{F}_r}{\partial U_r}$  are unclear.

The interpretations of above comparative statics are straightforward: when fuel price increases or the fuel efficiency is lower, carriers will slow their cruising speed to save fuel cost, thus resulting lower total fuel consumption and traffic quantity. When ship capital cost increases, carriers increase cruising speed to reduce the number of ships used and save on ship capital costs. Despite higher speed, total traffic volume decreases as a result of increasing ship capital cost, indicating shipping carriers reduce the number of ships in larger degree. Besides, when market is more collusive, carriers will reduce capacity deployed in the market so as to raise the price, thus achieving higher profit. It is noted that the optimal cruising speed is affected neither by market competition type, average shipping distance nor the average ship size. This is because that cruising speed is not a strategic variable for carrier to compete with each other. Carriers set optimal cruising speed in order to minimize operating cost given throughput, average route distance and ship size (as shown in FOC (4.2)).

#### 3. An Open ETS scheme

In this case, maritime carriers need to buy/sell emission permit with other industries. This implies that the market price of emission permit is (mostly) exogenous. In such a case, ETS is equivalent to a uniform charge on emission, which can be a positive tax/charge (if carriers buy emission permit) or negative subsidy (if carriers sell emission permit). Since there is a definite relationship between fuel consumption and gas emission, ETS is equivalent to a tax/subsidy on fuel consumption. Assuming that each carrier is pre-allocated a quota of free emission which is  $\theta$  ( $0 < \theta < 100\%$ ) percentage of her existing fuel consumption, a shipping firm's profit maximization problem is defined as follows for the case of a container carrier r = 1 or a bulk carrier r = 2, where  $\chi > 0$  is the exogenously determined ETS charge per ton of fuel.  $max_{q_{r,i},S_{r,i}} \pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r) \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} - \chi[\lambda_r S_{r,i}^3 \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} - \theta \tilde{F}_r]$  (8)

Since container and bulk shipping sector trade with the open ETS separately, the solutions for these two sectors are independent. The outcomes of trade are determined exogenously by emission permit price  $\chi$  and the target of emission reduction percentage  $(1 - \theta)$ .

The corresponding FOCs for maximization problem (8) are:  

$$\frac{\partial \pi_{r,i}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j \neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j \neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{1}{U_r S_{r,i} \rho/D_r} [(\eta + \chi)\lambda_r S_{r,i}^3 + \gamma_r] = 0$$
(9.1)

$$\frac{\partial \pi_{r,i}}{\partial S_{r,i}} = -\frac{q_{r,i}}{U_r \rho/D_r} \left[ 2 \left(\eta + \chi\right) \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2} \right] = 0$$
(9.2)

Imposing symmetry so that  $q_{r,1} = q_{r,2} = \cdots = q_{r,N_r} = q_r$ , and  $S_{r,1} = S_{r,2} = \cdots = S_{r,N_r} = S_r$ ;  $v_{ri,j} = v_{ri,g} = v_{r,i} = v_r$  ( $i \neq j \neq g$ ); the equilibrium quantity and cruising speed for container shipping group can be solved:

$$\bar{q}_r = \frac{2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta + \chi)\lambda_r \gamma_r^2}}{2U_r \rho b_r [(N_r + 1) + \nu_r]}$$
(10.1)

$$\bar{S}_r = \sqrt[3]{\frac{\gamma_r}{2(\eta + \chi)\lambda_r}} > 0 \tag{10.2}$$

And fuel consumption:

$$\bar{F}_{r} = \frac{\sqrt[3]{2\lambda_{r}\gamma_{r}^{2}}D_{r}(2a_{r}U_{r}\rho - 3D_{r}\sqrt[3]{2(\eta+\chi)\lambda_{r}\gamma_{r}^{2}})}{4\sqrt[3]{(\eta+\chi)^{2}}U_{r}^{2}\rho^{2}b_{r}[(N_{r}+1)+\nu_{r}]}$$
(10.3)

The non-negativity of  $\bar{q}_r$  and  $\bar{F}_r$  implies that  $2a_r U_r \rho > 3D_r \sqrt[3]{2(\eta + \chi)\lambda_r \gamma_r^2}$ (11)

Comparing solutions in (10) and (5), under the open ETS, it is observed that the equilibrium solutions in (10) are equivalent to adding the emission permit price  $\chi$  to fuel price  $\eta$ . From (7), we know  $\frac{\partial \tilde{q}_r}{\partial \eta} < 0$ ,  $\frac{\partial \tilde{s}_r}{\partial \eta} < 0$  and
$\frac{\partial \bar{F}_r}{\partial \eta} < 0$ . Therefore, it is clear that under the open ETS scheme, for any  $\theta < 1$ , the fuel consumption, traffic quantity and cruising speed for the shipping industry will reduce if there is any positive price for the emission permit. And the degree of reduction simply depends on the exogenous determined emission permit price  $\chi$ . Specifically, the larger  $\chi$  is, the more the fuel consumption, traffic quantity and cruising speed decrease.

Although the target emission reduction percentage $(1 - \theta)$  does not affect the equilibrium fuel consumption volume, traffic quantity and cruising speed (as  $\theta$  does not enter the FOCs for optimization problem (8)),  $\theta$  determines the trading behavior of the shipping industry with other sectors under the open ETS scheme. We define  $\theta'_r$  as the ratio of fuel usage in the open ETS scheme with that in no ETS, i.e.,

$$\theta_r' = \frac{\bar{F}_r}{\bar{F}_r} = \sqrt[3]{\left(\frac{\eta}{\eta+\chi}\right)^2} \frac{(2a_r U_r \rho - 3D_r \sqrt[3]{2(\eta+\chi)\lambda_r \gamma_r^2})}{(2a_r U_r \rho - 3D_r \sqrt[3]{2\eta\lambda_r \gamma_r^2})} < 1$$
(12)

Since  $\theta'_r$  is a decreasing function of  $\chi$ . When the price of emission permit ( $\chi$ ) increases, carriers have more incentive to reduce fuel usage and sell emission permits. Also, it is interesting to note that  $\theta'_r$  is irrelevant to market competition condition determined by number of shipping firms or their conduct parameters. This indicates that the market structure will not alter the emission abatement behavior of the two sectors.

Due to the fact that most of the containerships are newer than dry-bulk ships, it is generally believed that containers are more expansive and fuel efficient than dry-bulk ships. Then it is possible to analysis the different impacts of open ETC on the two shipping sectors. To examine the proportional throughput and output reduction due to ETS, we define the proportional reduction in throughput and speed as (13.1) and (13.2) respectively:

$$R_r = \frac{\tilde{q}_r - \bar{q}_r}{\tilde{q}_r} \tag{13.1}$$

Take partial derivatives of  $\overline{q}_r$  and  $\theta'_r$  w.r.t.  $\gamma_r$  and  $\lambda_r$ , we can obtain:

 $\frac{\partial R_r}{\partial \gamma_r} < 0$  and  $\frac{\partial R_r}{\partial \lambda_r} > 0$ , means that, *ceteris paribus*, containerships have less proportional reduction in shipping output.

$$\frac{\partial \theta'_r}{\partial \gamma_r} > 0$$
 and  $\frac{\partial \theta'_r}{\partial \lambda_r} < 0$ , mean that, *ceteris paribus*, container ships will use more fuel (sell less)

Of course, this theoretical analysis using comparative statics method does not take into account the difference in actual market demand, shipping distance, average ship size, etc, between two sectors. Nevertheless, the result is consistent with general expectation about the two sectors.

$$T_r = \frac{\tilde{q}_r - \bar{q}_r}{\tilde{q}_r} \tag{13.2}$$

Substituting (5.2) and (10.1) into (13.2) we get  $T_r = 1 - \sqrt[3]{\frac{\eta}{(\eta + \chi)}}$ . It is interesting to observe that  $T_r$  is only dependent on fuel price  $\eta$  and permit price  $\chi$ , implying that container ship and dry-bulk ship will have same proportional speed reduction.

The implementation of the common ETS scheme can affect the profit for the shipping industry when compared with the benchmark case (no ETS scheme). Substitute the  $\bar{q}_r$ ,  $\bar{S}_r$ ,  $\bar{F}_r$  back into the profit function, and totally differentiate that with respect to the permit price  $\chi$ , we get:

$$\frac{d\bar{\pi}_{r,i}}{d\chi} = \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial q_{r,i}}}_{=0} \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial \chi}}_{\geq 0} + \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial q_{r,j}}}_{\geq 0} \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial \chi}}_{=0} + \underbrace{\frac{\partial\bar{\pi}_{r,i}}{\partial \chi}}_{\geq or<0}$$
(14)

$$= (v_r - N_r + 1)b_r \bar{q}_r \frac{\partial \bar{q}_r}{\partial \chi} - [\lambda_r \bar{S}_r^3 \frac{\bar{q}_r}{U_r \bar{S}_r \rho/D_r} - \theta \tilde{F}_r]$$

Since  $v_r \leq N_r - 1$  and  $\frac{\partial \bar{q}_r}{\partial \chi} < 0$ , the first expression  $(v_r - N_r + 1)b_r \bar{q}_r \frac{\partial \bar{q}_r}{\partial \chi}$  is non-negative. This can be regarded as "Freight market" effect, because the increase in  $\chi$  reduces  $\bar{q}_{r,j}(\chi)$  of a carrier, which will result in larger increasing freight rate due to this aggregated effects. The second term,  $-[\lambda_r \bar{S}_r^3 \frac{\bar{q}_r}{U_r \bar{S}_r \rho / D_r} - \theta \tilde{F}_r]$ , can be regarded as "Emission Market" effect, which is negative when a shipping company buys permits and positive when a shipping company sells emission permits. If the market is more elastic, or the price of the emission permit is small, the sign for  $\frac{d\bar{\pi}_{r,i}}{d\chi}$  will be positive.

From (14), it is also clear that the change of the profit with respect to emission permit price is only depends on parameters  $\theta$ ,  $v_r$  and  $N_r$ . Therefore, it can be concluded that:

For Perfect collusion case ( $\nu_r = N_r - 1$ ), shipping firms' profits will decrease with  $\chi$  and be lower than benchmark case for any given  $\theta$ . For Bertrand competition case ( $\nu_r = -1$ ), shipping firms' profits will always be higher than the benchmark case. For Cournot competition case ( $\nu_r = 0$ ), when  $\theta < \frac{2}{N_r+1}$ , the profit change pattern is the same as the Perfect collusion case, while for  $\theta \ge \frac{2}{N_r+1}$ , the profit change pattern is the same as the Bertrand competition case.

#### 4. A Maritime Only ETS scheme (METS)

In the case of METS, the main difference is that the price of emission permit is no longer exogenously determined. Instead, it is the result of emission trade between the container and bulk sectors. In addition, the allowable emission ( $\theta < 1$ ) is proportional to her existing fuel consumption and given for free. Since the problem is to compare the different impacts on the two sectors with or without emission trade under the same emission reduction objective, the analysis can start with the emission reduction without the trade.

Since the allocation of free permits is proportional, the optimal solution is to use all the free permits when there is no trade. Therefore, the problem for each sector is a maximization problem with binding constraint:  $max_{q_{r,i},S_{r,i}} \pi_{r,i} = P_r q_{r,i} - (f_{r,i} + \gamma_r) \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r}$ (15)

s.t. 
$$\lambda_r S_{r,i}^3 \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} = \theta \tilde{F}_r$$

By introducing the Lagrangian multiplier  $\phi_{r,i} > 0$ , we can specify the corresponding Lagrangian function as follows.

$$L_{\phi_{r,i}} = P_r q_{r,i} - (f_{r,i} + \gamma_r) \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} - \phi_{r,i} [\lambda_r S_{r,i}^3 \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} - \theta \tilde{F}_r]$$
(16)

The corresponding FOCs for the Lagrangian function (16) in  $q_{r,i}$ ,  $S_{r,i}$ , and  $\phi_{r,i}$  can be derived as follows:

$$\frac{\partial L_{\phi_{r,i}}}{\partial q_{r,i}} = a_r - 2b_r q_{r,i} - b_r \sum_{j \neq i}^{N_r} q_{r,j} - b_r q_{r,i} \sum_{j \neq i}^{N_r} \frac{\partial q_{r,j}}{\partial q_{r,i}} - \frac{1}{U_r S_{r,i} \rho/D_r} [(\eta + \phi_{r,i})\lambda_r S_{r,i}^3 + \gamma_r] = 0$$
(17.1)

$$\frac{\partial L_{\phi_{r,i}}}{\partial S_{r,i}} = -\frac{q_{r,i}}{U_r \rho/D_r} \left[ 2 \left(\eta + \phi_{r,i}\right) \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2} \right] = 0$$
(17.2)

$$\frac{\partial L_{\phi_{r,i}}}{\partial \phi_{r,i}} = \lambda_r S_{r,i}^3 \frac{q_{r,i}}{U_r S_{r,i} \rho/D_r} - \theta \tilde{F}_r = 0$$
(17.3)

Imposing symmetry, and solving (17.1) and (17.2) for optimal quantity and speed as a function of  $\phi_r$ , and substituting them into (17.3), we have following important equation:

$$\theta \tilde{F}_r = \frac{\sqrt[3]{2\lambda_r \gamma_r^2 D_r (2a_r U_r \rho - 3D_r \sqrt[3]{2}(\eta + \phi_r)\lambda_r \gamma_r^2)}}{4\sqrt[3]{(\eta + \phi_r)^2 U_r^2 \rho^2 b_r [(N_r + 1) + \nu_r]}}$$
(18)

The parameter  $\phi_r$  is the shadow price of emission permit constrain. It indicates the contribution to the profit of the shipping company by relaxing the emission constraint by one unit, i.e.  $\frac{d\hat{\pi}_r}{d(\theta \tilde{F}_r)} = \hat{\phi}_r$ .

From economic reasoning, it is straightforward that when  $\hat{\phi}_1$  and  $\hat{\phi}_2$  are different, both container and bulk sectors have incentive to trade. The shipping group with higher  $\hat{\phi}_r$  will buy emission permits as long as the price is lower than  $\hat{\phi}_r$ . Any trading price *h* between  $\hat{\phi}_1$  and  $\hat{\phi}_2$  will lead to a Pareto improvement in two sectors compared with no trading.

From this, we can see that the direction of emission transfer between two sectors. At the equilibrium (no sector has incentive to trade), the shadow price of the two sectors are equal, i.e.:

$$\int \theta \tilde{F}_1 + \overline{\Delta} = \frac{\sqrt[3]{2\lambda_1 \gamma_1^2} D_1(2a_1 U_1 \rho - 3D_1 \sqrt[3]{2(\eta + \overline{h})\lambda_1 \gamma_1^2})}{4\sqrt[3]{(\eta + h)^2} U_1^2 \rho^2 b_1[(N_1 + 1) + \nu_1]}$$
(19.1)

$$\theta \tilde{F}_2 - \frac{N_1 \bar{\Delta}}{N_2} = \frac{\sqrt[3]{2\lambda_2 \gamma_2^2 D_2 (2a_2 U_2 \rho - 3D_2 \sqrt[3]{2(\eta + \bar{h})\lambda_2 \gamma_2^2})}}{4\sqrt[3]{(\eta + h)^2 U_2^2 \rho^2 b_2 [(N_2 + 1) + \nu_2]}}$$
(19.2)

When container and bulk groups trade at price  $\bar{h}$ , the traffic quantity, cruising speed and fuel consumption at the equilibrium are:

$$\hat{q}_{r} = \frac{2a_{r}U_{r}\rho - 3D_{r}\sqrt[3]{2(\eta+\bar{h})\lambda_{r}\gamma_{r}^{2}}}{2U_{r}\rho b_{r}[(N_{1}+1)+\nu_{r}]}, \hat{S}_{r} = \sqrt[3]{\frac{\gamma_{r}}{2(\eta+\bar{h})\lambda_{r}}}, \hat{F}_{r} = \frac{\sqrt[3]{2\lambda_{r}\gamma_{r}^{2}D_{r}(2a_{r}U_{r}\rho - 3D_{r}\sqrt[3]{2(\eta+\bar{h})\lambda_{r}\gamma_{r}^{2}})}}{4\sqrt[3]{(\eta+\bar{h})^{2}}U_{r}^{2}\rho^{2}b_{r}[(N_{1}+1)+\nu_{r}])}$$
(20)

Equations (20) are very similar to equilibrium results in the open ETS case (equation 10), except that the exogenous permit price in (10) are replaced by the equilibrium permit price. From this, we can see that the impact of the equilibrium price will have the same impact on the performance of the two sectors.

Since the emission permit is a valuable resource, from economic intuition, the shadow price for both sectors will increase with lower free emission permit quota, which will lead to higher price for emission permit. This can be illustrated by Figure 2, where the black curves stand for the shadow price with emission permit  $\theta_2$ , and the red curves are those with lower emission permit  $\theta_1 < \theta_2$ . It is clear that the market price for emission permit will be higher with lower emission permit.

# Figure 2: Change of $\overline{h}$ with $\theta$ ( $\theta_1 < \theta_2$ )



To understand how the market structure affects the emission trading price, using (5.3), (19.1) can be rearranged into  $\frac{\sqrt[3]{2\lambda_1\gamma_1}^2 D_1}{4U_1^2 \rho^2 b_1[(N_1+1)+\nu_1]} \left[ \frac{\left(2a_1U_1\rho - 3D_1\sqrt[3]{2(\eta+\phi_1)\lambda_1\gamma_1}^2\right)}{\sqrt[3]{(\eta+\phi_1)^2}} - \theta \frac{2a_1U_1\rho - 3D_1\sqrt[3]{2\eta\lambda_1\gamma_1}^2}{\sqrt[3]{\eta^2}} \right] = \Delta_1. \text{ Thus, } \forall \Delta_1 > 0,$  it is apparent that  $\phi_1$  increases when  $\nu_1$  decreases (see Figure (5)) thus the resultant  $\overline{h}$  is higher. Similarly, by

it is apparent that  $\phi_1$  increases when  $\nu_1$  decreases (see Figure (5)), thus the resultant  $\bar{h}$  is higher. Similarly, by rearranging (19.2), it can be proved that  $\phi_2$  and resultant  $\bar{h}$  increases when  $\nu_2$  increases.



It is easy to understand that when market is more competitive for the shipping sector buying emission permit, the emission permit price will be pushed up because carriers are more aggressive to acquire the permits so as to compete more effectively in the market. While for the shipping sector selling the emission permit, increasing market collusion may help carriers to have larger bargaining power in order to negotiate a higher permit price with the other shipping sector.

Finally, comparing the results of the open ETS and METS, it is clear that the impact on the shipping industry are the same only if the emission trading price in these two schemes are equal. The only difference is that the  $\chi$  is exogenous, while *h* is determined by the shipping sectors mutual trading and by the target emission reduction objective 1- $\theta$ .

#### 5. Model Calibration and Empirical Results

To simulate the economic impacts of ETS on the shipping industry, the above economic model needs to be calibrated. Real market data for international shipping in year 2007 is adopted for this numerical simulation. Ship's average cruising speed and size are calculated using data from Buhaug et al. (2009) (see Appendix 4). Container ship has an average speed  $\tilde{S}_1 = 25$  knots / hr<sup>vi</sup>, while dry-bulk ship's speed is  $\tilde{S}_2 = 14$  knots / hr. The average ship size is  $U_1 = 23,000$  tons for container ship, and  $U_2 = 49,000$  tons for dry bulk ship. In addition, we assume that a ship works 270 days per year ( $\rho = 0.74$ ).

Aggregate shipping throughput data is available from Review of Maritime Transport 2008 published by UNCTAD. In year 2007, container sector carried  $\tilde{Q}_1 = 1,264,000,000$  tons of cargo, and dry-bulk sector carried  $\tilde{Q}_2 = 4,023,000,000$  tons. From the Review of Maritime Transport 2008, the average freight rate for container sector is calculated to be  $\tilde{P}_1 = 240$  USD / ton for an average voyage distance  $D_1 = 9,093$  nautical miles (see Appendix 5). Ship bunker fuel price is assumed to be  $\eta = 250$  USD/ton. Capital cost per ship  $\gamma_r$  is a catch-all cost item for all cost items except the fuel. It is assumed that  $\gamma_1 = 100,000$  USD / day for container ship<sup>vii</sup>. Because data for dry-bulk sector is rather incomplete, it is thus assumed that dry-bulk ship has the same route distance as container ship ( $D_2 = 9,093$  nautical mils), but dry-bulk freight rate is only 1/5 of container freight rate ( $\tilde{P}_2 = 48$  USD / ton), and the capital cost for dry-bulk carrier is only 2/5 of the container ship's capital cost ( $\gamma_2 = 40,000$  USD / day)<sup>viii</sup>.

For model tractability, we assumed that there are  $N_r$  symmetric shipping firms. For container sector, worldwide capacity share of the top 15 container shipping operators correspond to a Herfindahl-Hirschman Index (HHI) of 995, equivalent to  $N_1 = 10$  symmetric firms competing in the market <sup>ix</sup>. For the dry-bulk market, it is assumed that there are  $N_2 = 20$  symmetric dry-bulk carriers in the market. Regarding market conduct parameter  $v_r$ , we assume  $v_1 = 0.8$  and  $v_2 = 0$ . This assumption reflects the fact that container shipping market is much more colluded, while dry-bulk market is more competitive. However, as our assumption on conduct parameter is rather subjective, a sensitivity test is thus conducted with different pairs of  $(v_1, v_2)$  in Section 5.3. The test result shows that changing values of conduct parameters confirms with the conclusions drawn from the calibration.

First, based on function (5.1), ship's energy efficiency parameter  $\lambda_r$  can be directly estimated as  $\lambda_1 = 6.95 \times 10^{-12}$  and  $\lambda_2 = 1.58 \times 10^{-11}$ . This result states that, given the same cruising speed, one container ship consumes less fuel than that of dry-bulk ship. However, as container and dry-bulk ships have different size, we need to adjust  $\lambda_r$  on the ship size so as to compare ship's fuel efficiency. Dividing  $\lambda_r$  by ship size, it is obtained that  $\frac{\lambda_1}{U_1} = 3.0 \times 10^{-16} < \frac{\lambda_2}{U_2} = 3.2 \times 10^{-16}$ . This implies that container ship is more fuel efficient than dry-bulk ship, which is in line with our expectation.

Finally, with the estimated  $\lambda_r$  and the following two equations (21) and (22), the unknown parameters in the demand function, the fuel consumption and profit with not ETS be estimated as summarized in Table 1.  $\tilde{P}_r = a_r - b_r \tilde{Q}_r$ (21)

$$\frac{\tilde{Q}_r}{N_r} = \tilde{q}_r = \frac{2a_r U_r \rho - 3D_r \sqrt[3]{2\eta\lambda_r \gamma_r^2}}{2U_r \rho b_r [(N_r+1)+\nu_r]}$$
(22)

Parameter	$a_1$	<i>a</i> <sub>2</sub>	$b_1$	<i>b</i> <sub>2</sub>
Value	835.69	117.67	$4.71 \times 10^{-7}$	$1.73 \times 10^{-8}$
Parameter	$ ilde{F}_1$	$\tilde{F}_2$	$ ilde{\pi}_1$	$ ilde{\pi}_2$
Value	$2.24 \times 10^{7}$	$1.19 \times 10^{7}$	$1.36 \times 10^{10}$	$7.01 \times 10^{8}$

Table 1: Derived Benchmark Case Model Parameter Values<sup>x</sup>

#### 5.1 Model calibration for Open ETS

The analytical model suggests that under open ETS, both container and dry-bulk sectors will have reduction in speed and throughput, and dry-bulk sector will have larger proportion of throughput reduction. This is can be seen from simulation result in Figure 4. It shows that container and dry-bulk sectors have the same proportion in speed reduction (Figure 4(a)). This observation is consistent with our prediction drawn from the analytical model (13.1) because this proportion is only dependent on fuel price and emission permit price. But as container ship has higher cruising speed, it will face larger speed reduction in magnitude. For throughput change, the dry-bulk sector has larger reduction in proportion. This can be explained when referring to (13.2): First, dry-bulk ship is less fuel efficient, making it more sensitive to fuel price increase  $x^i$  because it consumes more fuel *ceteris paribus*. Second, our calibration result shows that dry-bulk market is much more price elastic ( $b_2 < b_1$  and  $a_2 < a_1$ ) than container ship market, thus price increase due to ETS permit charge has a more severe negative impact on dry-bulk throughput .



From the analytical model, we also know that the emission reduction target  $(1 - \theta)$  is not binding for open ETS because carriers can trade permits with outside sectors. But the parameter  $\theta$  is important to decide carriers' permit trading behavior and also their profit. Figure 5 depicts the critical proportion  $\theta'_r$  derived from equation (12), while Figure 6 shows the change of carrier's profit with permit price  $\chi$  for different values of  $\theta$ . From Figure 5, it is clear that container sector always has higher  $\theta'_r$  than dry-bulk sector, indicating that

container carrier is more likely to buy emission permits than dry-bulk sector under open ETS. In addition, from Figure 6, it is clear that when carriers receive small amount of free permit allocation ( $\theta$ =0,0.1 and 0.2), their profits are more likely to decline under ETS. This is because carriers have to buy more permits from the open ETS market when receiving not enough free emission quota. This makes the negative "Emission Market" effect to dominant positive price rising "Freight Market" effect. However, when  $\theta$  is large enough, the positive price rising "Freight Market" effect will then prevail, making carriers to earn "Windfall Profit" under the open ETS. It is also noted that the profit for dry-bulk sector is much more impacted than the container



# Figure 5: Critical Proportion $\theta'_r$ with $\chi$





Figure 7: Proportional Change in Profit with  $\chi$  under Open ETS ( $\theta = 0.5$ )



#### 5.2 Model calibration for METS

Compared to open ETS, METS has the same impacts on international shipping sectors if emission permit prices are equal. However, under METS, the permit price is endogenously decided by the mutual permit

trading between container and dry-bulk sectors. With the estimated parameters, the shadow prices  $\hat{\phi}_r$ , and the resultant market clearance permit price  $\bar{h}$  can be simulated using equations (19). The simulation result is collated in Table 2. It should be noted that as the emission reduction target  $(1 - \theta)$  will always be binding under METS, regulator is thus unlikely to set a very rigorous emission reduction goal because small  $\theta$  will result in too much reduction in international shipping throughput<sup>xii</sup>. Therefore, we consider the range of  $\theta$  to be (0.6,0.95) for our simulation.

The simulation result essentially shows that the container sector always has higher fuel shadow price than that of dry-bulk sector ( $\hat{\phi}_1 > \hat{\phi}_2$ ). This indicates that under METS, container carrier will purchase emission permits from the dry-bulk sector. This result should be intuitive since the fuel is regarded as more valuable production materials for container sector because it has much higher freight rate and more fuel efficient vessels.

From numerical simulation, the impacts of emission free allocation amount and the market competition structure on METS equilibrium can be directly observed. The result is in line with the analytical model analysis demonstrated in Figure 2 and 3. Figure 8 and 9 are the numerical simulation for Figure 2 and 3 respectively. Figure 8 clearly shows that the permit clearance price  $\bar{h}$  increases when fewer emission quota is allocated. And in Figure 9, we see that the  $\bar{h}$  increases when the emission permit buyer (container sector) is more competitive (with lower  $\nu_1$ ); and when the emission seller (dry-bulk sector) is more collusive (with higher  $\nu_2$ ).

In addition, it is noted that the values of  $\hat{\phi}_r$ ,  $\overline{\Delta}$  and  $\overline{h}$  are significantly sensitive to the change in  $\theta$ . Small reduction of the permit allocation will result in significant change in market equilibrium of permit trading between container and dry-bulk sectors. Thus if METS is chosen by regulator, the value of  $\theta$  should be carefully designed so as not to impose too dramatic impact on international shipping industry.

Tuble 2: Equilibrium of METB for unreferent value	
$ heta = ar{h} = ar{\Delta} = ar{\phi}_1$	$\widehat{\phi}_2$
0.95 16.5 99,868 18.2	15.1
0.90 34.9 197,859 38.7	31.9
0.85 55.7 293,818 62.1	50.7
0.80 79.2 387,569 88.9	71.8
0.75 106.0 478,910 119.8	95.6
0.70 136.8 567,604 155.8	122.6
0.65 172.6 653,374 198.3	153.7
0.60 214.6 735,890 248.9	189.6

#### Table 2: Equilibrium of METS for different Values of θ

#### Figure 8: Simulated Change in METS Equilibrium with different θ



Figure 9: Simulated Change in METS Equilibrium with different  $v_i$ 



5.3 Sensitivity test for different conduct parameter combinations  $(v_1, v_2)$ 

To show that the above calibration result is robust when relaxing the assumption on conduct parameters, a sensitivity test is conducted using wide range of  $(v_1, v_2)$  combinations. The shadow price  $\hat{\phi}_r$  and clearance permit price  $\bar{h}$  are re-estimated shown in Table 3 and Table 4. It is clear that container sector always has higher shadow price than dry-bulk sector  $(\hat{\phi}_1 > \hat{\phi}_2)$ , indicating that container sector will always buy emission permits from the dry-bulk sector. The resultant clearance permit price  $\bar{h}$  does not alter too much in this sensitivity test. The conclusions of open ETS model calibration also do not alter under our sensitivity test, but to save space, the detailed result is eliminated but is available upon request.

$v_1$ or $v_2$	$\widehat{\phi}_1$	$\widehat{\phi}_2$
-0.8	97.9	92.1
-0.6	96.5	85.9
-0.4	95.2	80.5
-0.2	94.0	75.9
0.0	92.9	71.8
0.2	91.8	68.2
0.4	90.8	64.9
0.6	89.8	62.0
0.8	88.9	59.4

Table 3: Fuel shadow price for different  $(v_1, v_2), \theta = 0.8$ 

Table 4: Clearance Permit Price  $\overline{h}$  for different  $(v_1, v_2), \theta = 0.8$ 

						× 1/	<b>L</b> )/		
$\nu_2$ $\nu_1$	-0.8	-0.6	-0.4	-0.2	0.0	0.2	0.4	0.6	0.8
0.8	90.5	87.3	84.4	81.7	79.2	76.9	74.7	72.7	70.9
0.6	91.0	87.7	84.8	82.0	79.5	77.2	75.0	73.0	71.2
0.4	91.4	88.2	85.2	82.4	79.9	77.5	75.4	73.3	71.5
0.2	91.9	88.6	85.6	82.8	80.3	77.9	75.7	73.7	71.8
0.0	92.5	89.1	86.1	83.3	80.7	78.3	76.1	74.0	72.1
-0.2	93.0	89.6	86.6	83.7	81.1	78.7	76.4	74.4	72.4
-0.4	93.6	90.2	87.1	84.2	81.5	79.1	76.8	74.7	72.8
-0.6	94.2	90.7	87.6	84.7	82.0	79.5	77.3	75.1	73.1
-0.8	94.8	91.3	88.1	85.2	82.5	80.0	77.7	75.5	73.5

To summarize, dry-bulk sector faces larger proportional change in throughput and profit under the ETS. For the open ETS, container sector buy more or sell less emission permits and the dry-bulk sector is the opposite. For the METS, container sector has higher fuel shadow price and would purchase emission permit from dry-bulk sector. The market equilibrium for METS is sensitive to change in permit allocation amount  $\theta$ . Thus the regulator should carefully choose  $\theta$  if METS is decided to be implemented.

### 6. Summary and Conclusions

This study theoretically analyzes the impacts of the emission trading scheme (ETS) on the shipping industry by considering two different cases: open ETS and maritime only ETS. Since there are many different shipping activities, the differential impacts on shipping sectors are discussed for both container and dry-bulk sectors. The analytical model suggests that whether open or maritime only, ETS will decrease ship's cruising speed, throughput and fuel consumption for both container and bulk sectors. Under the open ETS, the emission reduction target is a non-binding constraint since carriers can trade their permits with other industries at an exogenous price. Dry-bulk sector will experience larger proportional reduction in its throughput and buy less (sell more) permits than container sector under open ETS. While under the maritime only ETS (METS), the emission reduction limit will definitely be reached, but the permit price is endogenously determined by the trading behavior and market structure of both container and dry-bulk sectors. It is theoretically predicted that the permit price will be higher when regulator assigns fewer free emission quotas. When the buying sector (selling sector) is less competitive (more collusive), the permit price will rise.

In order to draw solid practical implication, our analytical economic model is also calibrated using container and dry-bulk shipping operational data in year 2007. Several empirical results are obtained confirming and supplementing our theoretical conclusions. Our simulation shows that under Maritime only ETS, container carrier will buy emission permit from the dry-bulk side. The endogenous permit price will increase when container (dry-bulk) sector becomes more competitive (collusive). A sensitivity test confirms the robustness of our calibration results under different the market structures assumptions of container and dry-bulk sectors.

As the economic analysis on market-based measures (MBM) to reduce shipping  $CO_2$  emission has been quite scanty, our research thus provides timely insights for both regulators and industry practitioners to evaluate the effects to introduce ETS in shipping sectors. However, our study is also subject to several limitations leading to possible future research. First, shipping network can change when ETS is implemented regionally. Shipping firms might re-configure routes to avoid the emission charge. Second, shipping demand can be uncertain due to external economic situation. Thus the stochastic demand can be a more realistic assumption. We see these analyses as natural extensions of our study, although beyond the scope of the present paper.

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#### Appendix 1: Shipping carrier's market conduct with different conduct parameter values

The FOC for the profit maximization as equation (3.1) reveals that

$$\frac{\partial \pi_{r,i}}{\partial q_{r,i}} = P_r + P_r'(Q_r)q_{r,i}(1 + v_{ri,j}) - c_{r,i} = 0$$

 $c_{r,i} = \frac{1}{U_r S_{r,i} \rho/D_r} [\eta \lambda_r S_{r,i}^3 + \gamma_r]$ , which is the marginal cost for shipping company, and  $Q_r = \sum_{j=1}^{N_r} q_{r,j}$ ,  $j = 1, ..., N_r$ .

It is clear that when  $v_{ri,j} = 0$ , it is just the FOC for Cournot Competition. When  $v_{ri,j} = -1$ , we have  $P_r = c_{r,i}$ , meaning that the shipping company compete in Bertrand type. When  $v_{ri,j} = N_r - 1$ , the FOC becomes  $P_r + P'_r Q_r - c_{r,i} = 0$ , which is just the FOC for joint profit maximization (Perfect collusion) case. Since the competition type among the carriers must be between Bertrand and Perfect collusion, the value of  $v_{ri,j}$  should be between -1 and  $N_r - 1$ .

#### Appendix 2: Second-order derivative condition for maximization problem (3) and (8)

SOC for the optimization problem in equation (3)  $2^{2}$ 

$$\begin{vmatrix} \frac{\partial^2 \pi_{r,i}}{\partial q_{r,i}^2} & \frac{\partial^2 \pi_{r,i}}{\partial q_{r,i} \partial S_{r,i}} \\ \frac{\partial^2 \pi_{r,i}}{\partial S_{r,i} \partial q_{r,i}} & \frac{\partial^2 \pi_{r,i}}{\partial S_{r,i}^2} \end{vmatrix} = \begin{vmatrix} -b_r (2+v_r) & -\frac{D_r}{U_r \rho} (2\eta \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2}) \\ -\frac{D_r}{U_r \rho} (2\eta \lambda_r S_{r,i} - \frac{\gamma_r}{S_{r,i}^2}) & -\frac{2q_{r,i} D_r}{U_r \rho} (\eta \lambda_r + \frac{\gamma_r}{S_{r,i}^3}) \end{vmatrix}$$

-

Off diagonal is equal to zero by the first order condition (6.1). Therefore, for the SOC to hold, the product of the diagonal elements should be positive.  $-\frac{2q_{r,i}D_r}{U_r\rho}\left(\eta\lambda_r + \frac{\gamma_r}{s_{r,i}^3}\right) < 0$ , and  $-b_r(2 + v_r)$  is also negative because  $v_r \ge -1$ . So the SOC is satisfied.

SOC for maximization problem (8)

$$\frac{\frac{\partial^2 \pi_{r,i}}{\partial q_{r,i}^2}}{\frac{\partial^2 \pi_{r,i}}{\partial S_{r,i}}} = \frac{\frac{\partial^2 \pi_{r,i}}{\partial q_{1,i} \partial S_{r,i}}}{\frac{\partial^2 \pi_{r,i}}{\partial S_{r,i} \partial q_{r,i}}} = \begin{vmatrix} -b_r (2+v_r) & -\frac{D_r}{U_r \rho} [2(\eta+\chi)\lambda_r S_{r,i} -\frac{\gamma_r}{S_{r,i}^2}] \\ -\frac{D_r}{U_r \rho} [2(\eta+\chi)\lambda_r S_{r,i} -\frac{\gamma_r}{S_{r,i}^2}] & -\frac{2q_{r,i}D_r}{U_r \rho} [(\eta+\chi)\lambda_r +\frac{\gamma_r}{S_{r,i}^3}] \end{vmatrix}$$

Similar to the proof of SOC for (3), it can be proved that the SOC for (8) is also satisfied. ■

#### Appendix 3: Proof of results in (7)

As 
$$\tilde{q}_r = \frac{2a_r U_r \rho - 3D_r \sqrt[3]{2\eta\lambda_r \gamma_r^2}}{2U_r \rho b_r [(N_r+1)+v_r]}$$
, it is evident that  $\frac{\partial \tilde{q}_r}{\partial \eta} < 0, \frac{\partial \tilde{q}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{q}_r}{\partial D_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$ ,  $\frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$ ,  $\frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$ ,  $\frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$ ,  $\frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} < 0$ ,  $\frac{\partial \tilde{q}_r}{\partial v_r} < 0, \frac{\partial \tilde{q}_r}{\partial v_r} > 0$ , it is evident that  $\frac{\partial \tilde{s}_r}{\partial \eta} < 0, \frac{\partial \tilde{s}_r}{\partial \lambda_r} < 0, \frac{\partial \tilde{s}_r}{\partial \gamma_r} > 0$ ,  $\tilde{F}_r = \frac{\sqrt[3]{2\lambda_r \gamma_r^2} D_r (2a_r U_r \rho - 3D_r \sqrt[3]{2\eta\lambda_r \gamma_r^2})}{4\sqrt[3]{\eta^2} U_r^2 \rho^2 b_r [(N_r+1)+v_r]}$ , thus, it is clear that  $\frac{\partial \tilde{F}_r}{\partial v_r} < 0$   
As we have  $2 \Box \Box \Box > 3 \Box \sqrt[3]{2} \Box \Box \Box \Box^2}$  from (6), thus  $\frac{\partial \tilde{\Omega}_{\Box}}{\partial \Box} = -\frac{\sqrt[3]{2\Box \Box \Box^2} \Box (\Box \Box \Box - 3 \Box \sqrt[3]{2\Box \Box \Box \Box^2}}}{12\Box \sqrt[3]{\Box^2} \Box^2} \Box^2 \Box \Box (\Box + 1) + \Box \Box} < 0$ 

$$\frac{\partial \tilde{\Box}_{-}}{\partial \Box_{-}} = \frac{\sqrt[3]{2\Box_{-}^{-2}\Box_{-}(\Box_{-}\Box_{-}-3\Box_{-}^{-3}\sqrt[3]{2\Box_{-}\Box_{-}^{-2}})}}{6\sqrt[3]{2\Box_{-}^{-2}\Box_{-}^{-2}\Box_{-}(\Box_{-}+I)+\Box_{-}]}} > \text{or} < 0$$
$$\frac{\partial \tilde{\Box}_{-}}{\partial \Box_{-}} = -\frac{\sqrt[3]{2\Box_{-}\Box_{-}^{-2}\Box_{-}(\Box_{-}\Box_{-}-3\Box_{-}^{-3}\sqrt[3]{2\Box_{-}\Box_{-}^{-2}})}}{2\sqrt[3]{2\Box_{-}\Box_{-}^{-2}\Box_{-}(\Box_{-}+I)+\Box_{-}]}} > \text{or} < 0 \quad \blacksquare$$

#### Appendix 4: Data for Ship's Speed and Size

#### Table 5: Operation Statistics for Dry-bulk and Container Shipping Sectors in Year 2007

Туре	Size (ton for bulk; TUE for container)	Average carriage capacity (ton)	Average capacity utilization	Total work (million ton-nm)	Ship size (ton)	Average speed (knots)
Bulk	200,000+	227,000	50%	1,297,224	113,500	14.4
	100,000-199,999	163,000	50%	5,325,597	81,500	14.4
	60,000-99,999	74,000	55%	5,781,720	40,700	14.4
	35,000-59,999	45,000	55%	4,181,092	24,750	14.4
	10,000-34,999	26,000	55%	2,651,294	14,300	14.3
	0-9,999	2,400	60%	76,414	1,440	11
Container	8,000+	68,600	70%	822,258	48,020	25.1
	5000-7999	40,355	70%	1,765,365	28,249	25.3
	3000-4999	28,784	70%	2,005,250	20,149	23.3
	2000-2999	16,800	70%	987,297	11,760	20.9
	1000-1999	7,000	70%	644,848	4,900	19
	0-999	3,500	70%	199,588	2,450	17

Source: Buhaug et al. (2009)

Ship size for each sub-category of container /dry-bulk sector equals ship's average carriage capacity times ship's capacity utilization ratio. To calculate the average container / dry-bulk ship size, we use the total work share as weight. The ship's speed is calculated in the same manner.

#### Appendix 5: Freight rate and average route distance for container shipping industry

Table 6: Cargo Flow and Route Distance for Major Container Transport Routes in Year 2007					
<b>Trans</b>	pacific	Europ	e-Asia	Transa	tlantic
Asia-USA	USA-Asia	Asia-Europe	Europe-Asia	USA-Europe	Europe-USA
15.4	4.9	17.7	10	2.7	4.5
20.3		27.7		7.2	
26.80/		50.2%		13.0%	
50.	0 /0	50.	270	15.	0 70
5,780		12,355		5,450	
0 0	36				
7,0					
	Flow and Ro Trans Asia-USA 15.4 20 36. 5,7 9,0	Flow and Route Distance Transpacific Asia-USA USA-Asia 15.4 4.9 20.3 36.8% 5,780 9,036	Flow and Route Distance for Major Con TranspacificTranspacificEuropAsia-USAUSA-AsiaAsia-Europe15.44.917.720.32736.8%50.5,78012,9,036	Flow and Route Distance for Major Container Transpo Transpacific Europe-AsiaAsia-USAUSA-AsiaAsia-EuropeEurope-Asia15.44.917.71020.327.736.8%50.2%5,78012,3559,036	Flow and Route Distance for Major Container Transport Routes in YeTranspacificEurope-AsiaTransaAsia-USAUSA-AsiaAsia-EuropeEurope-AsiaUSA-Europe15.44.917.7102.720.327.77.36.8%50.2%13.5,78012,3555,49,03611.00011.000

Source: Review of Maritime Transport 2008, UNCTAD; APL container liner website

Table 7: Coll	Table 7: Container Simpping Service Freight Kate for Wajor Koutes in Fear 2007 (USD per FUE)					
Route	Transpacific		Europ	Europe-Asia		atlantic
	Asia-USA	USA-Asia	Asia-Europe	Europe-Asia	USA-Europe	Europe-USA
First quarter	1643	737	1549	755	1032	1692
Second quarter	1675	765	1658	744	1067	1653
Third quarter	1707	780	1952	777	1115	1725
Fourth quarter	1707	794	2054	905	1147	1766
Yearly average	1683	769	1803	795	1090	1709

|--|

Source: Review of Maritime Transport 2008, UNCTAD

Dividing container freight rate by the average route distance for each route, we can obtain route specific average yield (USD per TEU-nm). Then aggregating each route's yield using route cargo flow percent as weight, we can get the average yield for container sector, which is 0.0267 USD per ton-nm. Then multiplying this average yield by the average route distance 9,036 nms, we get the average freight rate for container sector as 240 USD per ton.

<sup>i</sup> Dry bulk group includes the five major bulks (iron ore, coal, grain, bauxite/alumina and phosphate rock) and other dry bulk.

<sup>ii</sup> Excluding Crude Oil group is because it has rather distinct operating characteristics compared to dry cargo shipments. As well, including Crude Oil group into our model will complicate our modeling analysis for closed ETS, making the mathematics not tractable.

<sup>iii</sup> There may be other cost proportional to the number of ships per year, such as labor cost, insurance cost etc. Considering these costs explicitly will not change our model except that in such a case  $\gamma$  would be sum of such cost and capital costs of ships.

<sup>iv</sup> In reality, ship number is incremental. When one ship is fully loaded, marginal additional cargo may require one more ship to be deployed. To make our analysis tractable, here, we assume that load factor of ship is 100% and the number of ship is continuous. The conclusion of the economic model will not alter when relaxing the above assumption.

<sup>v</sup>Using Conduct Parameter Method (CPM) or "Conjecture Variation" to measure market competition intensity is widely adopted in economic studies, such as Bresnahan (1981), Roberts (1984), Graddy (1995) and a review paper by Corts (1999). Brander and Zhang (1990, 1993), Fu et al (2006), Basso and Zhang (2008) applied CPM in air transport industry.

 $v^{i}$  Units for different parameters has been unified to do the numerical simulation. For example, the speed is converted into knots/year for the simulation. That is  $\tilde{S}_1 = 279,000$  knots / year;  $\tilde{S}_2 = 122,640$  knots / year.

<sup>vii</sup>We assume  $\gamma_1 = 100,000$  USD / day so that the estimated total revenue and total cost for container operator have the same digits. Assuming smaller  $\gamma_1$  makes the revenue too large when compared to cost.

viii These assumptions on dry-bulk sector should be reasonable because it is well recognized that dry-bulk sector has much lower freight rate and capital cost than container sector. Meanwhile, we will see later that the assumed  $\tilde{P}_2$  and  $\gamma_2$ create reasonable parameters estimation for the dry-bulk sector.

<sup>ix</sup> The 16<sup>th</sup> world largest container liner, Hamburg Sud, only has 1.55% in world container capacity in year 2007. This market share is very small with little contribution to HHI index. Thus we only consider the top 15 container liners in our study. The capacity shares of world top 20 container liners are available in Review of Maritime Transport 2008.

<sup>x</sup> Parameter a has unit as USD per ton. Parameter b has unit as USD per ton squared.

<sup>xi</sup> the permit charge can be regarded as tax on fuel

xii When  $\theta = 0.2$ , the output will reduce by 56% for dry-bulk sector and 20% for container sector. This dramatic output reduction may impose serious impact on international trade and economy.

# Service Fee and Capacity Choice of an Inland River Port

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### Abstract

The inland waterway transport has attracted a lot of attention from the countries and regions in the last fifteen years. Many projects all over the world have been carried out to develop the inland waterway transport as a mode favoured to alleviate road congestion. This paper studies the joint decision of the location, service fee and port capacity for one inland river port. We assume that the cargo shippers are spatially distributed along the river and they select the inland river port using transshipment service or the road transportation to the junction port connecting the river and the sea. Another problem of the inland waterway transport is that the navigational restriction is heterogeneous along the river. The vessels must abide by certain specifications, such as water draught, width and length of the locks. And thus, transport unit size is restricted and different, which affects the average transport cost per unit cargo from the port to the junction port. To incorporate the heterogeneous navigational restriction into the current study, we suppose the transport cost per unit cargo is monotonically increasing from the junction port to the inland port along the river. We develop a mathematical model to examine the joint choice of the port location, service fee and capacity of an inland river port and explicitly take into account the spatial distribution of shippers along the river and the navigational nature of the river.

Keywords: Inland River, port investment, waterway congestion, navigational condition heterogeneity

### 1. Introduction

A port places an essential role in the global supply chain, which provides transshipment service for cargo and/or passengers among various countries, waterways and shores, and multiple transportation modes. Recently, the inland waterway transport has attracted a lot of attention from the countries and regions since it is one of the environment-friendly transportation modes to alleviate road congestion, significantly (Rosacs and Simongati, 2007). In china, the percentage of waterway transportation in total freight transportation has been viewed to increase by three times from 1990 (about 10%) to 2010 (over 30%). Many projects all over the world have been carried out to develop the inland waterway transport. China's 12<sup>th</sup> Five-Year Plan continuously boosts the transportation via inland waterways. The country shows more efforts to make further development of advanced waterway channels on the Yangtze River and other rivers. The Deep-water Channels Renovation Project at the Yangtze River has been successively completed and further launched to construct 12.5-meter-deep waterways on the lower reaches of Nanjing section and 4.5-meter-deep waterways of Jingjiang river and the capacity expansion of branch shipping lanes of Xijiang river and the Beijing-Hangzhou Grand Canal. It is expected that, by the end of 2015, the total length of the advanced inland waterways will amount to 13,000 kilometers.

Previous studies focused on the competition among the seaports, especially, container seaports in Asia. The competition between Hong Kong and Singapore was analysed by Fung (2001) based on a forecast of demand for container handling services. Cullinane et al. (2004) analysed the development process of container terminals in China and its impact on the competitiveness of Hong Kong and other neighbour ports in three phases: 1978-1986, 1987-1997 and 1997-2010. Anderson et al. (2008) adopted a game-theoretic approach to examine the competition between Busan and Shanghai. The competition among container ports in East Asia

was widely analysed by Yap et al. (2006). Viewed the seaports as the nodes in a multi-modal transportation network, Wan and Zhang (2013) examined the interaction between the urban road congestion and the competition between two seaports. Similar topic on the hinterland partition resulted by the competition among seaports has been attracted many researchers (Zhang, 2009; de Borger and Proost, 2008; Zondag et al., 2012). Recently, using inland and coastal waterways, short sea shipping or river-sea shipping provides an effective method for road congestion mitigation and has attracted tremendous studies (Perakis and Penisis,2008; Radmilovic et al., 2011).

The purpures of this paper is to study the pricing, investment and location decisions of one inland port along an inland river. We assume that the cargo shippers are spatially distributed along the river and they want to transport their cargo to the overseas using the transhipment at the same junction port connecting the river and the sea. To consider the spatial characteristics of shippers, the freight demand is assumed to follow a given distribution along the river. Another one of the characteristics of the inland waterway transport is that the navigational restriction is heterogeneous dependent on the location of the inland port. The vessels must abide by certain specifications, such as water draught, width and length of the locks. And thus, transport unit size is restricted and different, which affects the average transport cost per unit cargo from the port to the junction port. Such as, on the Yangtze River, the ocean ships with 50,000 tons can navigate about 400 kilometres as far as to Nanjing, ships with a capacity up to 10,000 tons can navigate 1000 kilometres to Wuhan, but ships with only 1000 tons can navigate upstream to Chongqing. On Mississippi river, the ocean ships can reach Baton Rouge Port, the towboats with 40-60 barges can reach ST. Louis Port, and the towboats with only 12-15 barges can reach ST. Paul Port. The heterogeneity of the navigational condition along the river alters the selection of the inland river port operator and is seldom attracted the attentions of the researchers. To incorporate the heterogeneous navigational restriction into the current study, we suppose the transport cost per unit cargo is monotonically increasing from the junction port to the inland along the river. We develop a mathematical model to examine the pricing, investment and location decisions of the inland river port and explicitly take into account the spatial distribution of shippers along the river and the navigational nature of the river.

The paper is organized as follows. Section 2 introduces the problems and some basic settings. Section 3 proposes our mathematical model and shows some theoretic analysis. Finally, conclusions and some future research topics are presented in Section 4.

### 2. Basic Considerations and Assumptions

We consider an inland river with only one port, which offers waterway shipping service along the river to one junction port connecting the inland river and sea. Only the junction port can offer the deep sea shipping service. The cargo shippers are assumed to continuously distribute along the inland river and requires the deep sea shipping service. Adopting Hotelling's model framework, we can think of the port competing within a linear hinterland, normalized to [0,1]. Without loss of generality, we suppose that the junction port locates at point 0 and let  $x_1$  denote the location of the inland port,  $0 \le x_1 \le 1$ . The shippers at any point who achieve their deep sea shipping service may take two kinds of methods: one is to select the inland river port and transport their cargo to the port by road system and then to the junction port by inland river waterway; the other is to transport their cargo to the junction port directly by road system. The shippers must experience a waiting time and pay a certain service fee at the inland port if they choose the former method, while they can save a transport cost from the reduction of road transportation utilization.

The transportation cost for the customer at location x who is willing to utilize the inland river port  $x_1$  to transport transportation cost for the junction port includes three parts: (i) transportation cost from x to  $x_1$  via the road transportation system,  $c_R$ ; (ii) the service fee at the port for handling and packaging service,  $p_1$ , and the service time delay in monetary unit due to the port capacity of handling cargo,  $c_D$ ; (iii) the transportation cost from port  $x_1$  to the junction port,  $c_W$ , by waterway. Moreover, two types of congestion would occur when choosing the inland river. The first is the waterway congestion resulted by the throughput level or physical

capacity of the inland waterway and the dams along the inland river. The second is the service time delay at the port because of the limit capacity of handling the cargo, such as loading and unloading by cranes, moving by haulage machines, stacking on the yard.

Similar to the assumption adopted by the Hotelling's model (d'Aspremont, et al, 1979), we assume the transportation cost via road system is strictly increasing with respect to the travel distance between x and  $x_1$ . To obtain analytical results, the linear transportation cost function of road system is adopted in the current study, namely

$$c_{R}(x, x_{1}) = c_{R}^{0} |x - x_{1}| + c_{R}^{1},$$
(1)

where  $c_R^0$  is the marginal transportation cost via road system and  $c_R^1$  is the sunk cost of road system. Suppose the road system consists with a large highway network, and thus, the road congestion is neglected in the current study which is different to the previous studies of Zhang (2009) and Wan and Zhang (2013).

The transportation cost via waterway  $c_w$  depends on the location of the inland river port and the total cargo tonnage of the port. The throughput level or physical capacity of the inland waterway is location-variant along the river, which depends on the depth, width of the river and is hard to improve by the capacity expansion of ports. In addition, given the throughput at a certain location, more cargo tonnage requires more vessels to transport, which results in the inland river congestion. As Lave and DeSalvo (1968) suggested that the time delay is related to the vessel size and the total cargo tonnage. To capture the navigational nature and the inland river congestion, we assume that the average transportation cost per unit cargo via waterway from the inland river port to the junction port is expressed as the function of the cargo arrival rate, the distance away to the junction port, and the vessel size required to passing the waterway segment  $[0, x_1]$ , namely,

$$c_{W} = c_{W} \left( V \left( x_{1} \right), x_{1}, \lambda \right) \equiv c_{W} \left( x_{1}, \lambda \right), \tag{2}$$

where  $\lambda$  is the cargo arrival rate and  $V(x_1)$  is the throughput of the waterway segment  $[0, x_1]$ . The cargo arrival rate depends on the cumulative length of the river by assuming a mean cargo shipping demand rate l(x) per unit length along the river,  $\lambda = \int_{x \in I} l(x) dx$ , where I is the domain in which all shippers select the inland port for their cargo shipping service. We will discuss how to determine the domain in the next section in details. For any given location  $x_1$ , the throughput  $V(x_1)$  is given, the more cargo tonnage, the more average congestion delay to transport one unit cargo. Therefore, we assume that  $\partial c_w/\partial \lambda > 0$  and  $\partial^2 c_w/\partial \lambda^2 > 0$ . We further assume that  $c_w(x_1,0) > 0$  whenever  $x_1 > 0$  since the sunk cost of the transportation cost by waterway is always positive. Similar to Lave and DeSalvo (1968), we also assume that  $\partial c_w/\partial V < 0$  because, for given cargo tonnage, the lower of the throughput, the more transportation cost required to ship the total cargo.

The formulation (2) does capture the navigational condition on the transportation cost of waterway since the throughput  $V(x_1)$  depends on the location of inland river port,  $x_1$ . If the navigational condition is homogeneous along the river or V(x) = V(0),  $\forall x \in [0,1]$ , the transportation cost is only dependent on the waterway distance for given the cargo tonnage or arrival rate. If the navigational condition gets better or the throughput gets larger along the river far from the junction port, then  $V(x) = \min_{y \in [0,x]} V(y) = V(0)$  and it is the same as the case with homogeneous navigational condition. Without loss of generality, both two former cases are called homogeneous navigational condition. While, as the Yangtze River and Mississippi River, if the navigational condition is deteriorated or the throughput gets smaller along the river far from the junction port, i.e., V(x) > V(x') for any  $0 \le x < x' \le 1$ , then  $dc_w/dx_1 = \partial c_w/\partial V \cdot \partial V/\partial x_1 + \partial c_w/\partial x_1 > 0$ . Note that, the consideration of the deteriorated navigational condition results in a higher increasing rate of

transportation cost of waterway than the former cases. In the current study, the transportation cost in inland waterway is assumed to be the following model for theoretical analysis,

$$c_{W}(x_{1},\lambda) = (c_{W}^{0}x_{1} + c_{W}^{1}) + \frac{\beta\lambda}{V_{0} - \alpha x_{1}}, \alpha \ge 0, \beta \ge 0, V_{0} - \alpha > 0,$$
(3)

where  $c_W^0$  is the marginal transportation cost of inland waterway and  $c_W^1$  is the sunk cost of transportation cost via waterway. With the practical consideration, we assume that the road transportation has a larger marginal cost and a lower sunk cost than those of waterway transportation, namely,  $c_W^0 < c_R^0$  and  $c_W^1 > c_R^1$ . The bracketed term in eq. (3) is the transportation cost via waterway without congestion. The last term in eq. (3) captures the congestion delay along the inland river and  $\beta$  is a calibration parameter. The term is similar to the BPRs (Bureau of Public Roads) link performance congestion function adopted by the highway (Branston, 1976), which implies that the delay is positively relative to the highway volume and negatively relative to the capacity of the highway link. We simplify the general congestion term of BPR-function and extern the fixed link capacity as a function of the port location to capture the heterogeneity of navigational condition of the inland river. Adopting model (3), we consider three cases: (I) there is no cargo congestion in the inland waterway, namely,  $\beta = 0$  in eq. (3); (II) there is cargo congestion in the waterway, but the navigational condition is homogeneous, i.e.,  $\beta > 0$  and  $\alpha = 0$ ; more generally, (III) there is cargo congestion in the waterway, and the navigational condition is heterogeneous, i.e.,  $\beta > 0$  and  $\alpha > 0$ .

In addition, to consider the decision of the port capacity selection, as Kwasnica and Stavrulaki (2008), we introduce the M/M/1 queuing system to capture the service time delay in monetary unit at the inland river port. Given the service rate of the inland river port,  $\mu$  and the cargo arrival rate,  $\lambda$ , the service time delay is calculated by

$$c_{D}(\mu,\lambda) = \frac{\gamma}{\mu-\lambda}, \ \gamma > 0, \ \mu > \lambda.$$
<sup>(4)</sup>

In eq. (4), the service rate of the inland port  $\mu$  is directly related to the capacity of the port and  $\gamma$  is the parameter converting the time unit to monetary unit. Without confusion, the service rate of the inland river port in the current study is called as the capacity of the port. Furthermore, the investment cost of port is viewed as the linear function of the capacity,  $I(\mu) = \eta \kappa \mu$ , where  $\kappa$  is the unit capacity construction cost and  $\eta$  is the parameter converting the total cost to the unit planning period.

According to the discussion above, for any given the combination of the location, service fee and port capacity  $(x_1, \tau, \mu)$ , the dis-utility, denoted by  $U_1(x)$ , for the customers at x selecting the inland port to transship their cargo to the junction port can be expressed as

$$U_1(x|x_1,\tau,\mu) = c_R(x,x_1) + c_W(x_1,\lambda) + c_D(\mu,\lambda) + \tau.$$
(5)

Correspondingly, the customer at location x who utilizes the road transportation and transport their cargo to the junction port directly, then the dis-utility can be calculated as  $U_0(x) = c_R(x,0).$ (6)

The customers select the inland port if the dis-utility by the inland port is less than that by road system  $U_1(x|x_1,\tau,\mu) < U_0(x)$  and choose the road system for their shipping service otherwise. Investor of the inland port tends to maximize the profit by selecting the combination of the location, service fee and port capacity  $(x_1,\tau,\mu)$ . If the operation cost is normalized to zero, then the profit is the total revenue minus the investment cost and can be calculated as

 $P(x_1, \tau, \mu) = \tau \lambda - \eta \kappa \mu$ .

Generally, the social welfare is also the consideration of the investor since the inland port is infrastructure which provides the public service. However, it is hard to evaluate the indirect effect of the port to the whole supply chain market and environment. Therefore, in the current paper, we only consider the profit of the investor. We will develop a theoretical analysis to those problems.

### 3. Analysis

### 3.1 The customers' choice equilibrium

For any given combination of the location, service fee and capacity of the inland river port  $(x_1, \tau, \mu)$ , the customers either transport their cargo to the inland river port using transshipment service or to the junction port directly, which results in a binary choice framework. The customers at location x will choose the service with minimal dis-utility. Note that, for any given location  $x_1$ , service fee  $\tau$  and the port capacity  $\mu$ , the dis-

utility of transshipment service for the customers at location x only depends the distance between x and  $x_1$ .

Therefore, if the customer at the downstream of the inland river port selects the transshipment service, then all the customers at the upstream of the port surely choose the transshipment service. It is clear to see that the dis-utility of the pure road system is strictly increasing as the distance of the shipper's location to the junction port. For any given port location  $x_1$ , service fee  $\tau$  and the port capacity  $\mu$  of the inland river port, two types of equilibrium states will be observed: the inland river port attracts none of the shippers and the dis-utility of transshipment is higher than that by road transportation; there exists a unique equilibrium point, all shippers at the upstream of the point will choose transshipment service and others will transport their cargo by road network directly. Figure 1 (I) shows the dis-utility of the transshipment service and pure road transportation. In fact, if there is a strictly positive gap between the dis-utility of the transshipment service and pure road transportation (the former is less than the later), then the port attracts more shippers to select the transshipment service, which must increase the delay cost. The equilibrium state is achieved till the gap vanishes to zero. However, if the shippers shift to pure road transportation, then the dis-utility of the transshipment service strictly decreases because of the decreasing of the delay cost since the volume is decreases. That is why, at the second equilibrium state, the dis-utility of the transshipment service must equal that of the pure road transportation for all shippers who select the transshipment service. It must be pointed out that, when the congestion delay of the waterway and service delay on the port are ignored, for the second type equilibrium state, the dis-utility of the transshipment service will shift downward and there is fixed gap between the dis-utility levels of transshipment service and pure road transportation service, shown as in Figure 1 (II). In the following analysis, we assume that  $\beta > 0$  and  $\gamma > 0$  unless otherwise specified.



Figure 1: The Two Types of the Equilibrium States for the Transshipment Service

For the first type equilibrium state, if the inland port attracts none of customers, we know that the transportation cost of waterway has no attractiveness to all customers even to the customers at  $x_1$ . Mathematically,

$$c_{W}^{0}x_{1} + c_{W}^{1} + c_{R}^{0} |x - x_{1}| + c_{R}^{1} + \frac{\beta\lambda}{V_{0} - \alpha x_{1}} + \frac{\gamma}{\mu - \lambda} + \tau \ge c_{R}^{0}x + c_{R}^{1},$$
(8)

where  $\lambda = 0$  and  $x = x_1$ . From eq. (8), we know that  $x_1 \le x_L = (c_W^1 + \gamma/\mu + \tau)/(c_R^0 - c_W^0)$ . It is clear to see that, inequality (8) always holds when  $x_1$  is small enough since the marginal transportation cost by waterway is lower than that by road system, namely,  $c_R^0 > c_W^0$ . It is intuitive to see that, the customers near the junction port surely do not select the transshipment service and transport their cargo to the junction port by road system directly.

For the second equilibrium state, shown in Figure 1 (I), three cases would occur: (a) the inland river port only serves a part or the whole of customers at upstream of the port and the port cannot serve all customers at its upstream; (b) the inland river port serves all customers at upstream and a part of customers at downstream.

For case (a), the inland river port only serves a part of customers at upstream. Note that, all customers at upstream have the same level of dis-utility for the transshipment service as that with road transportation since the cargo arrival rate, location and port capacity are independent on the location of the customers at upstream. However, the transshipment dis-utility is increases with respect to the distance from the customer's location to the inland port at downstream and larger than that for the upstream customers. Therefore,

$$\begin{cases} U_{1}(x|x_{1},\tau,\mu) = U_{0}(x) & x \ge x_{1} \\ U_{1}(x|x_{1},\tau,\mu) > U_{0}(x) & x < x_{1} \end{cases}$$
(9)

Since  $x_1 > x_L$ , we know that, there exists unique positive cargo rate  $\lambda$  such that the equality of eq. (9) holds. Without loss of generality, we assume that the customers near the inland port have more incentive to adopt the transshipment service. Under this assumption, we know that, there exists a unique point (not equilibrium point), still denoted as,  $x^*$ ,  $x^* \in [x_1, 1]$  such that  $\lambda = l(x^* - x_1)$ . Substituting  $\lambda$  into the first equality of eq. (9), we immediately get  $x^*$ , which is the function of  $(x_1, \tau, \mu)$  and given by the following implicit function

$$\frac{\beta\lambda}{V_0 - \alpha x_1} + \frac{\gamma}{\mu - \lambda} + \tau = \left(c_R^0 - c_W^0\right) x_1 - c_W^1.$$
(10)

The polar case is that, the inland river port serves all customers at upstream, and thus, the cargo arrival rate is  $\lambda = l(1 - x_1)$ . In this case,  $(x_1, \tau, \mu)$  satisfies equilibrium condition (10) with cargo arrival rate  $\lambda = l(1 - x_1)$ .

For case (b), since the inland port attracts all customers at upstream and a part of the customers at downstream, we know that there exists a unique equilibrium point  $x^*$  with  $x^* < x_1$  such that

$$\begin{cases} U_1(x|x_1,\tau,\mu) = U_0(x) & x \ge x^* \\ U_1(x|x_1,\tau,\mu) > U_0(x) & x < x^* \end{cases}$$
(11)

with cargo arrival rate  $\lambda = l(1 - x^*)$ . From the equality of eq. (11), we can also obtain the equilibrium point  $x^*$ , which is also the function of  $(x_1, \tau, \mu)$  and given by the following implicit function

$$\frac{\beta\lambda}{V_0 - \alpha x_1} + \frac{\gamma}{\mu - \lambda} + \tau = 2c_R^0 x^* - (c_R^0 + c_W^0) x_1 - c_W^1, \qquad (12)$$
where the cargo arrival rate  $\lambda = l(1 - r^*)$ 

where the cargo arrival rate  $\lambda = l(1 - x^*)$ .

In this subsection, we consider the optimal selection of the location  $x_1$ , service fee  $\tau$  and the port capacity  $\mu$  of the inland river port to maximize the total profit, namely, consider the following maximization problem

$$\max_{(x_1,\tau,\mu)\in\Omega} P(x_1,\tau,\mu).$$
(13)

To obtain the optimal solution of problem (13), we assume that the optimal solution belongs to one of the later three cases depicted in the previous subsection. For each case, we fix the port location and derive the optimal selection of the service fee and port capacity adopting the standard optimization method. Therefore, we express the objective value as the function of the port location, and then, the optimal location will be selected to maximize the value function.

#### 3.2.1 Optimal decision of the inland river port without waterway congestion

The simplest but most commonly explored case is that the waterway congestion is a tiny part of the shipping cost and can be neglected or set  $\beta = 0$ . The inland river port is similar to the park-and-ride facility for urban transit transportation (Wang et al., 2004). We will investigate the optimal location, service fee and port capacity for the profit-maximization port investor. We now proceed to prove that, for given location  $x_1$ , the profit-maximization port investor either rejects to invest the inland port or selects optimal service fee capacity to attract cargo at both upstream and downstream. Firstly, it is not difficult to check that, for any given location  $x_1$ , at optimal service fee and port capacity ( $\tau, \mu$ ), equilibrium condition (10) holds. In view of eq. (10), it is convenient to substitute the cargo arrival rate  $\lambda$  for  $\tau$  as the decision variable. Taking the derivatives of *P* in  $\lambda$  and  $\mu$ , respectively, gives rise to

$$\frac{\partial P(x_1,\tau,\mu)}{\partial \lambda} = \left(c_R^0 - c_W^0\right) x_1 - c_W^1 - \frac{2\beta\lambda}{V_0 - \alpha x_1} - \frac{\gamma}{\mu - \lambda} - \frac{\gamma\lambda}{\left(\mu - \lambda\right)^2} = 0,$$
(14)

$$\frac{\partial P(x_1,\tau,\mu)}{\partial \mu} = \frac{\gamma \lambda}{\left(\mu - \lambda\right)^2} - \eta \kappa = 0.$$
(15)

Let  $\beta = 0$  in (14) and by simply arrangement of eq. (14), we have  $\tau = \gamma \lambda / (\mu - \lambda)^2$ . Combining eq. (15), the profit can be calculated as

$$P(x_1, \tau, \mu) = \tau \lambda - \eta \kappa \mu = \frac{\gamma \lambda}{(\mu - \lambda)^2} \lambda - \eta \kappa \mu = -\eta \kappa (\mu - \lambda) < 0.$$
<sup>(16)</sup>

Equation (16) implies that the operator earns a negative profit if the port only serves the upstream customers, which is impossible since the operator can select a zero port capacity and earn zero profit. Therefore, we know that, the investor either rejects to invest the inland port or selects optimal service fee capacity to attract cargo at both upstream and downstream. Now, suppose that the optimal service fee and port capacity  $(\tau, \mu)$  such that the inland port serves the customers at both upstream and downstream of the port or case (b) occurs. In this case, equilibrium condition (12) holds. Viewing the equilibrium point  $x^*$  as the function of  $\lambda$ ,  $x^* = 1 - \lambda/l$  and substituting to eq. (12), the profit can again expressed as the function of the arrival rate and port capacity. Following the similar method, we know that

$$\tau = \frac{2c_R^0 \lambda}{l} + \frac{\gamma \lambda}{\left(\mu - \lambda\right)^2} = \frac{2c_R^0 \lambda}{l} + \eta \kappa , \qquad (17)$$

and eq. (15). Let  $y = \lambda/l \in [0,1]$ , and from eqs. (17) and (15), equilibrium condition (12) can be rewritten as  $4c_R^0 y + \sqrt{\eta \kappa \gamma/l} y^{-1/2} - \left[ 2c_R^0 - \left( c_R^0 + c_W^0 \right) x_1 - c_W^1 - \eta \kappa \right] = 0.$  (18)

Also with eqs. (17) and (15), the profit can be calculated as  

$$P(x_1, \tau, \mu) = \tau \lambda - \eta \kappa \mu = 2c_R^0 l y^2 - \sqrt{\eta \kappa \gamma l} y^{1/2} = l y^{1/2} \left( 2c_R^0 y^{3/2} - \sqrt{\eta \kappa \gamma / l} \right).$$
(19)

To make positive profit, eq. (19) implies that,  $\sqrt{\eta \kappa \gamma/l} / (2c_R^0) = \overline{y}^{3/2} \le y^{3/2} \le 1$ . Consider the function f(y) defined by the left-hand-side of eq. (18), we get  $f(0+) = +\infty$  and f(1) > 0. To guarantee that there exists at least one solution such that the profit is positive,  $\overline{y}$  must satisfy  $f(\overline{y}) \le 0$ . Note that, for equilibrium condition (12),  $x^* \le x_1$ , namely,  $1 - x_1 \le y \le 1$ , and thus,  $f(1-x_1) \le 0$ . Therefore, there are two scenarios to determine the domain of port location and guarantee the positive profit: if  $1 - x_1 \le \overline{y}$ , then  $\overline{y} \le y \le 1$  and  $f(\overline{y}) \le 0$ ; if  $1 - x_1 > \overline{y}$ , then  $1 - x_1 \le y \le 1$  and  $f(1-x_1) \le 0$ . By direct calibration, we have

(I) If 
$$\frac{\eta\kappa\gamma}{l} \leq \frac{4(c_R^0 - c_W^0 - c_W^1 - \eta\kappa)^2}{3^3(5c_R^0 + c_W^0)}$$
, then  $x_1 \in [1 - \overline{x}^+, 1 - \overline{x}^-]$ , where  $f(\overline{x}^-) = f(\overline{x}^+) = 0$ ;  
(II) If  $\frac{4(c_R^0 - c_W^0 - c_W^1 - \eta\kappa)^3}{3^3(5c_R^0 + c_W^0)} < \frac{\eta\kappa\gamma}{l} \leq 4(c_R^0)^2 \left(\frac{c_R^0 - c_W^0 - c_W^1 - \eta\kappa}{5c_R^0 - c_W^0}\right)^3$ , then  $x_1 \in [1 - \overline{y}, \frac{2c_R^0 - c_W^1 - \eta\kappa - 3\sqrt[3]{2c_R^0 \eta\kappa\gamma l}}{c_R^0 + c_W^0}]$ ;  
(III) If  $\frac{\eta\kappa\gamma}{l} > 4(c_R^0)^2 \left(\frac{c_R^0 - c_W^0 - c_W^1 - \eta\kappa}{5c_R^0 - c_W^0}\right)^3$ , then  $x_1 \in \emptyset$ .

It is intuitive to see that the selection of the port operator is dependent on the parameters related to the characteristics of the inland river and port. The cost of road transportation, especially, the variable cost, must be large enough than the total cost of the waterway transportation and unit-time investment.

In addition, the profit function given by eq.(19) is strictly increasing in y or the cargo arrival rate  $\lambda$  at practically useful domain, and thus, the optimal port location is determined to maximize y or cargo arrival rate  $\lambda$ . Therefore, the optimal port location  $x_1$  must satisfy eq. (18) and maximize y. Viewing y as the function of  $x_1$  given by the implicit function (18) and taking the derivatives in  $x_1$  on both sides of eq. (18) give rise to

$$\frac{\mathrm{d}y}{\mathrm{d}x_1} = -\frac{y^{3/2}}{4c_R^0} \frac{c_R^0 + c_W^0}{y^{3/2} - \sqrt{\eta\kappa\gamma/l}/(8c_R^0)} < 0, \qquad (20)$$

since  $\sqrt{\eta \kappa \gamma / l} / (2c_R^0) = \overline{y}^{3/2} \le y^{3/2} \le 1$ . And thus, y is strictly decreasing with respect to  $x_1$ . It is clear to see that, from (I)-(III), the optimal port location is  $x_1^* = 1 - \overline{x}^+$  if  $\frac{\eta \kappa \gamma}{l} \le \frac{4(c_R^0 - c_W^0 - c_W^1 - \eta \kappa)^3}{3^3(5c_R^0 + c_W^0)}$ , and  $x_1^* = 1 - \overline{y}$  if  $\frac{4(c_R^0 - c_W^0 - c_W^1 - \eta \kappa)^3}{3^3(5c_R^0 + c_W^0)} < \frac{\eta \kappa \gamma}{l} \le 4(c_R^0)^2 \left(\frac{c_R^0 - c_W^0 - c_W^1 - \eta \kappa}{5c_R^0 - c_W^0}\right)^3$ . The optimal  $y^*$  or cargo arrival rate  $\lambda^* = ly^*$  is determined by eq. (18) with  $x_1 = x_1^*$  and optimal port capacity given by eq. (15),  $\mu^* = \lambda^* + \sqrt{\frac{\gamma \lambda^*}{\eta \kappa}}$ .

#### 3.2.2 Optimal decision of the inland river port without port service delay

In this subsection, we move to investigate the case without port service delay, or, the port congestion can be neglected and  $\gamma$  is set to zero. In this case, the operator tends to select the low level of port capacity. With a

practical consideration, we assume that the port investment cost is fixed and given. Therefore, the objective of the operator now is to select the optimal port location and service fee to maximize its revenue. Following the simple calibration, we know that, there exists three critical points,  $0 < x_L < x_M < x_H < 1$ , which partition domain [0,1] into four sub-domains. In domain  $[0, x_L]$ , the port attracts none of customers for any given positive service fee; In domain  $(x_L, x_M]$ , the port serves a part customers at its upstream; In  $(x_M, x_H]$ , the port serves all customer at its upstream; In domain  $(x_H, 1]$ , the port serves all customers at its upstream and a part of customers at its near downstream. The optimal service fee, and the corresponding cargo arrival rate and revenue are graphically shown in Figure 2. It is clear to see the optimal location  $x_1^*$  is  $x_H$  which is given by the following equation

$$\left(c_{R}^{0}-c_{W}^{0}-c_{W}^{1}\right)-2\left(c_{R}^{0}-c_{W}^{0}\right)\left(1-x_{H}\right)-\frac{2\beta l(1-x_{H})}{V_{0}-\alpha x_{H}}+\frac{\beta \alpha l(1-x_{H})^{2}}{\left(V_{0}-\alpha x_{H}\right)^{2}}=0,$$
(21)

and the corresponding optimal service fee  $\tau^* = (c_R^0 - c_W^0) x_H - c_W^1 - \frac{\beta l(1-x_H)}{V_0 - \alpha x_H}$ .

# Figure 2: Optimal Service Fee, Arrival Rate and Revenue of the Inland Port Varying with Location $x_1$



We now move to examine the effects of the cargo congestion of waterway and navigational heterogeneity. Note that, the inland port still attracts none of customers if the port location  $x_i \in [0, x_L]$  whether the waterway is congested or not. We first consider the case without cargo congestion in the waterway or  $\beta = 0$ . Following the similar analysis, we know that, the operator of the inland port first sets a service fee,  $\tau = (c_R^0 - c_w^0)x_1 - c_w^1$ , to serve only its upstream customers, and then sets a service fee,  $\tau = \frac{1}{2}(2c_R^0 - (c_R^0 + c_w^0)x_1 - c_w^1)$ , to serve both downstream and upstream customers. In this case,  $x_M'' = x_L'' = x_L$ ,  $x_H'' = (2c_R^0 + c_W^1)/(3c_R^0 - c_W^0) < 1$ , and domain [0,1] is now divided into three sub-domains with corresponding optimal pricing. For the case with cargo congestion in the waterway but without heterogeneity of the navigational condition, namely,  $\beta > 0$  and  $\alpha = 0$ . The optimal service fee is higher

with  $\alpha > 0$  than that with  $\alpha = 0$ . And thus, when  $\beta > 0$  and  $\alpha = 0$ , both  $x'_{M}$  and  $x'_{H}$  are less than  $x_{M}$  and  $x_{H}$  when  $\beta > 0$  and  $\alpha > 0$ , respectively. Figure 3 shows the effects of the cargo congestion in waterway and heterogeneity of navigational condition on the optimal service fee of port *i* at different locations. It is clear to see that the cargo congestion and navigational heterogeneity deteriorates the market power of the inland port. In addition, it must be pointed out that, the practical model without explicitly considering the cargo congestion and heterogeneity in waterway of the inland river will highly estimate the service fee, cargo arrival rate and revenue.

Figure 3: The Effects of Cargo Congestion and Navigational Heterogeneity on the Optimal Service Fee



### 3.2.3 General case

This subsection studies the general case, in which, both waterway congestion and port service congestion are considered in the basic model. One is natural to ask the problem how the waterway congestion and navigational heterogeneity affect the results obtained in subsection 3.2.1. Firstly, in comparison with the results in subsection 3.2.1, the method to calculate the optimal solution when the navigational condition is homogeneous or  $\alpha = 0$  and  $\beta > 0$  is very similar to that in subsection 3.2.1. However, it is a little difficult when the navigational condition is heterogeneous or  $\alpha > 0$  and  $\beta > 0$ .

First, for any given location  $x_1$ , we know that, any pair of the service fee and port capacity,  $(\tau, \mu)$  with equilibrium condition (10) and  $\lambda < l(1-x_1)$  is not optimal solution. If a certain pair of  $(\tau, \mu)$  is optimal and equilibrium condition (10) with  $\lambda < l(1-x_1)$ , then the first-order conditions (14) and (15) hold. The profit can be calculated as

$$P(x_1, \tau, \mu) = \tau \lambda - \eta \kappa \mu = \frac{\beta \lambda^2}{V_0 - \alpha x_1} - \sqrt{\eta \kappa \gamma \lambda}, \qquad (22)$$

which is strictly increasing in the cargo arrival rate. It is clear to see that, the profit can be increased by increasing the port capacity  $\mu$  and setting the service fee policy  $\tau$  with eq. (14). Now, we know that, the investor either rejects to invest the inland port or selects optimal service fee capacity to attract cargo at both upstream and downstream, namely, the optimal service fee and port capacity ( $\tau$ , $\mu$ ) are determined such that equilibrium condition (12) holds. From some standard analysis, we know that, the operator tends to select the optimal port location at downstream in comparison with that obtained in Subsection 3.2.1, and lower service fee and port capacity.

#### 4. Conclusions

Recently, the inland waterway transport has attracted a lot of attention from the countries and regions since it is one of the environment-friendly transportation modes to alleviate road congestion, significantly. This paper studies the joint decision of the location, service fee and port capacity for one inland river port by explicitly taking into account the spatial distribution of shippers along the river and the navigational nature of the river. Our model also considers the inland waterway and port service congestion. The heterogeneity of the navigational condition and the congestion of the inland waterway and port service are very important to consider the joint selection of the optimal location, service fee and capacity of the inland river port. We obtain the optimal solution of the model theoretically under various scenarios. The effects of the navigational condition heterogeneity and the waterway congestion on the optimal solution are analyzed when the port service congestion is neglected. To extend those theoretical results to the general case is the main direction of the current study.

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# Methodology to Maximise the Profitability of a Container Shipping Terminal through the Optimisation of Its Level of Automation

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# Abstract

Current trends in automation are generally accepted as a way to maximize the adapting of container shipping terminals to its business volume. This research is taking into account these trends through an analysis which considers as much the global reality of the terminal as its local reality. Automation could exploit its strengths as well as minimizing its weaknesses in a constant growing and changing market.

For which we have developed a model analysis that takes into account the technical, operational, financial and economic influences in the design of a container shipping terminal, from its conception as being dependent to generate business, all these influences are defined by the specific market of shipping of container and the specific terminal physical constraints.

To obtain this model it has been necessary to conduct a study of processes in the current context of container traffic and its connection to the design of marine terminals, as well as the methodologies proposed so far by different authors to address the process sizing and design of the terminal.

We classify the terminals according to their degree of automation (automated, semi-automated and nonautomated), container trip stage (import-export or transfer) kind of client (dedicated or multi-client) and size of ship (panamax, post-panamax and super-post-panamax).

Having defined the model that will serve as the basis for the design of a container shipping terminal from a multi-criteria approach, we will analyse the influence of various explanatory variables of the model and quantify their impact on economic performance, financial and operational aspects of the terminal. The next step is to define a simplified model that links the profitability of a terminal concession with the expected traffic on the basis of the degree of automation and the type of terminal considered.

This research is the result of the ambitious objective of providing a methodology to define the optimal choice of designing a container shipping terminal on the pillars of operational efficiency and profitability maximization of the business it generates.

Keywords: Container shipping terminal, operating efficiency, profitability, subsystem, concession, automation

# 1. Introduction

The constant redistribution of trade has made the port competition to move constantly towards a competitive process among logistic chains. The container shipping terminal as a productive sector of activity has to be competitive and respond efficiently to the requirements demanded by its clients in terms of quality of service.

In this context, the current trend is the increase of the automation as a first step to address the problems derived from the excess of competition and the necessity of efficiency. However this option doesn't have to be the optimum one and this research submits to deeper analyse this statement implementing a model of analysis in which the technical, operational, economic and financial parameters have to been considered, all of which within a perimeter defined by the market of the traffic shipping volume of containers as well as the physical

limitations introduced by the terminal itself.

Once this model is established, it is interesting to set a relationship between variables which weight more within the model (relationship between the variables of bigger weigh within it). It is clear that in order for a terminal of containers to make sense, it has to fulfil a function, that is, it has to respond to a potential or existing demand. For another part, equally for the management of a shipping terminal to be financially viable it has to be profitable. So these two variables, profitability and shipping volume could be the two variables of greatest weight in the model. It seems obvious, in a first approximation, to link the business profit of the container shipping terminal to the traffic which it can handle under some quality standards accepted by the clients and within some market conditions based on the balance offer-demand.

At a second stage of the analysis, two concepts can be isolated as having a substantial influence as much on the exploitation and operation of the terminal as on its business model: the concessionary model, defining the terminal financial context and the level of automation, defining its operational context. Therefore, the main objective of this research is to define the methodology required to achieve the highest degree of automation of a container shipping terminal considering the type of business it will carry out and its volume, this in order to maximize its profitability.

# 2. History

# 2.1. Automation concept

The prospect of growth in containers traffic is prompting the adoption of strategies which enable us to respond efficiently to the evolution of the demand. On the other hand the environmental limitations and the relation port-city on the coastal areas implies that the viability of the enlargement of the already existing port installations to attend the traffic of containers or the creation of new ones is getting more and more difficult. In this context, the search for solutions allowing maximizing the use of the available infrastructures is becoming more important. These solutions try to analyse in details the processes taking place in the container shipping terminal in order to increase the capacity of the installations, reaching the maximum productivity and efficiency in each process. For that purpose, the development of the automation is seen as an essential tool.

Consequently and considering this hypothesis as being correct, every containers terminal should tend to be automated, although the cost associated to it is paid off through the residual benefit derived from the reduction of the errors and risks of the human intervention. Situations in which a complete technological implantation is not reached, will be given the term of semiautomatic terminal, fairly accepted in the sector (Monfort et al, 2001).

# 2.2. *Quantification of the automation degree*

From an operation point of view, the maximum degree of automation could be an undeniable objective of any planner of a container shipping terminal, but whenever the concept of financial profitability of the terminal is introduced, the automation implementation is subject to the gradual optimal selection to maximize the profit, which is what matters when any commercial activity is analysed.

Option Terminal		Subsystem				
		Dock	Court	Interconnection		
1	Automated	Manual control of the cranes with or	OverHead Bridge Crane (OHBC) ó Automatic Stacking Crane (ASC)	Automatic Guided Vehicles (AGV)		
2	Semi-automated	without double trolley o twin lift	Rubber Tyred Gantry (RTG) ó Rail Mounted Gantry (RMG)	Platforms + tractors		
3	Non-automated		Straddle Carrier (SC)			

Table 1: Automation Options
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Source: own

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Table 1" exposes the different automation degrees which quantify this concept in the container shipping terminals:

- Option 1. Automated terminal. The main differences regarding the automation degree in a container shipping terminal are found in the main yard, considering the large variety of equipments and cranes that are employed and which use has some direct consequences in the sizing of the rest of the subsystems, the operational staff, the civil infrastructure, the associated productivity, etc.
- Option 2: Semiautomatic terminal. In this option, not all the process is automated and the workforce still plays an important role in the use of cranes and equipments and in the planning of the processes which occur within the terminal.
- Option 3: Non-automated Terminal. It tends to be a basic system which can attend the terminal operational needs but with a major participation of the workforce.

### 2.3. Business model of the container shipping terminal

When private capital is involved in container terminals it occurs under a concessionary regime rather than under private ownership. In this sense, the concessionary model is the most extended formula under the denomination Landlord Port, according to which the Harbor Authorities manage the port grounds, facilitate the main basic infrastructures and general services of the harbor, organize, construct the access areas and warehouses, also piers and other terrestrial areas, giving in concession terminals to private companies which provide all the services to the load and to the ship. The port is divided into independent port terminals and each operator of the terminal is responsible for the investment and maintenance of the infrastructures, superstructures and equipments.

### 2.4. Relation of variables in a container terminal

The first necessary data for the planning of a container shipping terminal is its capacity to respond to the demand. This capacity will be more limited whenever the uncertainty over the traffic is lower. The need for capacity of a container terminal is conditioned by the physical limitations of the terminal but also by its productivity in relative terms and by the efficiency of its operations. These concepts are closely related to the performance of the selected teams who carry out the different operations in the different subsystems of the terminal. The selection of the teams defines the layout and the operational management model of the terminal, as well as the investment volume necessary to purchase these equipments, which could condition the business's profitability (see "Figure 1").



### Figure 1: Relation of Variables in a Container Terminal

### 3. Literature Review

The increase of the productivity, being that of capital, machineries, workforce, or other is usually the objective of most of the studies, understanding that the productivity from an operational or economic point of view is the relationship between the production obtained and the resources employed. Consequently considering that the intention, the purpose and the scope are financial or operational, two kinds of objectives can be distinguished in the studies realized until now: operational or financial efficiency.

Obviously, both objectives are related, the final objective of a best operational efficiency is to reduce the costs, although occasionally, an increase of the operative performance implies other costs increase and on the contrary, a cost reduction might imply a worst performance. Many authors have developed works which aim focusing on the performance of the production in terms of tonne hour or containers hours (Roux, 1996), etc. waiting time and queues waiting trucks, waiting and queuing of ships to dispose of berth and cranes, machinery's cycle (Daganzo, 1989), crane strategy to work with the maximum of hands by ship, etc.

Some of the studies have a technical aim to maximize the production, others as the planning added of resources, try to optimize the intensity of work versus capital (technology) and they have a financial aim. As far as the method is concerned, considering that normally the hypothesis is based on heuristic criteria, we can say that all models are mathematical either non parametric, analytical or using simulators. As far as its scope is concerned, all of them have a microscopic aim, some of them at technical level of the production, others at cost level. In general, the aim to all of them is following criteria of budget efficiency and operations productivity.

We can consider that the containers terminals have not reached maturity. This kind of maritime operation has existed for more than 40 years, and as such it is in constant evolution providing the sources of studies and an increasing number of conferences (Muñoz, 2008).

### 4. Methodology

The methodology used turns around the definition of a model which joins the operational and financial components of a container shipping terminal. These are both components which are considered when evaluating the terminal as a business although in this investigation they are represented within a chain, imposing each of these components its own restrictions to the other one from the focus of the optimization and considering the degree of automation as a referenced once we define the operational model.

For the correct elaboration of the economic-operational model, it is necessary to have defined an area which can be applied to.

Other of the aspects which enable to contextualize the economic-operative model is the management model, which is the concessionary formula within the landlord model. Concretely, the interesting point of view is the investor's one, which looks for an investment's profitability and which is able to quantify in concrete terms the investment's benefits. The model moves away of this point of view which is more related with the general interest of the building works, of it social component and macro, more abstract although justifying the participation of the Administration in the building worked of shelters/ warehouses, dredging, road infrastructures, railways, etc.

After the calibration of the model, we work to apply the economic-operational model to the different kind of terminals according to the traffic and the automation degree. The aim is to characterize the link between the maritime containers terminal profitability and the traffic expected according to the selected automation degree. This will allow to obtain ranks in which the operation is optimized and the profitability is maximized for each considered automation level.

This application will be effective in all different types of businesses according to the kind of terminal (importexport and transfer), kind of market (multi-clients and dedicated) and kind of ships it is designed for.

### 5. Definition of the Model

It is about building a tool capable, by itself, to simulate the operating conditions of a maritime container terminal and calculate the parameters of profitability taking into account the inputs previously defined by the user of the same. It is due to this that the tool has been named "Economic Operating Model". The usefulness of this tool lies in its generality, this is, in its ability to adapt to external conditions imposed by the user and in its flexibility this is, in its capacity to provide comparative results between different operational options in a same maritime container terminal under concession system.

This tool can also be useful to provide a response when analysing the feasibility of a project and/or for a comparative analysis of various solutions for one same project regarding the minimum required return. It must be assumed that the model developed responds the determination of private profitability of a project that develops in a concessional context of a Port Authority of the State Port Authority, attending the "landlord" model of management.

The model guides to standard operating parameters and towards an optimized dimensioning of the maritime container terminal through the control of different ratios of productivity, yields, etc. It is therefore a dynamic programming that allows us to have control over the coherence of the parameters that are being introduced. The methodology develops in two perpendicular directions:

- Vertical: It regards the linkage of all necessary parameters to achieve the economic-financial model of the maritime container terminal.
- Horizontal: It regards the linkage of the operational and technical aspects to reach the complete operative model, having selected an automation option.

First, it is necessary to highlight all those aspects that constitute an input of the model:

- Commercial scenario: Parameters that indicate the expected traffic in the terminal, as well as its composition (import-export, transfer, 20" container, 40" container, etc.) and parameters that define the expected vessel type in the terminal;
- Physical scenario of the terminal: Length of the berthing line, draft, width of cargo area, warehousing area, etc. It is in this case where the model exercises one of its controls: the draft of the terminal has to be bigger than the vessel;
- Economic scenario: It is important, due to its subsequent influence on the price update, to establish an inflationary scenario that will take place during the whole concession period; length of the service-life of the concession; what fees and rates have to be paid and what fees and rates will be able to charge due to the demand and supply of the services, etc;
- Civil Works: Foreseen investments to be realized in Civil Works and the duration of the same;
- Debt: Equity and borrowed funds available and terms of repayment (term, interest rate, etc.);
- Characteristics of the equipment: This input group is purely technical and the model relies on the information obtained of diverse groups such as the ones that commercialize with cranes, as well as on the experience of other cases: yields, costs, service-life, etc.

There exists a strong interrelationship between the inputs of the model and the subsequent calculations, since they are the basis for determining aspects such as the equipment of the subsystems and the operation and management staff.

The operating model incorporates the degree of detail necessary and sufficient for the calculation of all cost at the level of investment and of operation of the terminal during the concession period.

The next step consists in obtaining the return lines, investment and expenses that will enable the calculation of profitability of the business: revenues primarily dependent of the traffic and the services fees; the investment or Capex (Capital Expenditure: equipment, infrastructure and superstructure); the expenses or Opex (Operational Expenditure: operation and maintenance costs, overhead costs, fuel, water, insurance, etc.).

In this point it is necessary to make use of the tools and economic models to raise the methodology of the calculation of the profitability of the project of investment: profit and loss statement, free-cash flow and balance sheet. From here on it is possible to define the indicators that will provide information regarding technical, economic and operative viability of the terminal:

- Profitability ratios for the shareholder: Net Present Value, IRR (Internal Rate of Return) and Payback (return period).
- Operating ratios: Dock productivity, of the court, of interconnection, degree of congestion, yields, etc.

# 6. Application of the Model

After the programming of the complete model it is necessary to carry out a series of simplifications to the same in order to obtain more conclusive results regarding the different type of maritime container terminals that are usually present in this study area or that could be present in case of need of capacity due to congestion problems.

These simplifications do not detract significance or rigor in the calculations, nor do they lower the information volume obtained on the terminal, but it reduces the number of inputs to be introduced by the user, except for the strictly necessary to assess the feasibility of your business in an operational context aimed the optimum. The reduction of these inputs is performed through the adoption of a serious of hypotheses, the acceptance of a range of normal operating ratios; average productivity required and accepted range of values as differentiators of the types of terminal.

- Traffic is the key variable that determines the design of the terminal, the need for capacity, the size of the terminal, the productivity based on the necessary and possible dimensions, appropriate performance and degree of automation to achieve those returns. All this will define the layout of the terminal and is the basis for building the economic and operational model of the terminal. "Traffic" is therefore the fundamental explanatory variable in the profitability of the terminal in this simplified model.
- Container journey phase. This concept allows us to distinguish between import-export terminals and transfer terminals, given that it is unusual to find terminals exclusively dedicated to one or the other. What is clear is that the business outlook is radically different in each case, and it so is profitability. Transhipment leaves less income as fewer operations are conducted, containers remain on the yard for less time, if at all, and fewer services are required, all of which reduce the operating margin. This means distinctions are made between import-export terminals and transfer terminals.
- Desired berthing productivity. This concept enables us to determine the terminal dimensions according to traffic volume. There are two kinds of productivities according to terminal type: 600 TEUs/year/m of berthing line for multi-client terminals and 1,200 TEUs/year/m of berthing line for dedicated terminals (Gonzalez, 2007).
- The type of ship for which the berthing line and cargo handling are dimensioned is a necessary factor for estimating a large part of the terminal investment; it conditions operating costs and staff numbers, and it is therefore another variable to consider.
- The degree of automation is the variable that defines the technological level of the terminal, how dependent it is on labour, the amount of investment, the computer equipment of the terminal, the operating model, its layout, all of which are factors determining the investment. This variable has a greater weight in the yard and interconnection equipment.
- The concession period shall be 30 years, of which 28 are operational; 20% equity is considered.
- Depending on the purpose, two types of terminal can be defined: import-export terminals or transfer terminals; a minimum of 75% of traffic must be of the terminal type.
- The degree of utilization of major subsystems is limited to 75% of maximum capacity.

For each variable, the options shown in "Table 2" are considered.

Variable		Salient implications in the	model
Traffic	-	VALUE!	
Container trip phase	-	Import-export:	1
(Type of business)	-	Transfer:	2
Productivity	-	Multi-client:	1
(Type of market served by the terminal)	-	Dedicated:	2
	-	Panamax:	1
Ship type	-	Post-panamax.	2
	-	Super-Post-Panamax:	3
	-	Automated:	1
Level of automation	-	Semiautomated:	2
	-	Non-automated:	3
n			

### Table 2: Possible values of the explanatory variables

#### Source: own

The combination of all options for each variable means a large number of scenarios must be analysed, but the results for two specific, extreme scenarios will be analysed:

- Import-export multi-client. These are the most commercially oriented terminals, with greatest uncertainty when scheduling berths; this reduces the productivity of the berthing line, lending greater importance to the yard and the agility of the interconnection equipment. Generally, containers remain in the port longer and the average revenue per TEU is greater than in the case of transfer terminals.
- Transfer dedicated. This is the usual case of exclusive use terminals (MSC terminal in the Port of Valencia) by a client where transhipment is the main activity. Generally, containers remain in the port for shorter periods, and therefore the average revenue per TEU is lower. On the other hand, berth scheduling is simplified and productivity increases. Dimensioning is simpler, uncertainties are reduced and profitability, although less, is virtually assured.

For comparison between the two scenarios, traffic is varied between 100,000 TEU a year and 10 million TEU a year in order to obtain the profitability curve based on traffic for each degree of automation, assuming berthing and cargo handling subsystems are sized for super-post-panamax.

# 7. Results

The following results represent the relationship between the shareholder's IRR and the traffic based on the degree of automation for each terminal type defined (see "Figure 2" and " Figure 3").





Figure 3: IRR as a Function of Traffic and Automation. Transfer – Dedicated – Super-post-panamax



For import-export – multi-client terminals, the following conclusions can be drawn:

- The curves show peaks for the following reasons:
  - The differential increase in traffic may involve the purchase of additional, not fully depreciated equipment, causing a decrease in profitability. The higher the traffic, the less important is this effect since the cost differential is diluted in the total volume of investment, which is greater.
  - The same is true when one increases the number of berths and their level of utilization is not high.
- The option of not automating the installation is only competitive for small volumes of traffic: 200,000 TEU per year. This option reaches asymptotes of return of 20%.
- The semi-automated and automated options show similar behaviour. An IRR of 30% is the asymptote of the business.
- For both cases of automation (complete and semi-complete), there is an important variation of profitability for shareholders up to traffic of around one million TEUs, from there the curve becomes very inelastic.
- As a general conclusion, full automation is an alternative only when there are physical and/or operational limitations in the terminal. Otherwise, results are similar to semi-automated installations.

The conclusions obtained for dedicated transfer terminals are as follows:

- The results justify the choice of separating import-export and transfer, because the transhipment option provides yields are much lower, around 12%, providing the option selected is full or semi-automation.
- Acceptable return thresholds (shareholder IRR of 10%) are obtained for traffic of around 600,000 TEU a year.
- With traffic in excess of 1.6 million TEU a year, it is better equip the yard with the automated option instead of the semi-automated, even though the differences in profitability are not great. We again refer to the physical and operational constraints as major factors when making a decision on the degree of automation in this type of terminal.
- The manual option should not be considered in any case.

The next step is to bring the model closer to a simple expression by a statistical approximation model. The best correlations are obtained for expressions of the type (see Eq. 1):

$$IRR_{acc} = a \cdot Ln(Traffic) + b \tag{1}$$

Where:

*IRRacc* is the internal rate of return for shareholders, expressed in %. *Traffic*, expressed in TEUs a and b are parameters to be calibrated.

For the full model, that is, for the traffic rank between 0 and 10 million TEUs, the settings that are obtained for each operating scenario are those that can be seen in "Figure 4" and in "Figure 5".

Figure 4: IRR Adjustment Model according to Traffic and Automation. Import-export - multi-client



Figure 5: IRR Adjustment Model according to Traffic and Automation. Transfer – Dedicated



"Table 3" shows the different parameters of each adjustment according to terminal type and degree of automation.

Table 3: Characterization of the Ac	ljustment for the Full Range of Traffic
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Type of Terminal	Level of automation	Adjustment and goodness of fit				
		а	b	R2	Error	
					Average	Dev
Import-export – multi-client	Automated	0.0394	-0.3305	0.8165	-0.44%	6.29%
	Semiautomated	0.0348	-0.2509	0.7982	-0.17%	6.22%
	Non-automated	0.0231	-0.1677	0.7396	-0.91%	4.94%
Transfer - dedicated	Automated	0.0179	-0.165	0.6669	-0.30%	19.49%
	Semiautomated	0.0148	-0.1192	0.6192	-0.86%	8.57%
	Non-automated	0.0144	-0.1453	0.7632	-2.30%	7.83%

Source: own

### 8. Conclusions

The conclusion of the research is that maximizing the automation of a maritime container terminal is not always synonymous with success in operating results and profitability linked to that terminal. There are physical conditions, financial, commercial, and so on, from whose analysis and interrelation can be obtained the optimal automation that maximizes the benefit for the given conditions, and balances terminal productivity. Other findings from the model adjustment are:

- In import-export terminals, shareholder returns of between 3.5 and 4.5 times higher than in transhipment terminals are obtained, all other conditions being equal.
- In dedicated terminals, yields are between 1.4 and 2.3 times higher than those in multi terminals.
- Full automation is the most profitable option for dedicated import-export terminals above 1.2 million TEU a year and dedicated transhipment terminals from 1.6 million TEU a year. Otherwise, semi-automation is optimal, unless physical or other limitations suggest otherwise.
- The non-automated option is not comparable with any automation option whatever the annual traffic, the type of business, the customer being served and the ship type for which is dimensioned. Shareholders IRR of the same order of magnitude is only obtained for an import-export terminal up to 200,000 TEU a year for panamax vessels.
- Setting a minimum return of 10.5% as a lower threshold to the shareholder's investment in importexport terminals is achieved with the partial automation option for traffic of 200,000 TEU a year for both multi-client terminals and dedicated terminals. For multi-client transfer terminals, this profitability level is not reached; if the terminal is dedicated, this profitability level can only be reached with traffic between 1.4 and 1.8 million TEU a year, depending on the type of ship design and full automation.
- In all terminals, beyond a traffic level of around 2 million TEU a year, return is virtually inelastic to traffic. Regardless of the business that takes place in the terminal, the ship design type and degree of automation, the growth of the TIR per 100,000 TEU moved does not exceed 0.35%, while up to 2 million TEUs, that growth is around 5% in multi-client terminals and 10% in dedicated terminals.

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# Imposing of Responsibility on States' to Guarantee Labour Standards for Seafarers under the MLC 2006: Can the ILO Achieve Its Goal?

#### Dan Malika Gunasekera<sup>i</sup>

The long waited need of securing a single document for the rights of sea-faring work force is gradually becoming a reality after a lapse of few months in this 2013 with the Maritime Labour Convention adopted in 2006<sup>ii</sup> reaching its date of commencement into force fixed at August 20th. Under the auspices of the International Labour Organization, the High-level Tripartite<sup>iii</sup> Working Group on Maritime Standards<sup>iv</sup> that first met from 17 – 21 December 2001 has already made history by fulfilling its task of covering complex issues within a limited scope of substance. It is quite obvious that the intention for which this Convention was brought into being has well been met as a matter of incorporating various international maritime labour standards into a single coherent international instrument.<sup>v</sup> During the initial discussions, it was felt by the drafters that the existed standards were often inconsistent and unclear and that the frequent revision procedures were in fact incapable of enabling their rapid adoption in meeting the special needs of the developing industry.<sup>vi</sup> The idea behind, was to create a balance between the industry's tradition and the need to innovate of the working standards in conjunction with the ILO's present approach of providing decent work agenda for the maritime workforce. Nevertheless, it was well viewed that the proposed instrument should be simple, clear and easy to apply so that States could implement it without much of hassle.

It was brought to the knowledge of the drafters at initial stage to have due regard to practical problems faced by States with the ratification and implementation of the existing standards on labour<sup>vii</sup>, and the majority's view was to complement it with a distinct Convention insisting upon 'technical cooperation' based on 'flexible approach'. Since there were much of concerns on the procedure through which IMO's STCW Convention 95<sup>viii</sup> was brought into being, participating delegations view it as a role model despite of the law making procedures involved in IMO and ILO at varying degrees<sup>ix</sup>. As many States regarded 'favourable treatment' would cause considerable harm as evidenced in some previous international instruments that would result in non-acceptance, much of the support were had towards the concepts 'no more favourable treatment' and 'substantial equivalence' clauses as a matter of supporting the idea of a level playing field especially considering the developing countries with much assistances in technical means. Nevertheless, the end result proved the upholding of the flexibility approach rather to gain consensus among participating States. The present work will concentrate on the application of this flexibility approach in achieving conventional objectives and issues that surround the implementation of State obligations.

### 1. Shortcomings and Weaknesses of Prevailed Tools

Referring to the immediate sources on which the existed regime that stood until the adoption of the MLC, the Working Group steadily observed the very nature of application and their deficiencies in relation to the ILO Convention No. 147<sup>x</sup>, IMO's Safety of Life at Sea<sup>xi</sup> as well as national legislations on the related aspect. However, much of its concerns were directed on their enforcement rather than mere application of their existence in order to identify the shortfalls as well as the matters surrounding the issue at hand. Having identified the areas that lacked proper enforcement in wake of the industry developments despite the prevalence of diversified rules and regulations aforesaid, it was the common decision of the group to bring in the substance to a single international regime. Much concern were directed towards consolidating the prevailing instruments to a single regimes as observed aforesaid, and there seemed to have no indication of introducing new standards apart from the general developments in certain areas but to decide on the use of proper workable principles. Primarily, the drafters entrusted upon them the duty to practically impose responsibility to all States to ensure that decent conditions of work apply on all ships that are placed or come under their respective jurisdiction<sup>xii</sup> rather than affording theoretical set of rights to seafarers that have already been incorporated in various other similar instruments of maritime nature.<sup>xiii</sup>

Apart from mere consolidation, the ILO's Tripartite Committee was highly concerned of the absence of a single coherent legal instrument that covers this particular subject in a more meaningful manner through

which State obligations could thus be brought into place. Representing all corners of the maritime field of interests, the Committee primarily focused on amalgamating all the said interests to represent this single document. Therefore, it was highly emphasized that issues such as human rights at work, employment and incomes, social protection and security as well as social dialogue should be well addressed<sup>xiv</sup> in its forth coming agendas. In view of these concerns, the drafters mainly focused on identifying over-lapping or conflicting provisions of the existing instruments while adopting a two folded system of mandatory and non-binding application of the recommended standards as a matter of remedying the prevailing shortcomings and weaknesses.

# 2. In Realization of a Bill of Rights

It was mainly in the agenda of the ILO drafters that Convention must introduce a bill of rights for seafarers in compromise of the safety and environmental standards already put in place by the IMO thus eliminating substandard shipping.<sup>xv</sup> Much emphasis were had on the initial reports such as the "Impact on seafarers' living conditions of changes in the shipping industry"<sup>xvi</sup> and "Ships, slaves and competition"<sup>xvii</sup> while the latter's statement that; thousands of seafarers work under modern slavery and on slave ships, raised much of the concerns for its justification against sub-standard shipping practices. Therefore, the need of a consolidated framework instrument containing key principles along with the annexes incorporating detailed requirements had to be met as a primary element. According to the views of several Government delegations, this would certainly establish a social level playing field for quality shipping while ILO's institutional ambitions stretched towards overcoming obstacles in national legislations and procedures. In turn this would realize the achieving of the strategic objectives of the ILO in maritime industry linked with the ISM Code<sup>xviii</sup> for effective enforceability.

In its final draft, the ILO has been successful in setting up the required standards as Regulations and the Code spreading into five areas titled<sup>xix</sup> (1) Minimum requirements for seafarers to work on a ship<sup>xx</sup>; (2) Conditions of employment<sup>xxi</sup>; (3) Accommodation, recreational facilities, food and catering<sup>xxii</sup>; (4) Health protection, medical care, welfare and social security protection<sup>xxii</sup>; and (5) Compliance and enforcement<sup>xxiv</sup>. Considering the subjects covered under the said respective Titles, this piece of work obviously operates as a means of charter for the shipping industry and especially to its work force. They have been well complemented with corresponding Regulations that require the maintenance of the relevant standards<sup>xxv</sup> while providing the necessary guidelines for the use of its systematic application. These regulations have not only imposed duties on States to ensure that proper surveillance be carried out in its implementation of the rights of the related labour, but thus provide complete attainment of dutiful opportunities in retrospect for the seafarers of the 21<sup>st</sup> century. It is noteworthy that the seafarers' competence has well documented by the MLC 2006 without leaving any loopholes in the process of issuing required certificates by competent authorities of States. Matters falling within the purview of the STCW Convention in relation to training have also been given due recognition through a standardized labour convention of this nature in order to fully supplement the needs of the trade as a gap filing source within ILO competence remarkably. Therefore, the instrument could be highly rated as a Bill of Rights as intended by its drafters rather than a mere set of international rules.<sup>xxvi</sup>

In contrast, the MLC provides seafarers with job safety subject to the necessary statutory requirements through State adherence unlike the other regimes that deal with specific issues as to certification, competency, safety and etc that do not singularly address the core matters as a collective document. It is therefore, the duty of States to ensure the due recognition of their respective obligation in undertaking, to give complete effect of its provisions in order to secure the right of all seafarers<sup>xxvii</sup> who fall under each of their jurisdictions to decent employment. <sup>xxviii</sup> In doing so, the States are obliged to respect the rights and principles set out in the Regulations and to implement each of them in accordance with the mandatory Standards provided in Part A of the Code<sup>xxix</sup> while giving due consideration to implementing their responsibilities in the manner set out in the non-mandatory Standards provided in Part B<sup>xxx</sup>. In such context, proper justification could well be placed against the revising of 37 maritime related ILO instruments<sup>xxxii</sup> while embodying all up-to-date standards of existing international maritime labour Conventions and Recommendations found in other instruments<sup>xxxiii</sup> of it dealing with general topics on labour. Considering the entirety of it, the MLC 2006 operates undoubtedly as an umbrella convention with respect to seafarers' labour rights<sup>xxxiii</sup> and in particular as an instrument covering all areas of work oriented privileges rather than a 'code of rights and corresponding duties'.
Evidently, the seafarers have been granted the fundamental labour rights including the right to safe and secure workplace, right to fair terms of employment, right to decent working and living conditions on board, right to health protection, medical care, welfare measures and other forms of social protection<sup>xxxiv</sup> while strictly imposing the onus on States to guarantee their fulfillment.

### 3. State Obligations: Burdensome but Executable

The conventional provisions have imposed extensive duties on States with considerable magnitude on unilateral, co-operative and consultative basis for the better realization of its goals. In particular, States are bound to apply the Convention in strict terms covering all categories of seafarers<sup>xxxv</sup> employed in commercial shipping<sup>xxxvi</sup> engaged in trans-boundary or international navigation<sup>xxxvii</sup>. But however, the application of the said provisions are excluded from ships that are engaged in fishing or in similar pursuits thereby omitting fishing personnel and their employees and further the ships of traditional build such as dhows and junks. These exclusions continue, as in other similar cases, to warships or naval auxiliaries that fall within the purview of one's national security concerns and in particular, to defense naval officers of the States. xxxviii In case a State is confronted with doubts as to application of the provisions with regard to complications surrounding the ascertainment of a seafarer, ship or ships of a particular category within conventional meaning, the matter shall be decided by its competent authority<sup>xxxix</sup> having obtained the views of the relevant shipowners' and seafarers' organizations based on consultative onus.<sup>x1</sup> Furthermore, a State is at liberty to exclude the application of the provisions of the Code in case its national laws or regulations 'at present time' and its collective bargaining agreements or other measures deal with the issue at hand in a manner different to that of the conventional provisions and to such extent of conflict. But however, this allocation has only been made with respect to ships of less than 200 GT not engaged in 'international vovages'.<sup>xli</sup> Importantly, there are two main issues that arise with respect to this said provision. One is the use and means of the term 'at present time' which was not specifically dealt with at committee level though the President of the Conference recalled in its final session the importance of minimizing problems associated with the application of the Code in relation to smaller ships that would really come into conflicts with prevailing national legislations of respective States.<sup>xlii</sup> It is clear that such affordability was granted in view of the flexibility approach advocated throughout the law making process for the ascertainment of a level playing field. Therefore, it is on these two grounds that the text has been drafted accordingly where the final outcome appears to be a settlement in allowing to afford protection via national laws, regulations or other measures.<sup>xliii</sup> Nevertheless, it has been stressed that such national provisions would have to comply with the Articles and Regulations of the Convention.<sup>xliv</sup> But however, the travaux préparatoires do not unveil any related discussion on the specific use of 'at present time' though they suggest it to be of the 'material time' the competent authority is confronted with the issue for its determination, inferring future times instead of the time of drafting. The other is the use and means of 'international voyages' where the Convention specifically applies to external waters within its definition of 'ship' in Article II.1 (i) that contradicts with the use of the former and does not provide any sense for that specific use except the fact that these concerns were enumerated during working group stage where it was felt that domestic trade should be carefully considered since cabotage has certainly influenced the legislations of certain countries.<sup>xlv</sup> But however, the final text suggest that the later addition of Article II.6<sup>xlvi</sup> was not a means of a gap filler in order to accommodate prevailing practices of States, and therefore, create no significant influence on the matter at hand.

Unilaterally, the States are obliged to provide decent working conditions while particularly guaranteeing the fundamental rights such as freedom of association and right to collective bargaining, elimination of forced or compulsory labour, abolition of child labour and elimination of discrimination<sup>xlvii</sup> and further endorsing on itself to implement and enforce laws and regulations or other measures<sup>xlviii</sup> in fulfilling those ends. In doing so, the States are expected to effectively exercise its jurisdiction and control over ships that fly its flag<sup>xlix</sup> even in circumstances of convenience including their due diligence required in regular inspections, reporting, monitoring and legal proceedings<sup>1</sup> in relation to the respective rules and regulations. It is an utmost requirement to make sure that ships under their respective jurisdiction carry a 'maritime labour certificate' and a 'declaration of maritime labour compliance' as required by the Convention. <sup>li</sup> Importantly, the latter document was renamed from its original 'declaration of compliance' in order to avoid confusion with ISM Code requirement pursuant to shipowners' proposal<sup>lii</sup> thereby introducing two new formats for the latter as well as the former documents mentioned above in the Appendix to the Code without leaving any possibility

for unilateral creation by a State. However, the inspection aspect was given much priority in determining the best suitable wording since its' wings spread over the non-States' Parties beyond the application to ones who ratify. While Member States have exclusive powers over its ships in ensuring compliance, they are also duly authorized as they wish to extend that power over the ships that fly a different flag during such time the particular ship is in a port of such inspecting State <sup>liii</sup> in accordance with international law thereby implementing Port State and Flag State Controls. However, the Members States are prohibited from less favouring ships that fly the flag of Member States over a non-Member, <sup>liv</sup> thereby encouraging the obtaining of more ratification.

### 3.1 Onus on cooperative and consultative arrangements

Apart from individual action, Members are bound to cooperate with each other for the purpose of ensuring the effective implementation and enforcement of the Convention by virtue of its Article I.1 in conjunction with the *Preamble* and particularly furthering their respective obligations under the international public law on the use of the sea<sup>lv</sup> that requires state cooperation in the marine sector, especially concerning the maintenance of its integrity needs. In turn, this would enable Member States to fully comply with the conventional requirements in their individual capacities while engaging in mutual exchange of information and each others' practical difficulties in developing a proper check and balance system. Furthermore, the Convention has fully endorsed the interplay between States and participatory stakeholders that evidently took an active role throughout the drafting process. But however, the said roles of those respective organizations have not been limited to mere participatory extent as States are further bound to resort for future consultation especially regarding matters that need consultation in respect of any derogation, exemption or other flexible application of the Convention.<sup>1vi</sup> In circumstances where such organizations do not exist within a Member State, the latter is bound to refer such matter to the Committee<sup>lvii</sup> prior to the taking of such decision. The Convention has well recognized this role of the stakeholders by entrusting upon them the voting power<sup>lviii</sup> in the said Committee that could cause some impact on the issues at hand. It proves the limit to which the influence that these stakeholder organizations could pose on individual States and their respective constituent competent authorities as a matter of importance of their presence in maritime trade. However, such an approach is apparent in the ILO system where the contributions of social partners are reciprocally recognized to maintain flexibility.lix

### 3.2 Implementation

Whether it may involve one's national provisions of the law and regulations or other measures that become compatible to execute its due obligations in applying the relevant Regulations of the Code, a State is deemed to implement the conventional objectives in the manner specified by itself. It further provides that such corresponding means of enactment become substantially equivalent in one's duty to implement the said relevant Regulations for the purpose of achieving the general objects of the mandatory Part of the Code thus giving effect to those provisions<sup>1x</sup> in the process of proper implementation. In a more general context, a proper system of inspection and evaluation would be extremely inevitable in line with the fulfillment of declaration of maritime labour compliance thus ensuring Member States' commitment towards upholding the principle of decent work emphasized in the *Preamble* to the Convention. Therefore, the collective efforts brought about by the Convention itself through its drafting process need to accommodate effective implementation and enforcement of the respective obligations of Member States.

### 4. ILO's Competence and Fulfillment of State Obligations: Is It Realizable?

With few more months to go for the MLC to come into force<sup>lxi</sup>, the most important question is whether it could fulfill the purpose for which the Convention was brought into being. It is nevertheless important to note that the Convention becomes binding only upon the Members of the ILO who have registered their respective ratifications.<sup>lxii</sup> In general, the ILO maintains the practice that its respective standards are formulated in a manner flexible enough<sup>lxiii</sup> to be translated into national law<sup>lxiv</sup> and practice with due consideration<sup>lxv</sup> based on diversified domestic factors of its Member States. Standing on this flexibility approach that was evidently taken use of in the present Convention making, the Organization allow States to lay down temporary standards that are lower than those normally prescribed<sup>lxvi</sup>. This would enable ratifying States to reserve certain duties

by declaration to derogate that would in turn result in maintaining sub-standards. This is exactly the measure that transpires from the application of Article VII and further relaxation introduced by Article VI that operates two folded. The former Article would thus restrict the possibility of a Member State to arrive at a unilateral decision though such obligation is vague enough to proceed for like decisions that lead to maintain sub-standards while the latter Article enable flexibility to introduce national laws with a larger margin of appreciation. It is therefore, questionable whether the Convention has been able to fully respect the so-called 'Bill of Rights' that is certainly in place for the maritime industry through IMO interference. However, the ILO's much recently adopted 'integrated approach' methodology<sup>lxvii</sup> has been well evidently used in the present text referring to it as a whole that correspond to the improving of coherence, relevance and impact of standards-related activities and developing a plan of action that embodies a coherent package of tools to address the present subject.<sup>lxviii</sup>

Considering the effect of this Convention that revise those existing standards introduced by the list of conventions mentioned in Article X, it is in a way much feasible for Members States to apply the present one as a whole. But however, it would not certainly affect the maintaining of sub-standards presently practiced by some Members though the attainment of fully fledged rights of the seafarers tend to fall into conflict against the conventional goals that reflect much adversarial scenario. Unlike in the case of the IMO which operates as a 'watch-dog' in commercial maritime that is engaged in regulatory matters<sup>lxix</sup> concerning shipping as its main source, the ILO's approach towards realizing occupational rights are much centralized towards personoriented than that of the industry. This in fact imposes a higher degree of scrutiny upon the latter's competence requiring the realization of its organizational goals to the fullest. Therefore, one must bear in mind the respective obligations of these different organs and the nature of their importance in contrast in ascertaining whether the ILO has been able to achieve the end results of the MLC as a matter of fact. To date, much of the emphasis has been centered towards gaining wide ratification of States<sup>1xx</sup> thus diverting the attention on the implementation aspect as well as post-ratification burden of States. It is quite questionable whether the Guidelines<sup>lxxi</sup> introduced in consequent to the adoption of the MLC would provide sufficient means of handling the issue of proper implementation but seem to restrict their application to narrow scopes of decent work agenda such as on-board complaints mechanism<sup>lxxii</sup> and detention of ships lacking compliance. One might possibly see that these guidelines would serve the purpose for the seafarers in protecting their rights, but it can be measured only as a means of technical mechanism on conventional adherence. At least to a considerable degree, it can be concluded that the conventional goals have thus been achieved in respect of personal needs of seafarers with respect to health, education, accommodation, food and sanitary standards and employment security and benefits, training and social security rights<sup>lixxiii</sup> with some over lapping situations with other corresponding IMO instruments discussed above. It is therefore, quite necessary to implement the MLC 2006 by the respective Members States in utmost good faith towards the realization of its goals in order to assess the success of it as a global leader in labour standards for seafarers.

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<sup>&</sup>lt;sup>ii</sup> Adopted in February, 2006 by the 94<sup>th</sup> Int'l Labour Conference at a maritime session in Geneva

<sup>&</sup>lt;sup>iii</sup> This was called Tripartite due to the involvement of three main representative stakeholders consisting of namely Governments, Shipowners and Seafarers

<sup>&</sup>lt;sup>iv</sup> The decision to set up this forum was taken at the 280<sup>th</sup> Session of the Governing Body of the International Labour Organization in March 2001 subsequent to the proposal made by the Joint Maritime Commission in its 29<sup>th</sup> Session in January 2001

<sup>&</sup>lt;sup>v</sup> See C. Doumbia-Henry, D. Devlin and M. L. McConnel, *The Maritime Labour Convention*, 2006 *Consolidates Seafarers' Labour Instrument*, American Society of International Law Insights, Vol. 10, Issue 23, Sep. 13, 2006

<sup>&</sup>lt;sup>vi</sup> See TWGMLS-FR-2002-01-0305-1-EN.Doc/v2, p2, paragraph 4

<sup>&</sup>lt;sup>vii</sup> See *id*, p.11, paragraph 55

viii The Standard of Training, Certification & Watchkeeping Convention 1978 as amended by Protocol 1995

<sup>ix</sup> ILO requires the communication of relevant national legislation at the time of ratification while IMO maintains a different method

<sup>x</sup> Concerning Maritime Standards in Merchant Ships, Geneva, 29 October 1976.

<sup>xi</sup> International Convention for the Safety of Life at Sea (SOLAS) 1974 adopted by the International Maritime Organization.

xii See TWGMLS-FR-2002-01-0305-1-EN.Doc/v2, p27, point 8

<sup>xiii</sup> For further reading, see M. L. McConnell, *The ILO's Maritime Labour Convention, 2006: Filling a Gap in the Law of the Sea*, Mepielan e-Bulletin, Mepielan Centre, 7 April 2011 available at http://www.mepielan-ebulletin.gr/default.aspx?pid=18&CategoryId=2&ArticleId=55&Article=The-ILO%E2%80%99s-Maritime-Labour-Convention,-2006:-Filling-a-Gap-in-the-Law-of-the-Sea

xiv See TWGMLS-FR-2002-01-0305-1-EN.Doc/v2, p27, subparagraph (b)

<sup>xv</sup> See *supra* n.4, p. 3, paragraph 13.

<sup>xvi</sup> Presented by the ILO to the JMC's 29<sup>th</sup> Session.

<sup>xvii</sup> Report of the International Commission on Shipping (ICONS).

<sup>xviii</sup> International Safety Management Code of the IMO

xix See Explanatory Note to the Regulations and Code of the Maritime Labour Convention, paragraph 5

<sup>xx</sup> Title 1 - Minimum Requirements for a Seafarer to Work on a Ship: Regulations 1.1 Minimum Age, Standard A1.1, Guideline B1.1; 1.2 Medical Certificate, Standard A1.2, Guideline B1.2; 1.3 Training and Qualifications; 1.4 Recruitment and placement, Standard A1.4, Guideline B1.4

<sup>xxi</sup> Title 2 – Conditions of Employment: Regulations 2.1 Seafarers' employment agreements, Standard A2.1, Guideline B2.1; 2.2 Wages, Standard A2.2, Guideline B2.2; 2.3 Hours of work and hours of rest, Standard A2.3, Guideline B2.3; 2.4 Entitlement to eave, Standard A2.4, Guideline B2.4; 2.5 Repatriation, Standard A2.5, B2.5; 2.6 Seafarer compensation for the ship's loss or foundering, Standard A2.6, Guideline B2.6; 2.7 Manning level, Standard A2.7, Guideline B2.7; 2.8 Career and skill development and opportunities for seafarers' employment, Standard A2.8, Guideline B2.8

<sup>xxii</sup> Title 3 – Accommodation, Recreational Facilities, Food and Catering: Regulations 3.1 Accommodation and recreational facilities, Standard A3.1, Guideline B3.1; 3.2 Food and catering, Standard A3.2, Guideline B3.2

<sup>xxiii</sup> Title 4 – Health Protection, Medical Care, Welfare and Social Security Protection: Regulations 4.1 Medical care on board ship and shore, Standard A4.1, Guideline B4.1; 4.2 Shipowners' liability, Standard A4.2, Guideline B4.2, 4.3 Health and safety protection and accident prevention, Standard A4.3, Guideline B4.3; 4.4 Access to shore-based welfare facilities, Standard A4.4, Guideline B4.4; 4.5 Social security, Standard A4.5, Guideline B4.5

<sup>xxiv</sup> Title 5 – Compliance and Enforcement: Regulations 5.1 Flag State responsibilities, 5.1.1 General Principles, Standard A5.1.1<sup>°</sup>, Guideline B5.1.1; 5.1.2 Authorization of recognized organizations, Standard A5.1.2, Guideline B5.1.2; 5.1.3 Maritime labour certificate and declaration of maritime labour compliance, Standard A5.1.3, Guideline B5.1.3; 5.1.4 Inspection and enforcement, Standard A5.1.4, Guideline B5.1.4; 5.1.5. On-board compliant procedures, Standard A5.1.5, Guideline B 5.1.5; 5.1.6 Marine casualties; 5.2 Port state responsibilities, 5.2.1 Inspections in port, Standard A5.2.1, Guideline B5.2.1; 5.2.2 On-shore seafarer complaint-handling procedures, Standard A5.2.2, Guideline B5.2.2; 5.3 Labour supplying responsibilities, Standard A5.3, Guideline B5.3

<sup>xxv</sup> For further reading on international labour standards, see J. Heintz, *Global Labour Standards: their impact and implemention*, Working Paper Series, Political Economy Research Institute, University of Massachusetts Arnherst, No. 46, November 2002

<sup>xxvi</sup> For further reading, see also The Int'l Transport Workers' Federation, *A Seafarers' Bill of Rights: An ITF Guide for Seafarers to the ILO Maritime Labour Convention*, 2006, available at http://www.itfseafarers.org/files/publications/23556/SBoR\_English\_inside\_small.pdf

<sup>xxvii</sup> Art. II.1(f) states that "Seafarer means any person who is employed or engaged or works in any capacity on board a ship to which this Convention applies"

<sup>xxviii</sup> See Art. I.1

<sup>xxix</sup> See Art. VI.2

<sup>xxx</sup> id

<sup>xxxi</sup> See Art. X – Effect of Entry Into Force

<sup>xxxii</sup> Found in the Preamble of MLC 2006 and in particular, the Forced Labour Conv., 1930 (No. 29); the Freedom of Association and Protection of the Right to Organize Conv., 1948 (No. 87); the Right to Organize and Collective Bargaining Conv., 1949 (No. 98); the Equal Remuneration Conv., 1951 (No. 100); the Abolition of Forced Labour Conv., 1957 (No. 105); the Discrimination (Employment and Occupation) Conv., 1958 (No. 111); the Minimum Age Conv., 1973 (No. 138); and the Worst Forms of Child Labour Conv., 1999 (No. 182)

<sup>xxxiii</sup> See M. L. McConnel, D. Devlin and C. Doumbia-Henry, *The Maritime Labour Convention*, 2006: A *Legal Primer to an Emerging International Regime*, Martinus Nijhoff, 2011, p 41

<sup>xxxiv</sup> See Art. IV

<sup>xxxv</sup> See *supra* n. 27

<sup>xxxvi</sup> According to Art. II.4, it applies to all ships whether publicly or privately owned and originally engaged in commercial activities

<sup>xxxvii</sup> See Art. II.1(i) which defines that Ship means a ship other than one which navigates exclusively in inland waters or waters within, or closely adjacent to, sheltered waters or areas where port regulations apply <sup>xxxviii</sup> See Art. II.4

<sup>xxxix</sup> According to Art II.1(a), it means the minister, government department or other authority having power to issue and enforce regulations, orders or other instructions having the force of law in respect of the subject matter of the provisions concerned

<sup>x1</sup> See Art. II.3 and Art. II.5

<sup>xli</sup> See Art. II.6

<sup>xlii</sup> See ILC94-PR7(Part I)-2006-02-0376-1-En.doc, p. 7/19, paragraph 114

<sup>xliii</sup> See ILO Handbook, *Guidance on implementing the Maritime Labour Convention, 2006 Model National Provisions*, Geneva, 2012

<sup>xliv</sup> See *supra* n. 42

<sup>xlv</sup> See STWGMLS-FR-2002-08-0085-1-EN.Doc/v2, p. 26, paragraph 162

<sup>xlvi</sup> See ILC94-PR7(Part I)-2006-02-0376-1-En.doc, p. 7/19, paragraph 115

<sup>xlvii</sup> See Art. III

xlviii See Art. V.1

<sup>xlix</sup> See Art. V.2

<sup>1</sup>See *id* 

<sup>li</sup> See Art. V.3

<sup>lii</sup> See High Level Tripartite Working Group on Maritime Labour Standards (Fourth Meeting) Final Report, TWGMLS-FR-2004-04-0034-1-EN.Doc/v2, 19-23 January 2004, p. 18, paragraph 84

<sup>liii</sup> See Art. V.4

<sup>liv</sup> See Art. V.7

<sup>1</sup><sup>v</sup> More specifically, the United Nations Conv., on the Law of the Sea, 1982

<sup>lvi</sup> See Art. VII

<sup>1vii</sup> According to Art. XII.2, the Committee means the Special Tripartite Committee that shall consist of two Government representatives of each ratified State, and the representatives of Shipowners and Seafarers appointed by the Governing Body of the ILO, which is the Executive Body, after consultation with the Joint Maritime Commission

<sup>lviii</sup> See Art. XIII.4

<sup>lix</sup> See also, H. Mosley, T. Keller and S. Speckesser, *The role of social partners in the design and implementation of active measures*, Employment and Training Papers, Social Science Research Centre, Berlin, 1998, ISBN 92-2-111287-X

<sup>1x</sup> See Art. VI.4

<sup>1xi</sup> As per Art. VIII.3, it shall come into force 12 months after the date on which there have been registered ratifications by at least 30 Members with a 33% over the world gross tonnage of ships. Accordingly, this milestone has been reached 20<sup>th</sup> August 2012 and therefore, it shall come into force on 20<sup>th</sup> August 2013. For list of country ratifications see http://www.ilo.org/dyn/normlex/en/f?p=1000:11300:0::NO::P11300\_INSTRUMENT\_ID:312331<sup>1xii</sup> See Art. VIII.2

<sup>lxiii</sup> See *supra* n. 59

<sup>1xiv</sup> See *supra* n. 43

<sup>lxv</sup> ILO, *How International Standards are Created*, Cartier Working Party - Working Party on Policy regarding the Revision of Standards (1995-2002): Information note on the progress of work and decisions taken concerning the revision of standards (updated in June 2002) available at http://www.ilo.org/global/standards/introduction-to-international-labour-standards-creation/lang--en/index.htm

<sup>lxvii</sup> See also International Labour Conference, *Strengthening the ILO's Capacity: Continuation of the discussion possible consideration of an authoritative document, ILO, Geneva, 97<sup>th</sup> Session 2008, p. 16<sup>lxviii</sup> See <i>supra* n. 65

<sup>1xix</sup> Article 1(a) of the IMO Convention provides that the IMO's competence lies on providing machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade and to encouraging and facilitating the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships

<sup>1xx</sup> For further reading, see Maritime Labour Convention 2006: Action Plan 2006 – 2012, ILO, 2010 available at http://maritimesun.com/news/wp-content/uploads/2012/02/Action-Plan-for-MLC-2002.pdf

<sup>1xxi</sup> Guidelines for Flag State Inspections under the Maritime Labour Convention 2006 and Guidelines for Port State Control Officers carrying out inspections under the Maritime Labour Convention 2006

<sup>lxxii</sup> See also D. Dimitrova and R. Ilanpain, *Seafarers' Rights in the Globalized Maritime* Industry, Kluwer, 2010, p. 85

<sup>lxxiii</sup> See also J. A. Menacho, *How the "Maritime Labour Convention, 2006" will improve seafarers' conditions, related with employment rights, and safe and secure workplace?*, MSEA Class of 2010 - WMU available at http://www.wmu.sof.or.jp/fw\_jesus\_01.pdf

# International Law and Policy on Ensuring a Healthy Seafaring Workforce

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### Abstract

Health of the global maritime workforce is an utmost importance to the industry for purposes of human safety, environmental goals and good economic outcomes. Given the international nature of the industry, it faces many issues and challenges in attaining a healthy workforce. This paper analyses aspects of international law and policy in the attainment of this goal. Research on and initiatives of the industry are mostly focused on many other areas such as business and trade, labour and the ocean environment. Seldom is there a focus on the specific area of health and well being of its workers despite the fact that they are central in the functioning of the industry. Labour is the most elastic of all seafaring elements, which is easily impacted specially during challenging economic times. International law focusing on the health of seafarers is mostly hinged on labour laws. Most of these laws are in the form of conventions promulgated by the ILO and the IMO. Other UN agencies are also involved in minor and specific areas such as HIV/AIDS, health regulations, etc. The tripartite model used by the ILO in law and policy-making is seen as sufficient. The maritime industry is privileged to have advanced more in international laws and policies compared to other areas of international labour thus helping in placing order in the industry. It becomes a good model for other trades. There are however unaddressed areas and continuing challenges that the industry faces in safeguarding the health of workers thus innovative and pertinent approaches should be developed.

Keywords: International Health Law, Seafarers, Health Policy

### 1. Introduction

Internationalization and globalization are two phenomena that have changed the world of work (Stiglitz, 2002). A more intertwined and liberal economic global order has facilitated the mobility of workers (Ottaviano and Puga, 1998). This transboundary movement of workers has spawned many challenges in the field of health and welfare. As these workers become 'distanced' from the care of their states, they become reliant on the healthcare services of another state that normally falls short of providing care to their non-citizens. Among these mobile workers or so-called 'migrant workers', the seafaring sector is the most unique as they pose many challenges as they are most of the time at sea, making it an interesting case to understand and scrutinize.

Seafaring is considered the most international of all the jobs in the world (Alderton and Winchester, 2002). It employs some 1,384,000 seafarers aboard the world's ships (BIMCO/ISF, 2010). They play a significant role in the global economy as they move 90% of the global trade transporting produce and resources from the different corners of the world thus fuelling the global economy and the progress of individual states. Without them the world, will never be the same.

The important role of seafarers in world trade commands a special recognition and attention from the international community. The inherent nature of seafaring (e.g. working away from home for a long period, exposure to hazards, etc.), the need to have safe and accident-free shipping, and the avoidance of environmental disasters such as oil spills from tankers, also provide the impetus for a special attention on this global workforce. It is in this context that health and safety and welfare of seafarers are paramount.

The attainment of a healthy and safe global workforce is sometimes not a straightforward endeavour. The highly global maritime workforce faces various predicaments within a globalized work environment—for

example, a seafarer from Ukraine working on a Liberian-flagged ship owned by a German company and managed by a Greek shipping management company. Normally this seafarer is working with other seafarers mostly from East and South East Asia or Eastern Europe with ship officers from Western Europe. They would carry the goods from China while the ship is anchored in Brazil. Many of the aspects of seafaring would be insured with the Protection and Indemnity Clubs based in the United Kingdom.

This international nature of working conditions has been advancing, enabled by a neoliberal and capitalist framework. Though as much as this framework advances the industry and global trade, it is also within this context that places seafarers in a precarious predicament when it comes to labour, health and welfare issues. For example, what does international health law mandates, if ever they do indeed exist, when a Chinese seafarer meets an accident onboard a Saudi Arabian tanker flagged under Panama while unloading oil in Rotterdam, the Netherlands?

It is within this context that this paper is conceptualized. I argue that ensuring the health of mobile populations such as seafarers is nuanced and that international treaties play a very important role in the global governance of their health thus possibly providing a good framework for other mobile populations. I am asking in this paper the following question—how is the health of international seafarers ensured from a global legal governance perspective? To answer this question, I specifically aim to do the following:

- discuss the current state of the seafaring sector focusing on the health and welfare and other relevant factors such as labour;
- identify the different international actors and their roles in the health of seafarers;
- present the various international standards and instruments relevant to the health of the sector;
- enumerate the rights of seafarers that concerns health emanating from and mandated by the different international standards and instruments and
- provide a critical analysis on the role of these standards and instruments on how they ensure the health of global seafarers.

### 2. Understanding Seafaring and Health of Seafarers

There are various reasons why seafarers decide on a profession at sea. Financial reward tops these motivations (McKay and Wright, 2007) as the profession is seen as a quick way to achieve social mobility within the society. To see the world is another common reason to go to sea. However, despite the good compensation and other positive attributes of seafaring, literature has always portrayed the profession as a sacrifice (Lamvik, 2002).

This sacrifice is manifested in the risk to life and limbs they face making the profession one of the riskiest in the world. Many of these health problems have been documented in the submissions to the landmark report of the International Commission on Shipping (ICONS) in 2000. They are prone to all forms of health issues including infectious diseases, occupational health problems such as accidents, lifestyle diseases, mental health problems, etc. This is due to many realities that seafarers face such as the force of nature—from wind, sea, and climate on top of the workplace environment.

For example, the changing time zones and the movement of ship towards different parts of the world expose the seafarers to changing temperatures from the hottest to the coldest. Other stressors include heat in the workplace, noise, ship movement and seasickness, and climatic changes during the voyage. The nature of their work interacts with different factors such as being in confined and small spaces onboard, long voyages, lack of entertainment, seeing the same people, performance of difficult tasks, piracy, job uncertainty, problems with the family, and other conditions present in substandard ships, which add to the stressful situation onboard.

A significant consequence of a seafaring life is that of being away from home and family (Parreñas, 2008). Extended periods of absence become a major source of stress affecting their psychological wellbeing. There is a prolonged absence from the family and this intermittent pattern of work has undesirable consequences. This is manifested by feelings of homesickness and loneliness. This feeling of loneliness is also heightened

when they have been onboard for a long period of time making them suffer from social isolation (Sampson and Thomas, 2003).

Other factors that contribute to the stressful lives of some seafarers working onboard are the demands of work itself. It becomes a vicious cycle because the effect reflects on their work performance. This is categorized as 'high work demand' which also includes: time pressure, hectic activities, high volume of work, high responsibility for their own activities, pressure due to decision-making, monotony, and lack of independence (Oldenburg et al., 2009).

Adding to the stress is the impact of changing time zones on the sleep and work cycle—an element that is beyond the control of seafarers. This makes their sleeping time either shorter or longer causing fatigue. This is one of the neglected human factors that is a consequence of the moving ship. Working irregular hours have adverse effects on maritime safety and individual health and well-being. This is categorized under psychosocial stressors, which include shifting work, long working times per day, irregular working times, and lack of sleep (Oldenburg et al., 2009).

It is within this background that this human resource need to be well taken cared of. Health issues of the crew have caused catastrophic consequences such as major maritime accidents and oil spills. The fact that world trade keeps on increasing, there is a need to globally address the health issues seafarers are embedded in.

### 3. Players in the Global Maritime Industry

The global maritime industry is a complex industry. To address the health issues seafarers face needs to be a collective effort of different stakeholders as there are many actors who play important roles. A good insight of the global maritime industry is imperative to better understand health governance of the workforce at the international level. This entails knowledge of the different actors involved in this highly globalized business. Based on the study by Mouchtouri et al. (2010), some of the important organizations in the area of maritime health are: International Maritime Health Association (IMHA), International Society of Travel Medicine (ISTM), International Maritime Organization (IMO), International Shipping Federation (ISF), Cruise Lines International Association, International Chamber of Shipping, International Transport Workers' Federation, European Cruise Council, and the European Community Shipowners' Association. The latter two are based and focused on European shipping.

Many of these organizations can be categorized based on the personality they carry whether that of the governments and the states, shipowners or the business sector and the labour sector or seafarers. Additionally, there are interest groups such as the medical practitioners, academic and research institutions and the non-profit entities, which includes the customers (passengers) and religious groups (welfare organizations). Fitzpatrick and Anderson (2005) provides a similar overall view of the major actors in the maritime industry which they categorized into regulators, customers, suppliers and the civil society.

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### Figure 1: Major Actors in the Maritime Industry



Source: Fitzpatrick and Anderson (2005)

Aside from the fact that this framework shows different actors, we can also deduce that seafarers are embedded within different legal regimes as they work with various nation states and legal frameworks. As they move from one geographical entity to another, they are subject to different laws and regulations. This shifting legal regime becomes a challenge to many seafarers and impact on the various aspects of their life and work. The different roles that they play would be discussed in the next section.

### 4. Global Framework of Health Governance

Seafarers have historically received special treatment in terms of lawmaking because of their inherent risky predicaments. The nature of their work provided them entitlements as a work group prior to the modern mainstreaming of labor protection. Different agencies of the United Nations (UN) led many of these initiatives. The International Labour Organization (ILO) helped shape many of the standards protecting seafarers. The World Health Organization<sup>i</sup> (WHO) and the International Maritime Organization<sup>ii</sup> (IMO) actively supported the maritime labour and health-related activities of the ILO together with minor support from other UN agencies such as the International Organization of Migration<sup>iii</sup> (IOM). These international agencies vary in their degree of involvement on the promotion of health of seafarers. ILO would be considered to play a major role, as ILO Conventions and Recommendations are important legal instruments, which will be explained in a while. These instruments remain the primary tenets that govern much of the practical aspects of the daily health issues of seafarers.

Instruments ensuring health care to seafarers are generally hinged on human rights approaches and declarations. The fact that seafarers are human beings entitles them to human rights. Another context by which seafarers are ensured of their health is based on labour instruments. Though some of these instruments specifically address specific health issues, many are subsumed within labour laws making health one small aspect of the law. Being workers ensures them of rights that they deserve within the workplace. The definition of workplace becomes tricky because they stay within the ship even after work hours thus providing some legal ramifications as most contracts are based on onboard stay instead of work hours.

What are the bases of seafarers' rights? The major sources of the rights of seafarers are based on the standards of the ILO, human rights standards promulgated by the UN and regional bodies, the IMO, and other related standards (Fitzpatrick and Anderson, 2009). Box 1 presents the main human rights treaties of the UN and regional bodies. Since seafarers are foremost humans, they are guaranteed to enjoy a number of rights as stated in these instruments. These principles are universal and can be interpreted by national and international courts.

### **Box 1. International Human Rights Instruments**

### **International Bill of Human Rights:**

- 1. Universal Declaration of Human Rights 1948
- 2. International Covenant on Economic, Social and Cultural Rights 1966
- 3. International Covenant on Civil and Political Rights 1966

### **Regional Human Rights Treaties:**

- 1. European Convention for the Protection of Human Rights and Fundamental Freedoms 1950
- 2. European Social Charter 1961 and European Social Charter (Revised) 1996
- 3. American Convention on Human Rights 1969
- 4. African Charter on Human and People's Rights 1981

### **Thematic United Nations Human Rights Treaties:**

- 1. International Convention on the Elimination of All Forms of Racial Discrimination 1965
- 2. Convention on the Elimination of All Forms of Discrimination against Women 1979
- 3. Convention Against Torture and other Cruel, Inhuman or Degrading Treatment or Punishment 1984
- 4. Convention on the Rights of the Child 1989

The ILO has promulgated more than 40 Conventions and more than 30 Recommendations setting labour standards solely for the maritime sector. Conventions are instruments that bind States towards a number of

obligations within international law upon ratification by that State<sup>iv</sup>. Some of these instruments specifically address the health of seafarers. With the others, health is a consequence after their implementation. These standards become the bases of rights. Among these ILO Conventions, there are eight that are considered fundamental as listed in Box 2.

### **Box 2. Fundamental ILO Conventions**

- 1. ILO Forced Labour Convention 1930 (ILO C29)
- 2. ILO Freedom of Association and Protection of the Right to Organize Convention 1948 (ILO C87)
- 3. ILO Right to Organize and Collective Bargaining Convention 1949 (ILO C98)
- 4. ILO Equal Remuneration Convention 1951 (ILO C100)
- 5. ILO Abolition of Forced Labour Convention 1957 (ILO C105)
- 6. ILO Discrimination (Employment and Occupation) Convention 1958 (ILO C111)
- 7. ILO Minimum Age Convention 1973 (ILO C138)
- 8. ILO Worst Forms of Child Labour Convention 1999 (ILO C182)

These eight Conventions have become the bases of ILO's decent work  $agenda^v$ , which includes employment creation, rights at work, social dialogue and social protection. Even if these Conventions do not directly address health issues of workers, the implementation of these standards has spillover effects to health, which is subsumed in rights at work and social protection.

The unique work characteristics of seafaring as explained earlier prompted the creation of separate agreements for the maritime sector within ILO sessions. Specific sessions solely for seafaring were held resulting into a number of maritime Conventions<sup>vi</sup> as presented in Box 3. Many of these conventions address the different difficulties that seafarers face at work.

### **Box 3. ILO Maritime Conventions**

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	C007 - Minimum Age (Sea) Convention, 1920
	C008 - Unemployment Indemnity (Shipwreck) Convention, 1920
	C009 - Placing of Seamen Convention, 1920
	C016 - Medical Examination of Young Persons (Sea) Convention, 1921
	C019 - Equality of Treatment (Accident Compensation) Convention, 1925
	C022 - Seamen's Articles of Agreement Convention, 1926
	C023 - Repatriation of Seamen Convention, 1926
	C047 - Forty-Hour Week Convention, 1935
	C053 - Officers' Competency Certificates Convention, 1936
	C054 - Holidays with Pay (Sea) Convention, 1936
	C055 - Shipowners' Liability (Sick and Injured Seamen) Convention, 1936
	C056 - Sickness Insurance (Sea) Convention, 1936
	C057 - Hours of Work and Manning (Sea) Convention, 1936
	C058 - Minimum Age (Sea) Convention (Revised), 1936
	C068 - Food and Catering (Ships' Crews) Convention, 1946
	C069 - Certification of Ships' Cooks Convention, 1946
	C070 - Social Security (Seafarers) Convention, 1946
	C071 - Seafarers' Pensions Convention, 1946
	C072 - Paid Vacations (Seafarers) Convention, 1946
	C073 - Medical Examination (Seafarers) Convention, 1946
	C074 - Certification of Able Seamen Convention, 1946
	C075 - Accommodation of Crews Convention, 1946
	C076 - Wages, Hours of Work and Manning (Sea) Convention, 1946
	C091 - Paid Vacations (Seafarers) Convention (Revised), 1949
	C092 - Accommodation of Crews Convention (Revised), 1949 (No. 92)
	C093 - Wages, Hours of Work and Manning (Sea) Convention (Revised), 1949
	C095 - Protection of Wages Convention, 1949
	C097 - Migration for Employment Convention (Revised), 1949
	C108 - Seafarers' Identity Documents Convention, 1958
	C109 - Wages, Hours of Work and Manning (Sea) Convention (Revised), 1958

C130 - Medical Care and Sickness Benefits Convention, 1969
C133 - Accommodation of Crews (Supplementary Provisions) Convention, 1970
C134 - Prevention of Accidents (Seafarers) Convention, 1970
C143 - Migrant Workers (Supplementary Provisions) Convention, 1975
C145 - Continuity of Employment (Seafarers) Convention, 1976
C146 - Seafarers' Annual Leave with Pay Convention, 1976
C147 - Merchant Shipping (Minimum Standards) Convention, 1976
C154 - Collective Bargaining Convention, 1981
C163 - Seafarers' Welfare Convention, 1987
C164 - Health Protection and Medical Care (Seafarers) Convention, 1987
C165 - Social Security (Seafarers) Convention (Revised), 1987
C166 - Repatriation of Seafarers Convention (Revised), 1987
C178 - Labour Inspection (Seafarers) Convention, 1996
C179 - Recruitment and Placement of Seafarers Convention, 1996
C180 - Seafarers' Hours of Work and the Manning of Ships Convention, 1996
C181 - Private Employment Agencies Convention, 1997
C185 - Seafarers' Identity Documents Convention (Revised), 2003
MLC - Maritime Labour Convention, 2006
P147 - Protocol of 1996 to the Merchant Shipping (Minimum Standards) Convention, 1976

ILO Recommendations, on the other hand, deal with the same subject matters as the Conventions, however, they are not binding but only set guidelines on certain principles by providing more detailed definition of standards or advance standards. Box 4 presents the ILO maritime Recommendations passed by the ILO to date.

Box 4. ILO Maritime Recommendations
R009 - National Seamen's Codes Recommendation, 1920
R010 - Unemployment Insurance (Seamen) Recommendation, 1920
R027 - Repatriation (Ship Masters and Apprentices) Recommendation, 1926
R028 - Labour Inspection (Seamen) Recommendation, 1926
R048 - Seamen's Welfare in Ports Recommendation, 1936
R049 - Hours of Work and Manning (Sea) Recommendation, 1936
R075 - Seafarers' Social Security (Agreements) Recommendation, 1946
R076 - Seafarers (Medical Care for Dependants) Recommendation, 1946
R077 - Vocational Training (Seafarers) Recommendation, 1946
R078 - Bedding, Mess Utensils and Miscellaneous Provisions (Ships' Crews) Recommendation, 1946
R090 - Equal Remuneration Recommendation, 1951
R091 - Collective Agreements Recommendation, 1951
R105 - Ships' Medicine Chests Recommendation, 1958
R106 - Medical Advice at Sea Recommendation, 1958
R107 - Seafarers' Engagement (Foreign Vessels) Recommendation, 1958
R108 - Social Conditions and Safety (Seafarers) Recommendation, 1958
R109 - Wages, Hours of Work and Manning (Sea) Recommendation, 1958
R137 - Vocational Training (Seafarers) Recommendation, 1970
R138 - Seafarers' Welfare Recommendation, 1970
R139 - Employment of Seafarers (Technical Developments) Recommendation, 1970
R140 - Crew Accommodation (Air Conditioning) Recommendation, 1970
R141 - Crew Accommodation (Noise Control) Recommendation, 1970
R142 - Prevention of Accidents (Seafarers) Recommendation, 1970
R153 - Protection of Young Seafarers Recommendation, 1976
R154 - Continuity of Employment (Seafarers) Recommendation, 1976
R155 - Merchant Shipping (Improvement of Standards) Recommendation, 1976
R173 - Seafarers' Welfare Recommendation, 1987
R174 - Repatriation of Seafarers Recommendation, 1987
R185 - Labour Inspection (Seafarers) Recommendation, 1996
R186 - Recruitment and Placement of Seafarers Recommendation, 1996
R187 - Seafarers' Wages, Hours of Work and the Manning of Ships Recommendation, 1996

IMO is another specialized agency of the UN tasked to promote safety at sea and protect the marine environment. It espouses the importance of human element or all human activities related to shipping in fulfilling its tasks thus limiting maritime casualties. IMO also adopts Conventions and Protocols that provide standards for the protection of seafarers through good working conditions as presented in Box 5.

### Box 5. IMO Conventions

- 1. International Convention for the Safety of Life at Sea 1974
- 2. International Management Code for the Safe Operation of Ships and for Pollution Prevention 1993 (under Chapter IX of SOLAS)

3. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 as amended

When it comes to WHO instruments, the International Health Regulations (2005) is the most appropriate instrument against the international spread of diseases with minimum interference to world traffic. The WHO, UN's specialized agency for health, is mandated to implement solutions for health problems and keep the health of the peoples of the world at best levels. In this instrument are provisions and measures that address health of travelers, conveyances or other inanimate objects, points of entry, or other authorities related to international voyages. Member states are mandated to implement these measures.

Though all these instruments may be similar in many aspects, there are conceptual differences between IMO Conventions and the ILO and human rights treaties. As will be discussed in the next section, human rights treaties and ILO Conventions espouse the creation of rights for individuals, which can be asserted against States within their courts before it can be brought to the international level for arbitration. IMO Conventions are not meant to create rights but imposes obligations on States creating benefits instead of rights.

### 5. Seafarers Health-Related Rights

Rights as human beings and workers are the cornerstone of the different instruments and standards laid down to safeguard the health of global seafarers. It is within this rights framework that international law and policy are hinged. There are a number of rights seafarers should enjoy based on what have been agreed upon at the international level. Fitzpatrick and Anderson (2005) summarize the different rights of seafarers in their book Seafarers' Rights. I discuss further these rights and zero in on those related to health or have implications to their health. I will discuss where these rights emanate from the different international laws promulgated.

### 5.1 Right to life

States under which ships are flagged should be bound to ensure the protection of lives onboard their ships based on the treaties and international instruments they ratified. States where ships are docked in port (port states) or where ships are plying their coasts have the same obligations. Unfortunately, this may not be possible with the state of Somalia, which is infested by pirates as it is considered a 'failed state'. Seafarers also have the right to refuse working for ships, which are not seaworthy. In case a seafarer dies due to unworthy conditions onboard, the family may invoke against human rights violations. Instruments that guarantee right to life are: UDHR Article 3, CCPR Article 6, ECHR Article 2(1), ACHR Article 4 and AC Article 4.

### 5.2 *Right to health and medical care*

Seafaring is a risky profession. Their exposure to health hazards makes it imperative for them to exercise their right to health and medical care. Many instruments within the realm of international human rights address health issues such as UDHR Article 25, CESCR Article 12, CEDAW Article 12, CRC Article 24 and ESC Article 11. Most of these instruments require the state to recognize the right of the citizens to attain highest attainable state of physical and mental health.

When it comes to ILO Conventions, ILO C73 (ILO Medical Examination (Seafarers) Convention 1946) stipulates that a certificate of fitness from a medical practitioner is needed before he is hired onboard. ILO

C164 (ILO Health Protection and Medical Care (Seafarers) Convention 1987) stipulates that seafarers should be provided free medical care and health protection comparable to that onshore while employed. It also provides immediate care by a doctor in port without delay. ILO C55 (ILO Shipowners' Liability (Sick and Injured Seamen) Convention 1936) requires shipowners to provide treatment and benefit to seafarers when they become sick, injured or when they die while in active service. The seafarer remains paid while he is onboard even if he is sick and his repatriation be paid by the company.

### 5.3 *Right to safe and healthy working conditions*

### The case of Skye v Maersk Line Limited Corporation

(Case 11-21589-CIV-Altonaga/Simonton Skye v Maersk Line Limited Corporation [2012] United States District Court Southern District of Florida) sets a legal precedent on how shipowners can be sued for dangerous working conditions onboard thus affecting the overall health of their seafarers. These can be based on ILO C147, ILO P147, ILO R155 that provide the provision of minimum standards for a safe and healthy working condition onboard ships. These complement other international standards that require flag states to provide minimum shipboard conditions for safety, security and living. It provides port states the right to inspect and detain ships specially when they deem it necessary when seafarers are fatigued at work.

ILO C180 ensures sufficient rest to limit fatigue by stipulating efficient and safe manning. ILO C92 and C133 provide decent living accommodations and welfare and recreational activities. ILO C68 and C69 ensure access to quality food and water onboard prepared by qualified catering personnel. Accident prevention, radio medical service and medicine chests on board are stipulated by ILO C134, R142, R105 and R106. When there is an accident onboard, the crew can call medical advice through the radio and use the medicines onboard.

CESCR Article 7(b) and ESC Article 3 also ensure safe and health working conditions. States are stipulated to abide by these international standards. Within the IMO, IMO Assembly Resolution A.890(21) is another instrument together with Regulation V/14 of the SOLAS Convention. These provided for a number of standards within the ship. Resolution A.931(22) of the IMO Assembly and the ILO Governing Body provides financial security for seafarers' contractual claims for personal injury or death. An example is the case of *Cama v CKP Fishing Company Limited* (Cama v CKP Fishing Company Ltd [2004] FJHC 349; HBC0205D.2003S) wherein the plaintiff suffered thermal injuries while working in the freezer of the boat and sued the shipping company for not providing suitable equipment such as insulated or thermal gloves

### 5.4 Freedom from forced labour

Many instruments prohibit all forms of slavery. This includes UDHR Article 4, CCPR Article 8, ECHR ILO C105. The two latter standards define succinctly forced labour (ILO C29, Article 2.2). Though this may not be directly a health issue, there are many ways that health would be a related consequence. The 'servile status' of a seafarer places him at harms way such as not being provided with food and proper accommodations or no access to health services when needed or not being repatriated when very ill.<sup>vii</sup>

### 5.5 *Freedom from torture, cruel, inhuman and degrading treatment*

This may somewhat relate to the previous one, however, there are specific instruments that emphasizes these points—UDHR Article 5, CCPR Article 7, ECHR Article 3, ACHR Article 5(2) and AC Article 5. All flag states flown by ships are responsible in carrying out these principles on board their ships. This even includes those who are not seafarers such as stow-away who are mandated to be cared for under international human rights agreements.

### 5.6 Freedom from discrimination

There are many ways that discrimination may present in the shipping industry. For example, there are differences in salary depending on the nationality of the person. Those who come from developing countries earn lesser than those from richer countries. This is possibly in violation of ILO C100 and C111. These

seafarers also have lesser health benefits. Another form of discrimination is not allowing those living with HIV to work onboard ships.

### 5.7 *Right to legal remedy and access to justice*

Many seafarers are embroiled in many legal problems including health-related issues such as occupational accidents. Despite the fact that they are guaranteed legal assistance as stipulated in the UDHR Article 8, ECHR Article 6, ACHR Articles 8 and 25, AC Article 7(1)(a), CERD Article 6, CAT Articles 13 and 14 and the CRC Article 37(d), many of them are unable to redress their grievances. Flag states should be able to provide the legal remedy such as right of access to justice. Unfortunately, many cases cannot be heard as seafarers are far away from the flag states making it impossible to file cases.

### 5.8 *Right to employment agreement*

Most seafarers sign employment contracts before they go onboard ships as stipulated by ILO C22. <sup>viii</sup> However, many of these contracts are not fulfilled specially those related to health making it a major issue for many seafarers. For example, health benefits are not provided because of the expenses that shipping companies would incur. They might provide immediate care and repatriation after an accident, but they will not provide long-term care. A criticism of the new contract for Filipino seafarers is on employers being responsible only for paying occupational injuries and diseases that are job related and a compensation for injuries, illnesses and disability that is limited by the agreement. In this new contract, workers are required to disclose their past medical conditions, disabilities and medical histories or else they face the risk of disqualification from compensation and benefits, termination from employment and other punitive sanctions.<sup>ix</sup>

### 5.9 *Right to shore leave*

Shore leave is an important part of the working lives of seafarers. According to the study by Kahveci (2007), shore leave is seen as imperative for the physical and mental well-being of the seafarers. It helps them psychologically as they take a respite from onboard life even just for a short while. ILO C108 and C185 provide the facilitation of shore leave of seafarers to allow them to visit ports. There are dedicated shore leave services provided by the local authorities, international welfare and religious organizations and private entities such as the seafarers' welfare centres in many ports of the world. Despite the availability of these centres, seafarers are unable to access them because of the heavy workload when the ship is in port, fast turnaround time, lack of information about the port, and policy restrictions of the port authorities based on their interpretation of the ISPS Code (Kahveci, 2007).

### 5.10 Right to reasonable working hours and holidays

Rest is an important part of onboard life of seafarers to keep them mentally and physically healthy. It becomes specially important as their work and living space are one making it a challenge to demarcate. This is enshrined in CESCR Article 7(d) providing 'rest, leisure and reasonable working hours and periodic holidays with pay, as well as remuneration for public holidays'. ILO C47 stipulates 40 working hours. ILO C180 prescribes the working and rest hours of seafarers given the changing time zones they traverse. ILO C146 provides the entitlement of annual leave with pay. IMO's STCW Convention stipulates 10 hours of rest within a 24-hour period.

### 5.11 Right to social security and welfare

Many international human rights instruments stipulate right to security when unemployed, sick, disabled, widowed, become old and when there is no means of income. This includes UDHR Article 25, ESC Article 12 (1) and 13, and CESCR Articles 9, 16 and 17. In the seafaring sector, many seafarers believe that they are not covered by social security due to a number of reasons such as inability to pay national contributions as they work onboard, finding social security useless as benefits are minimal, and the contractual nature of work. The industry is still looking for a good framework on how to establish an international program for social security of seafarers as recommended by the International Maritime Health Association as many seafarers pay

out of pocket for their long term health issues, that of their families, and for their retirement expenses (Jensen et al., 2013).

### 5.12 Right to repatriation

Any seafarer who needs to go back home to his home country or to a certain port for various legitimate reasons such as medical and health reasons is entitled to repatriation by his company at their cost. This is stated in ILO C23 and ILO C166. Repatriation includes "medical treatment when necessary until the seafarer is medically fit to travel to the repatriation destination" (ILO C166, Article 4.4). If the shipowner is unable to do its obligation, the flag state is responsible to take over (ILO C166, Article 5). If neither of the two is unable to repatriate the seafarer, based on the Vienna Convention on Consular Relations<sup>x</sup> Articles 5, 28 and 36, the port state or the national can arrange his repatriation and recover the cost from the flag state. IMO/ILO Resolution A.930 (22)<sup>xi</sup>, the Joint IMO/ILO Ad Hoc Expert Working Group on Liability and Compensation regarding Claims for Death, Personal Injury and Abandonment of Seafarers, include statements on repatriation of seafarers.

## 6. Way Forward: A Consolidated 'International Law' for Health

The shipping industry has moved forward fast because of increasing global trade after liberalization. This also led to more governance instruments such as those of the ILO and the IMO. Given the numerous, and some outdated standards, the changing shipping technology, increasing global trade, and importance of the effect of oil spills, there was a move to consolidate all ILO standards into a single instrument (Appave, 2005). This resulted into the Maritime Labour Convention (MLC C186)<sup>xii</sup> which was drafted and signed in 2006 and which will take effect this year 2013 based on 30 ratifications. To date, 24 countries (60% of global shipping) already ratified representing 33% of gross tonnage of ships. The MLC is seen as a way forward by updating and consolidating standards of existing international maritime labour Conventions and Recommendations. This is deemed to complement other international maritime laws namely SOLAS, STCW and MARPOL.

Contents of the MLC includes: Title 1, Minimum requirements for seafarers to work on a ship; Title 2, Employment conditions; Title 3, Accommodation, Recreational Facilities, Food and Catering; Title 4, Health Protection, Medical Care, Welfare and Social Security Protection; and Title 5, Compliance and Enforcement. These are the grouping of sixteen articles containing general provisions. As seen from the titles two directly pertains to health while the others impact on health.

Titles 3 and 4 impact directly on the health of seafarers, while Titles 1 and 2 have implications to their health similar to the different standards discussed earlier. Title 1 includes medical fitness of the seafarer who would undergo medical examination. Title 2 includes rest hours, shore leave, safe manning level and repatriation. This move to consolidate the standards is a good way to update international health law to address better the changing needs of the workers. Since the MLC will be in effect in August 2013, the effectiveness of the convention would be seen in the coming future.

### Conclusion

Seafaring is a unique population workgroup that commands special attention because of their important role in the global economy. Inherent to the job are different determinants that place them at risk that may result in maritime disasters. There are many international standards and instruments that ensure the health and welfare of global seafarers. Most of the laws on health are hinged on laws of labour and welfare. Health is seen as a consequential effect. For example, labour contracts would primarily focus on labour elements with a minor aspect of health included. Due to many global advancement and changes, health has become mainstreamed in many international laws that focus on seafarers. Governance and regulation have adapted to the changing times. Human rights have become central in many of these standards. There are still many challenges and issues to be addressed including the implementation by the different nation states and actors. All in all, the international laws for the seafaring industry provide an interesting model in the protection of the health of other international mobile populations or migrant workers.

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<sup>i</sup> WHO is involved in the health-related activities of the maritime industry under its occupational health programmes. They manage 4 WHO Collaborating Centres for the Health of Seafarers based in Ukraine, Denmark, Germany and Poland.

<sup>ii</sup> IMO includes health-related activities for purposes of maritime safety and other related activities. They include health and welfare of the crew as central in policymaking as a healthy workforce would mean fewer accidents such as ship collisions and oil spills.

<sup>iii</sup> IOM works with the maritime industry in the area of HIV/AIDS in partnership with many stakeholders. They see mobility and migration as a driving factor of HIV spread.

<sup>iv</sup> Member States of the ILO available at http://www.ilo.org/public/english/standards/relm/country.htm

<sup>v</sup> See http://www.ilo.org/global/about-the-ilo/decent-work-agenda/lang--en/index.htm

<sup>vi</sup> Details on these are available at ILO, *Maritime Labour Conventions and Recommendations*, 4th edn (1998).

vii This is documented in the ITF publication Sweatships—what it's really like to work onboard cruise ships (2002).

<sup>viii</sup> For a sample of an seafarer's employment contract, see http://www.poea.gov.ph/docs/sec.pdf

<sup>ix</sup> See comments of DB Stevenson of the Center for Seafarers' Rights of The Seamen's Church Institute at http://www.sailors-club.net/index.php?option=com\_myblog&show=poeas-standard-agreement-for-filipino-seafarers-.html&Itemid=101

<sup>x</sup> See http://untreaty.un.org/cod/avl/ha/vccr/vccr.html

<sup>xi</sup> See

http://www.imo.org/OurWork/Legal/JointIMOILOWorkingGroupsOnSeafarerIssues/Pages/IMOILOWGLiabilityCompensationForDeathAbandonment.aspx

<sup>xii</sup> See http://www.ilo.org/global/standards/maritime-labour-convention/WCMS\_090250/lang--en/index.htm

# A Simultaneous Model of Flag Choice and PSC Inspection

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### Abstract

Flag choice and Port State Control (PSC) inspection are two most important yet mutually dependent factors in the international shipping industry. Estimate the contribution of PSC inspection on the flagging out decision can help policy makers to understand the effectiveness of PSC inspection. However, studying the impact of one on the other without taking into account their endogenous impact could result in biased estimation. This paper integrates a binary logit model for flagging out decision and a linear model for explaining PSC inspection rate in a 3 Stage Least Square framework, by joining the actual ship registration data from Lloyd's ship register with the corresponding PSC inspection records from Paris MOU, Tokyo MOU, and Indian MOU. The empirical results show that in addition to the ship characteristics, national policies, PSC and Flag State Control (FSC) all have significant impacts on the flagging out decision. For the PSC inspection equation, the results suggest that the ship characteristics, operators' properties, and flag choice could determine a vessel's inspection rate. In addition, the contribution of PSC inspection rate on the flagging out behavior is much underestimated in single equation model, indicating the actual deterrence of PSC inspection on the flagging out behavior is not incorporated.

Keywords: Flag Choice, Port State Control Inspection, Simultaneous equation, Endogeneity, Maritime Policy

### 1. Introduction

Flag choices and Port State Control (PSC) inspections are two of the most critical factors that shaping maritime safety of international shipping. Flag choice refers to the selection of nationality of a ship by the decision maker—most likely the operator due to its responsibility for the operation of the ship. The most preferred are the Flag of Convenience (FOC) countries, because they offer an opportunity to avoid strict regulations and policy requirements, as well as the high national taxation, thus can reduce operation cost and increase competitiveness (Metaxas, 1981; Thuong, 1987; Bergantino & Marlow, 1998). As a result, the proportion of open registered vessels has grown continuously from 21.6% in the 1970s to 71.5% in 2012 (UNCTAD, 1997-2012).

The fast expanding of the open registration fleet and the low performance of flag states, especially in some FOC countries, raised serious concerns from international society, particularly the coastal states, on the substandard shipping and its threat to the maritime environment and shipping safety. This leads to the regional cooperation among the coastal states initiate an alternative way to maintain the standard of shipping—Port State Control (PSC) (Kasoulides, 1993; Clarke, 1994; Ozcayir, 2001). PSC is the enforcement of International conventions on maritime safety and environment by the coastal states. It inspects the foreign vessels when they are calling the port of a coastal state.

Theoretically, a high PSC inspection rate should be deterrence for the ship operator to register the ship in a FOC country, as risk factors attached to a flag and the IMO convention ratification are two most important

factors in setting PSC inspection priority (Sage, 2005), and FOC ships are often associated with substandard vessels and high risk (Li & Wonham, 1999b), as well as non-ratification of conventions (ICS, 2012). In practice, however, the deterrence of PSC inspection may not be strong enough to offset the benefits available from flying a FOC flag. This will be reflected in the ship registration and ship inspection data: although many PSC inspections are targeted at FOC ships, there is still increasingly larger percentage of ships that are registered in FOC countries.

Therefore, it is very important to exam the marginal impact of PSC inspection on the flagging out decision of the ship operators, in order to evaluate the sufficiency of the PSC enforcement. However, due to the fact that interaction between the flagging out behaviour and PSC inspection rate are bidirectional, estimating the impact of PSC inspection on the flagging out behaviour without taking into account the impact of flagging out decision on the PSC inspection will lead to biased results. This can result in over-estimate the performance of PSC inspection, and may lead to wrong decisions in determining the right effort in PSC control.

A literature review on the analysis of flag choice and performance of PSC reveals that no existing studies have ever examined the interactions of flag registration and PSC inspection in an integrated framework. This paper analyzes the flagging-out decision of ship operators and determinants of PSC inspection rate simultaneously in an integrated framework. The flagging-out decisions are modeled using a binary logit model where ship operators are assumed to select to fly a national flag or a flag of open registry, where the PSC inspection rate is modeled in a linear statistical equation of ship attributes including the nationality of the flag.. Compared with the single equation model, the results from the simultaneous equation model show some significant differences in the flagging-out behavior, and the PSC inspection rate has much higher impact on the flagging-out behavior. Similarly, flying a flag of the open registers appears to be the most important factor in the PSC inspection.

Next section provides a review of existing literature on the analysis of flag registration and PSC. It is followed by a brief introduction of the model used in this research. Section four describes the data. Section five reports on the model estimation results and discussions, and section six concludes.

### 2. Literature Review

As flag choice and PSC are two of the most important issues in international maritime policy, not surprisingly, there are many studies analysing the flag selection behaviour of the world merchant fleet, and effectiveness of PSC. In flag selection behaviour, many studied why decision makers choose to flag out (Bergantino & Marlow, 1998; Hoffmann et al., 2005; Luo et al., 2011). Bergantino & Marlow (1998) used survey data to rank the relative importance of factors affecting the use of foreign flag, and quantified the likelihood of flagging out in terms of ship types, age, trade and the difference in basic salary, national insurance payment, training cost, and repair and maintenance cost between national flag and foreign flag using binary logit model. They found that most important factors for flagging out are savings in crew costs (26%) and compliance costs (12%), as well as to escape bureaucratic control from the national flag (17%) and availability of skilled labour (13%). Hoffmann et al. (2005) used a binominal probit model to analyse the determinants of flagging out using ship operator as the decision maker. The model variables include attributes of the vessel, operator country, vessel builder country, and classification society. Luo et al (2011) extend the previous studies by modelling not only whether to flag out, but also the selection of a specific flag under quasi-open registers or full open flags. In addition to the variables in (Hoffmann et al., 2005), it included the difference in the company share and crew requirement between the national flag and the open register, as well as the impact of PSC inspection rate on the vessel flag selection. However, the endogeneity of between the flag selection and PSC inspection has not been incorporated in the previous study.

The purpose of PSC control is to address the low flag state performance, maintain the standard of shipping and reduce the maritime accidents (Bell, 1993; Kasoulides, 1993; Clarke, 1994). Although it is not a direct measure to curb the increasing trend of flagging out, it will indirect reduce the attractiveness of the FOC countries as it is often a concern for low standards (Gianni, 2008; Coles & Watt, 2009), and correlated with

low safety record (Li & Wonham, 1999a; Li & Wonham, 1999b; Alderton & Winchester, 2002).

There are many studies on the development of PSC control and its function to correct the deficiencies, reduce accident and pollution from shipping (Cuttler, 1995; Kiehne, 1996; Ozcayir, 2001). In practice, to assist the efficiency of PSC, there are studies to help prioritize the ships for inspection through statistical modelling (Li, 1999; Xu et al., 2007; Sage, 2005), using satellite information for monitoring (Florens & Foucher, 1999), design optimal management mechanism (Gawande & Bohara, 2005), through economic analysis (Li & Cullinane, 2003), as well as develop integrated inspection support system (Hamada et al., 2002).

There are many empirical studies on the effectiveness of PSC (Cariou et al., 2008; Cariou & Wolff, 2011; Cariou et al., 2009; Knapp & Franses, 2007; 2007b; 2008). Cariou et al. (2008) found that the number of deficiencies can reduce by 63% following a PSC inspection. Cariou et al. (2009) found that the major contributors to detention are ship age, classification society and the place of inspection. Cariou and Wolff (2011) studied the behaviour of change flag and change classification society, and found that vessels with lower standard are more likely to have frequent shift for flags and classification societies. In all these three studies, the set of explanatory variables are age of the ship, the flag of registry, the type of ships, and classification society. The study of Knapp and Franses are focused on comparing the differences of different PSC regimes. The found that the main differences in the probability of detention are mainly due to the differences in port states and the definition of deficiency (Knapp & Franses, 2007), and recommend to coordinate the PSC regimes by promoting the harmonization of inspection database, and developing global Integrated Ship Information System (Knapp & Franses, 2008). They combined the PSC inspection records with the ship casualty database, modelled the probability of casualty as a logistic function of ship attributes, classification, owner information, flag, as well as the PSC inspection numbers (Knapp & Franses, 2007b), identified the contributing factors to ship casualty, and pointed out the directions to increase PSC efficiency.

Compared with the existing research, our study has two distinctive features. First, in the PSC control, we focus on the inspection rate, not on the deficiency number or detention. Second, we use the simultaneous model, rather than a single model, to accommodate the impact of endogeneity between flag choice and PSC inspection. Therefore, our model is more appropriate to the problem we are addressing: whether PSC inspection is effective in deterring the flagging out.

### 3. Methodology

In this study, we establish two statistical equations to model the dynamic interactions of the flag-out decision of the ship operator and the PSC inspection rate. The impact of PSC inspection on the flag-out decision is modeled using a binary choice logit model, which assumes utility maximization in the operator's flagging out decision. Use *y* to denote the unobservable net benefits that a ship operator can obtain through flying a foreign flag. The net benefits is assumed to be a linear function of various variables, including the attributes of the ship, the economic status and policy requirements of the flag state, i.e.,  $y = x\beta + INSPECT\beta' + \varepsilon$ , where *INSPECT* denotes each vessel's inspection rate by PSC authority, and *x* is a vector of other variables that may affect the flagging out decision, and  $\varepsilon$  is the random variable.

Since the net benefit is unobservable and what we can observe is the flag flown on the ship, we design a dummy variable FF=1 if the flag of the ship is different from the nationality of its operator, i.e., the ship is flagged-out, and FF=0 when the ship and its operator has the same nationality. Clearly, FF=1 if y>0, otherwise FF=0. Assuming that  $\varepsilon$  is independently and identically distributed (*i.i.d.*) with logistic distribution, the probability for a vessel to flag out can be written as:

$$Prob(FF=1) = Prob(y>0) = \frac{e^{x'\beta + INSPECT\beta'}}{1 + e^{x'\beta + INSPECT\beta'}}$$
(1)

The flag of a ship is also an important concern when the PSC officer determines whether to inspect the vessel. The impact of flying a foreign flag on the PSC inspection rate can be formulated as a function of various influencing factors.

## $INSPECT = z\gamma + FF\gamma' + u$

where z includes the vessel's characteristics, FF is a dummy variable indicating whether it is flying a foreign flag, and u is a *i.i.d.* with normal distribution.

Since the dependent variables of FF and INSPECT are independent variables in the other equation, these two equations are determined simultaneously, so the system is interdependent. In the estimation of each equation, the error terms will be correlated with endogenous variables (FF and INSPECT). This means that OLS estimators are inconsistent.

A general method of obtaining consistent estimates is the method of instrumental variables. The exogenous variables in the system are perfect instrumental variable for the estimation, because they are correlated with the endogenous variables as they appear in the equations, and they are independent to the error term as they are exogenous variables. The IV estimator will be consistent and have asymptotic covariance matrix. The various estimators that have been developed for simultaneous equations modes are all IV estimators such as two-stage least squares (2SLS), three-stage least squares (3SLS). As the 2SLS is not sufficient to make full use of the correlation between error terms, 3SLS method is applied in the estimation process for the coefficients in the system (Greene, 2008).

### 4. Data Description

Our data contains detailed information at individual ship level, which comes mainly from two sources. The first major source is the 2009 PC Register of ships from Lloyd's Register, which consists of 120,000 vessels of 100 GT (Gross Tonnage) and above. Our analysis selects 48,477 vessels that are larger than 400GT, as smaller vessels are mainly engaged in coastwise trade and seldom flagged out. The second source is the Port State Control (PSC) Inspection and Detention record from three regional offices, namely Tokyo MOU from 2000 to 2008, Paris MOU from 2005 to 2006, and India MOU from 2002 to 2008. The PSC data and ship registration data are linked together by the IMO number of the ship. The rest of the data is from various sources, such as the Annual Report from Economic Freedom of the World, BIMCO's Shipping Industry Flag State Performance, World Casualty Statistics of Lloyd's Fairplay, and previous literature. Next we first introduce the variables used in the flag-out decision, then the PSC inspection rate.

Since ship operators are the main decision-maker of a vessel for flag choice, the ship is counted as flagged-out if the nationality of the ship operator is not the same as that of the ship. Ships that are flying the second register of their own country are considered to be flying their national flag, while those registered in other countries' second ship registers are considered flagged out. In the database, 54% of the ships (26,366) are flying foreign flags. A dummy variable (FC) is used to indicate the flag status. If the ship is flying a foreign flag, FC equals to 1; Otherwise, 0.

It is argued in the previous study that flag-out behaviour of a ship is correlated with where it is build. In this study, we use a dummy variable (BUILTOPER) to indicate whether the operator is from the country where the ship is built. If yes, BUILTOPER=1. Our data shows that if yes, only 38% of the vessels flag-out; if no, 60% of them choose to flag out.

Ship size may also affect the flag out decisions, as larger ships are more likely deployed in international shipping routes where the high competition compels the ship operators to fly a foreign flag to save operation cost. In the data sample, 48% are smaller vessels with less than 10,000 DWT. 38% of the smaller vessels are flagged-out, while in larger vessels, the flag-out percentage is 69%. We used the log of the ship carrying capacity (LDWT) in the statistical analysis.

Whether old ships are more likely to flag-out? We identified the age of the ship when it is flagged-out and included the variable, REAGE, to test it. From the data, it appears that more than half of the vessels in both new ships (<10 years) and old ships (>20 years) are flagged-out, while the flag-out rate is less than half if it is

between 10 and 20 years old.

Ships serving different cargo sectors may have different flag out rates. We use dummy variables BULK, TANKER, CONTAINER and OCARGO to test the different flag selection behaviours of different ships. OCARGO is the reference ship type, which includes roro, reefer, combination and miscellaneous vessel types. According to the data, container vessels have the highest flag-out ratio (76%), followed by bulkers (63%), tankers (50%), and other vessels (46%).

Existing research found that ships whose classification society is a member of the International Association of Classification Society (IACS) are often regarded as high quality vessels (Hoffmann et al., 2005; Li et al., 2009). To test this, 10 dummy variables are used to a ship's classification society. The names of the classification agency, their variable name, and percentage in the world fleet: Nippon Kaiji Kyokai (CNKK, 14.3%), Germanischer Lloyd (CGEL, 11.2%), Lloyd's Registry (CLLR, 10.1%), Bureau Veritas (CBUV, 8.3%), Det Norske Veritas (CDNV, 7.6%), American Bureau of Shipping (CABS, 8.1%), China Classification Society (CCCS, 3.9%), Russian Maritime of Shipping (CRUS, 3.8%), South Korea Register (CSKR3.3%), and Registro Italiano (CREI, 1.3%). The other classification agencies that are not belong to IACS accounted for 28.1% of the world fleet. They are grouped under COTH, and used as a reference dummy. Our data shows that 64% of the ships classified by IACS are flagged-out. For the non-IACS classified ships, the flag-out rate is 45%.

The country of origin can also have significant impact on the flag-out behaviour of the ship. As the ship operator is assuming the major responsibility for this decision, the country of the operator is used. First, the impacts of tax are tested using the variable TOPMARTAX, which is the average income tax of the government for the highest income levels over 2002-2006, from the Freedom of the World Annual Report. The average value of this variable in the data is about 40%. Second, the economic status of a country can also affects its decision for flag out. To test this, we use the operator country's GDP per capita (LGDPCAP). The average GDP per capital in our dataset is US\$18,617. Our data shows that developed countries flag out 66% of their vessels, while under-developed countries only flag out 49%. Lastly, we also include the continent where the country is located (AFRICA, ASIA, EUROPE, AMERICA, OCEANIA), to test whether the flag-out behaviour has any regional patterns.

Finally, we design four variables to represent the difference between the operating country and the open registry country. First, the difference in flag state performances (DFSPERFORM), from the Shipping Industry Flag State Performance Table (BIMCO, 2009), are constructed to test whether the flag state performance is a major determinants. The higher this value is, the worse the flag state performance. In our data, the average is -0.770, indicating on average, the open registries have worse performance record. Second, this model includes the difference in the average ship accidents that causing ship loss (DLOSSRATE), from the World Casualty Statistics 1998-2007 (Lloyd's Fairplay). This variable is included to test the high losing rate of a flag state can drive the ship away. The data shows that average losing rate in is -0.209%, indicating the open registers have higher losing rate. The other two variables in this group, namely DCOMPANY and DCREW, represent the differences in the flag state requirement on the holding company's equity share and nationality of the crew. The requirements of each country are collected from various sources, including *Li* and *Wonham* (1999) and *Hill Dickinson LLP* (2008), which is available from Luo *et al* (2012). Due to their direct impact on a ship's operating costs, these two variables have important implications on the flag-out decision.

The average ship inspection rate is 1.1 per year according to the data from the three MOUs. Join the PSC inspection record with ship registration database, we found that 70% of the ships whose inspection rate is above average fly a foreign flag, while the rate for ships with lower than average inspection rate is only 46%. Different cargo ships also have different inspection rate. Our data shows that the average inspection rate is the highest for Bulk ships, which is about 1.67 times per year. Container ships, tankers are 1.022 and 0.57 times per year, respectively. The other cargo types also have a high inspection rate, which is about 1.17 times per year.

### 5. Empirical results and discussion

In order to compare the results from simultaneous equation estimates with those from single equation estimates, we report both of them in the following Table 1 and Table 2.

### 5.1. Flagging out decision equation

Table 1 illustrates the binary logit model for the flagging out decision equation from simultaneous equations estimates (left) and that from the single equation estimates (right).

The single equation estimate results are similar with the results from Hoffmann *et al.* (2005) and Luo *et al.* (2011). However, some estimated coefficients from simultaneous equations are significantly different from, or even have opposite signs.

	Estimates f	rom simult	aneous equations	Estimates from single equation		
Variable	Estimate	t Value	Approx Pr> t	Estimate	Wald Chi-Square	Pr > ChiSq
INTERCEPT	-20.3235	-4.88	<.0001	-8.7685	818.23	<.0001
BUILTOPER	-0.9639	-4.93	<.0001	-0.7282	471.33	<.0001
LDWT	0.6059	7.70	<.0001	0.4262	1248.29	<.0001
REAGE	-0.1083	-3.40	0.0007	0.0252	333.34	<.0001
BULK	-0.0235	-0.14	0.8923	-0.5629	190.28	<.0001
TANKER	1.2610	4.06	<.0001	-0.3774	124.00	<.0001
CONTAINER	0.8123	4.74	<.0001	0.0792	2.50	0.1137
TOPMARTAX	0.0505	4.87	<.0001	0.0303	399.07	<.0001
LGDPCAP	1.1928	3.94	<.0001	0.2399	187.85	<.0001
AFRICA	5.1311	3.48	0.0005	1.9404	63.36	<.0001
ASIA	0.0278	0.04	0.9696	0.8576	16.00	<.0001
EUROPE	0.6133	0.86	0.3923	1.0391	23.98	<.0001
AMERICA	2.5595	2.52	0.0118	0.7341	10.88	0.001
DFSPERFORM	-0.2408	-2.48	0.0133	-0.1593	129.94	<.0001
DLOSSRATE	0.2175	0.36	0.7193	0.3109	3.21	0.0732
DCOMPANY	-0.0174	-0.50	0.6142	-0.0841	31.52	<.0001
DCREW	0.1201	2.05	0.0408	0.0588	14.16	0.0002
CNKK	-1.3688	-3.23	0.0013	1.0252	457.92	<.0001
CGEL	-0.9454	-2.79	0.0053	1.2106	450.63	<.0001
CLLR	-3.1814	-4.99	<.0001	0.2761	28.09	<.0001
CBUV	-2.6122	-4.65	<.0001	0.5108	92.33	<.0001
CDNV	-1.5048	-3.68	0.0002	0.8338	172.89	<.0001
CABS	-2.4973	-4.50	<.0001	0.4077	46.60	<.0001
CCCS	-10.2099	-3.63	0.0003	-0.2848	18.76	<.0001
CRUS	-4.8135	-3.20	0.0014	0.8525	174.81	<.0001
CSKR	-10.8171	-3.59	0.0003	-0.1984 7.98 0.00		0.0047
CREI	-7.3629	-3.85	0.0001	-0.8264	57.36	<.0001
INSPECT	7.5355	3.80	0.0001	0.2544	715.86	<.0001

Table 1: Results for flagging out equation from simultaneous and single equation estimates

Similar with the former two studies, vessels built in operator's countries and with a small carrying capacity are less likely to flag out. In the single equation estimate, the coefficient for the vessel age at registration is positive. Luo et al. (2011) analyzed that it is may be due to the high maintenance cost that motivate them to choose a foreign flag. However, after controlling the endogenous problems in the two equations, the sign of this coefficient change to negative. It suggests that the likelihood that an operator will choose a foreign flag decreases with vessel age. This result is somewhat surprising in that substandard ships with older age are more likely to register in open registers. As Hoffmann et al (2005) analyzed that it is possibly caused by *pro*-

active attempts by open registers to attract younger ships with benefits. Another explanation includes that older vessels are less likely to trade internationally because of the difficulties in complying with international standards.

For TANKER and CONTAINER ships, the estimates in simultaneous equations are different with those from single equation. The estimated coefficients are positive and highly significant. This suggests that tanker and container vessels are more likely to flag out compared with other cargo ships.

Estimates for characteristics of the operator's country are similar in simultaneous and single equations. High income tax rate and GDP per capita motivate vessels to flag out because of high operating costs. Coefficients for country locations suggest different flagging out decisions among operators in different areas. Coefficients on DFSPERFORM and DLOSSRATE indicate that ship operators prefer to register in a country that does not enforce relevant international laws and regulations strictly and has a low loss rate record. The sign on DCREW suggests that a vessel is more likely to flag out if the operator's country enforces a stricter nationality requirement on the crew.

The key differences between single and simultaneous equation estimates are the coefficients of the classification societies. In the single equation estimates, 7 coefficients of the 10 high quality classification society are significantly positive which means that operators tend to flag out IACS classified vessels with high quality. With controlling of the endogenous problems of flag out decision and PSC inspection rate, all these 10 coefficients are negative. This indicates that the flagging out vessels are more likely to be lower quality ships with all other factors being unchanged.

Finally, the coefficient of the endogenous variable INSPECE is positive and significant in both models. It suggests that a vessel is more likely to be flagging out if its PSC inspection rate is high. In other words, high inspection rate may not be an effective way to lower operators' choice of foreign flags. In addition, compared with two estimated coefficients, the single equation model is much lower than the result from the simultaneous equation. This indicates without considering the endogenous variable, the impact of inspection rate on the flag-out behavior is under-estimated. This implies that the actual attractiveness of open registers is very high. In other words, the PSC control is not effectively deterring the flagging out of the world merchant vessels.

In conclusion, without considering the endogenous effect of the flag-out behavior with the PSC inspection rate, the estimate results are biased or underestimated. New or low quality ships are more likely to flag-out. Tanker and container ships are also have higher probability to fly a foreign flag. These results are more close to real world practice, because generally speaking, operators tend to choose a foreign flag for the vessels with lower quality, which are also those that may induce a high PSC inspection rate.

### 5.2. Inspection rate equation

Table 2 illustrates the estimation results for the PSC inspection rate equation from simultaneous equations (left) and single equation (right).

	Estimates from simultaneous equations			Estimates from single equation		
Variable	Estimate	t Value	Approx Pr> t	Estimate	t Value	Pr> t
INTERCEPT	2.8280	15.6100	<.0001	-0.9971	-9.27	<.0001
LDWT	-0.0818	-8.50	<.0001	0.1581	22.01	<.0001
AGE	0.0268	38.99	<.0001	0.0402	62.59	<.0001
BULK	0.4236	15.13	<.0001	0.1472	5.98	<.0001
TANKER	-0.3532	-15.02	<.0001	-0.6221	-31.19	<.0001
CONTAINER	-0.4505	-13.86	<.0001	-0.4009	-14.01	<.0001
LGDPCAP	-0.1772	-20.61	<.0001	-0.0197	-2.88	0.004

 Table 2: Results for inspection equation from simultaneous and single equation estimates.

AFRICA	-2.3039	-14.10	<.0001	-0.9633	-11.41	<.0001
ASIA	-1.5702	-11.20	<.0001	-0.6071	-8.70	<.0001
EUROPE	-2.1057	-15.04	<.0001	-0.6800	-9.65	<.0001
AMERICA	-1.9917	-13.69	<.0001	-1.2327	-16.68	<.0001
FF	3.0432	43.93	<.0001	0.6106	36.79	<.0001
CNKK	0.3381	9.27	<.0001	1.0055	33.87	<.0001
CGEL	0.1647	4.03	<.0001	0.7661	23.09	<.0001
CLLR	0.6133	16.44	<.0001	0.7746	24.05	<.0001
CBUV	0.6237	16.48	<.0001	0.9233	28.23	<.0001
CDNV	0.1508	3.36	0.0008	0.6751	18.63	<.0001
CABS	0.3938	9.30	<.0001	0.5506	15.45	<.0001
CCCS	0.9664	22.47	<.0001	0.8897	21.97	<.0001
CRUS	0.4357	9.87	<.0001	0.7183	18.16	<.0001
CSKR	1.3688	29.02	<.0001	1.3591	30.70	<.0001
CREI	1.2944	17.10	<.0001	0.9170	13.47	<.0001

Different to the flagging out decision equation, there are no significant differences between the simultaneous model and single equation estimates except ship size and flag. The negative significant coefficient for LDWT in the simultaneous model suggests that larger vessels are less likely to be inspected by the PSC authority. Compare with the single equation model, the PSC inspection frequency for the ships that flying the flag of an open registry 5 times higher. In other words, without consider the endogenous of ship inspection and ship registration, the impacts of fly a foreign flag on the PSC inspection is underestimated. This result provides a more convincing evidence that the PSC is effectively reducing the flag-out behavior, as ships with a foreign flag are inspected more often.

The positive coefficient of AGE also suggests that the average inspection rate for older ships is higher. This is reasonable as older ships generally have more problem than new one, hence are more likely to be inspected by the PSC authority.

The positive coefficient of BULK suggests that the inspection rate for bulk vessels are higher than dry cargo vessels. However, the negative coefficients for TANKER and CONTAINER suggest that the inspection rate for tanker and container are lower. As Hoffmann et al. (2005) and Li et al. (2012) have analyzed that tanker and container vessels are less likely to have an accident, so it is reasonable to inspect them less often.

For the characteristics of the operators, the negative coefficient for LGDPCAP suggests that the more developed the country is, the lower its vessel being inspected by PSC authority. The negative coefficients for AFRICA, ASIA, EUROPE, and AMERICA suggest that inspection rates are lower for vessels from these 4 areas than those from Oceania.

Finally, the coefficients for the 10 IACS classification society are all significantly positive suggesting a higher inspection rate of IACS classified vessels. Although the flagging out decision suggests that an IACS classified vessel is less likely to flag out, once it choose to use a foreign open flag, the PSC will enforce a relatively higher inspection rate on the IACS vessels.

### 6. Conclusion

This study analyses the determinants of flag-out decision and PSC inspection rate taking into account the reciprocal impact of ship operator's flagging out decision and the PSC's inspection rate. A binary choice model is applied to study the flag-out decision, and a linear model is adopted to explain the frequency of PSC inspection. The endogeneity are accommodated by estimating these two models simultaneously using 3SLS. The data includes the ship registration records of the world merchant fleet from the Lloyd's PC Register of Ships, joined with the PSC inspection records from Tokyo MOU, Paris MOU and India MOU using the unique IMO number of each ship. In addition to the ship information, the economic and policy conditions of

operator's country, and geographical relationships are also taking into account. The main innovation of this study is that it combines these two equations with simultaneous equation techniques to avoid endogenous problems between flagging out decisions and inspection rate. The contribution is that it provides a better estimate on the effectiveness of PSC control in reducing the flagging out of world merchant fleet.

The empirical results show that in addition to the ship characteristics, national policies, PSC and Flag State Control (FSC) all have significant impacts on the flagging out decision. The higher the inspection rate of a ship, the more likely it will flag out. Generally speaking, operators tend to choose a foreign open flag for the vessels with lower quality even these vessels will induce a high inspection rate from the PSC authority. For the PSC inspection equation, the results suggest that the ship characteristics, operators' properties, and flag choice could determine a vessel's inspection rate. Since a foreign flagged vessel has a higher rate of inspection by PSC, measures that reduce the probability of being inspected by the PSC can indirectly reduce the likelihood of flagging out.

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# Study on Vessels' Economic Viability under Drastic Fluctuation of Oil Price

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### 1. Introduction

Referred to Veenstra [1], to be successful in the shipping industry depends not only on entrepreneurship, market insight, and, some say, but also a certain lack of risk aversion. Furthermore, success also depends on the capabilities of the main asset to a large extent: the vessel itself. The vessel is a durable asset with specifications, such as cargo-carrying capacity, length, width, maneuverability and speed, that are, in general, difficult to change. Therefore ship owners are faced with two important questions:

- Do I have the right vessel for a given trade or working area?
- What is the best performance that I can achieve with a given vessel? How does it work most economically?

This paper is about vessel operations and not about trading in vessels. Vessels' performance consists of vessels' propulsion performance, commercial performance, safety performance and environmental performance [2]. By making a link between the technical specifications of the vessel (which is the answer to question 1, and the input to question 2) with the measurement of operational performance (which is the input to question 1, and the answer to question 2), this paper attempts to answer the question 2 in the way of commercial performance, that is, economic viability of a vessel, assuming that given by a right vessel. For this purpose, we introduce the economic viability to assess the commercial performance of a vessel.

### Fig 1: Relationship between Vessel Speeds with Annual Income & Cost



Bulk shipping concerns the transportation of raw materials for heavy industry, like iron ore and coal. Demand for transportation is governed by changes in world consumption of bulk commodities, as well as changes in

the geographical demand and supply pattern. Bulk shipping imposes a significant influence on the world macro economy. With the booming demand for iron ore and other metal ores in emerging economies (e.g. China), more and more bulk vessels have been supplied to the world shipping market by shipping companies. Thus how to get the best economic viability of vessels has been the core purpose of shipping companies when facing fierce competition in the bulk shipping market. According to our findings, along with the booming demand for bulk shipping since 1998, oil price nearly has the same trend in the same period (since 1998 to 2008). However the continued escalation of bunker fuel prices combined with the prolonged oversupply of shipping capacity, especially bulk carriers, accentuate the importance of the existing tradeoffs between bunker fuel savings through vessel speed reduction, and the loss of vessel revenues due to slow steaming. As bunker fuel fee accounts for 20-50% of the total operational cost, shipping companies have to deal with the balance between oil price and vessel speed aiming to get the best economic viability (see in Fig. 1). However, since 2008, with the start of financial crisis, both the bulk shipping market and oil market suffered heavy shocks: the BDI index fell down from the peak to around 700; the oil price also dropped down from the peak to the trough and then fluctuates drastically in the past 3 years. At present, the influence of the financial crisis has not gone, and the oversupply of bulk carriers and less demand for bulk goods have push shipping companies at a huge disadvantage. Thus, how to keep vessels' economic viability under drastic oil price fluctuation is very crucial for shipping companies.

Therefore, our study on bulk vessels' economic viability will focus on one economic indicator and provide a method to help shipping companies gain best economic benefit.

The remainder of this paper is organized as follows. Section 2 contains a brief literature review of vessels' economic viability and the introduction of economic indicators. Section 3 introduces the methodology of the study. A modified model is applied to the empirical study in Section 4 while Section 5 presents the conclusions of the paper.

### 2. Literature Review

### 2.1 Literature Review

There is a huge body of the literature on vessels' economic viability or performance. But most of the researches focus on the liner ship operations. Many researchers have provided general discussions on the economies of scale achieved by large containerships [3-6]. Akio et al. examined the economic viability for deploying container mega vessels by applying game theory in analyzing competition in the shipping industry [7]. However, they all focus on the economies of scale for achieving economic viability, not on the relationship between economic viability and bunker fuel price. Veenstra et al. [1] discussed the economic performance in vessel design and shown us a lengthy review of previous work which gave us the relationship between economic viability and technical aspects of shipping.

Xie et al. have paid attention to vessels' economic viability using a simple model of sensitive analysis with 3 impact factors: freight rate, vessel price and oil price in a 10% rate of change [8]. There research has given us a basic method to study bulk vessels' economic viability under the case of oil price fluctuation. Liu et al. [9] have investigated the economic potential of using the Northern Sea Route (NSR) as an alternative route between Asia and Europe by taking 3 main factors (bunker price, navigable time and Russian NSR fees) into consideration. It is a good way to seek the influence of bunker price on vessels' economic viability. Ronen studied the effect of oil price on containership speed and fleet size [10]. They have constructed a cost model to analyze the tradeoff between speed reduction and adding vessels to a container line route to minimize the annual operating cost of the route to get the best economic viability. More and more researches have focused on container vessels' economic viability by taking bunker price and  $CO_2$  emission reduction into consideration. Corbett et al. studied the effectiveness and costs of speed reduction on emissions from international shipping by taking bunker price into consideration [11]. A method to study the economic effectiveness of a European speed limit policy against an international bunker-levy to reduce  $CO_2$  emissions from container shipping was then provided [12]. It expanded the economic viability to a macroscopic view with the influence of oil price.

As seen above, the research tendency seems to focus on the effectiveness of some policies and the economies of scale of container vessels. However, few researches have been done on vessels' economic viability. Only few researchers focused on vessels' economic viability against oil price volatility to a small extent of 10% [8]. Since the world macro economy is down-going continuously, most shipping companies suffer heavy losses due to the oversupply. The oil price keeps fluctuating drastically in the past few years (see in Fig.2, the volatility can be over 50% in a short time) and bunker fuel fee imposes a heavy influence on vessels' operating cost, how to maintain vessels' economic viability under the drastic oil price volatility is critical both to shipping companies and researchers.

### 2.2 Economic Indicator

Traditional economic viability assessment methods for vessels' commercial performance has several economic indicators and in this paper we introduce 3 most widely used ones: Net Present Value (NPV), Internal Rate of Return (IRR), Required Freight Rate (RFR), as in equations below.

$$NPV = \sum_{t=1}^{N} (P/F, i, t) \cdot A_t - P = \sum_{t=1}^{N} (P/F, i, t) (B_t - Y_t - S_t) - P$$
(1)

$$(A/P, IRR, N) = \frac{B-Y}{P} = \frac{IRR \cdot (1 + IRR)^{N}}{(1 + IRR)^{N} - 1}$$
(2)

$$RFR = \frac{AAC}{Q}, RFR = \frac{P(A/P, i, N) + Y}{Q}$$
(3)

Where N is the duration; P is initial investment; F is future benefit; i is the interest rate;  $A_t$  is the benefit in year t;  $B_t$  is the income in year t;  $Y_t$  is the operating cost (exclude bunker fee) in year t;  $S_t$  is the oil price in year t; AAC is average annual cost; Q is the annual volume per vessel.

NPV is an indicator of how much value an investment or project adds to the firm. With a particular project, if NPV is a positive value, the project is in the status of positive cash inflow in the time of t. If NPV is a negative value, the project is in the status of discounted cash outflow in the time of t.

Because the IRR is a rate quantity, it is an indicator of the efficiency, quality, or yield of an investment. This is in contrast with the NPV, which is an indicator of the value or magnitude of an investment. An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital.

RFR is a freight rate which is obtained so that all expenses are covered, with a remainder sufficient for the returns on investment in analysis of the economic merit of a shipping project.

### 3. Methodology

Given that the oil price fluctuates drastically, it is necessary to first ascertain the fluctuation pattern of oil price. Then we can get a proper approach to study vessels' economic viability under the oil price volatility pattern.

### 3.1 ARCH model

To make a comprehensive understanding on the uncertainty of oil market, building an econometric model to take a deep step is necessary. Many researchers have used time series method ARCH (Auto Regressive Conditional Heteroscedasticity) model [13] to analyze the fluctuation of oil price. The ARCH models are employed commonly in modeling volatility of financial time series that exhibit time-varying volatility clustering, that is, periods of swings followed by periods of relative calm. The ARCH model was first introduced by Engle to model the volatility of UK inflation. Since then this methodology has been employed

to capture the empirical regularity of non-constant variances, such as stock return data, interest rates and foreign exchange rates, for example, Bollerslev and Melvin among others [14]. ARCH model was widely used in stock market, money market and foreign exchange market and has achieved great excellence. Thus, many researchers have paid attention to use ARCH model in oil market.

ARCH model has 3 basic forms:

(1) Linear ARCH (q) model:  $\varepsilon_t$  is a random process:

$$\varepsilon_t = \sqrt{h_f \cdot v_t} \tag{4}$$

And assuming that  $\{V_t\}$  is independently identically distributed,  $E(V_t) = 0$ ,  $D(V_t) = 1$ . Then:

$$h_{t} = a_{0} + \sum_{i=1}^{q} a_{i} \varepsilon_{t-i}^{2}$$
(5)

(2) Linear GARCH (p, q) model.

$$h_{t} = a_{0} + \sum_{i=1}^{q} \alpha_{i} \varepsilon_{t-i}^{2} + \sum_{j=1}^{p} \beta_{j} h_{t-j}$$
(6)

Where  $\alpha_0 > 0, \alpha_i \ge 0, \beta_j \ge 0, i = 1, 2...q, j = 1, 2...p.$ 

### (3) Exponential GARCH (p, q) model, namely EGARCH (p, q) model:

$$\ln h_{t} = a_{0} + \sum_{j=1}^{\infty} \pi_{j} \left\{ v_{t=j} \right| - E \left| v_{t=j} \right| + g^{*} v_{t-j} \right\}$$
(7)

ARCH model makes it clear that fluctuations in time series can be forecasting and it indicates that past fluctuations have positive and retarding effect. For forecasting, ARCH model is much more accurate than Lease Square Method.

### 3.2 Sensitivity Analysis

Sensitivity analysis (SA) is the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input [15]. A related practice is uncertainty analysis which focuses rather on quantifying uncertainty in model output. Ideally, uncertainty and sensitivity analysis should be run in tandem.

In this paper, we introduce the one-way sensitivity analysis. It is a form of sensitivity analysis is to simply vary one value in the model by a given amount, and examine the impact that the change has on the model's results.

### 4. Empirical Study

### 4.1 ARCH Effect Verification

We collect the data from the U.S. Energy Information Administration from January 1998 to March 2012. The total 740 weekly data are shown in Fig. 2. As we can see from Fig. 2, the oil price volatility is very violent.



To buffer the fluctuation, we do logarithm transformation to the raw data and get the first difference to stand for percentage rate of return. See the statistics in Table 1.

Table 1: Statistics for WTI Percentage Rate of Return					
Mean	0.243202				
Std. Deviation	4.595864				
Skewness	-0.344458				
Kurtosis	5.710845				
J-B	241.2179(0.00)				
AC(1)	0.155(0.00)				
Q(10)	33.454(0.00)				
$Q^{2}(10)$	107.89(0.00)				
ADF	-14.14591 (0.00)				





The ARCH verification of oil price indicates that the fluctuation of oil price has a characteristic of clustering and lasting which means that the past swing has positive and retarding effect. According to such persistence characteristic of oil price volatility, we suggest an approach to decompose the oil price time series into several short intervals to smooth the drastic fluctuation, among those intervals the price volatility should be controlled in 20% in each interval. As seen in Fig. 4, we decompose the oil price time series into 18 intervals from 2011.1.5 to 2012.3.9.

### Fig.4: Decomposition of Oil Price Time Series



### Weekly Cushing, OK WTI Spot Price FOB (\$ per Barrel)

4.2 *Comparison and Selection of Economic Viability Indicator* 

Error pervades in each economic analysis method, thus how to compare and select the best indicator of economic viability to minimize error keeps us going further in the research. With the 3 major economic indicators: NPV, IRR and RFR, we need to seek the best indicator to conduct our verification.

$$NPV = \sum_{t=1}^{N} (P/F, i, t) \cdot A_{t} - P = \sum_{t=1}^{N} (P/F, i, t) (B_{t} - Y_{t} - S_{t}) - P$$
(8)

 $A_t$ : income at year t;  $B_t$ : operational income at year t;  $Y_t$ : operational cost at year t;  $S_t$ : oil price at year t; P: initial investment, namely vessel price; *i*: the benchmark rate of investment

 $\sum_{t=1}^{N} (P/F, i, t) \cdot A_{t}$ 

As we can see from equation (9), generally, NPV is relatively much smaller to  $\overline{t=1}$  and P. Thus a huge error exists when the equation from is a large value minus a large value; especially the Percentage Error would increase dramatically.

$$(A/P, IRR, N) = \frac{B-Y}{P} = \frac{IRR \cdot (1 + IRR)^{N}}{(1 + IRR)^{N} - 1}$$

(9)

The error increases in IRR in the same way with that in NPV as the Percentage Error rises violently due to a drastic volatility in oil price.

$$RFR = \frac{P(A/P, i, N) + Y}{Q} \tag{10}$$

The equation here is by add operation, thus the Percentage Error should be relatively stationary concerning drastic oil price fluctuation. So RFR is a relatively proper economic indicator for vessels' economic viability verification under drastic oil price fluctuation.

### 4.3 Sensitive Analysis

In this paper, we choose a bulk vessel named Ocean Universe as an example for our empirical study. Parameters of Ocean Universe can be seen in Table 2 & 3below.

Table 2: Ocean Universe Main Parameters								
Name	DWT	Length	Width	Draft	Oil Cons.	Vessel speed		
Ocean Universe	DWT	m	m	m	t/d	n mile/h		
	245609	326.00	53.00	19.20	55.6	14.15		
Source Clarkson Shipping Intelligence								

Source: Clarkson Shipping Intelligence

### Table 3: Economic Viability of Ocean Universe in Tubarao-Beilun Route

Vessel type DWT	Build Cost \$10,000	Round trip time/year	Crew fee \$10,000	Depreciation \$10,000	Maintenance fee \$10,000	Insurance fee \$10,000			
245609	7500	4.06	29.00	356.25	112.50	52.50			
Fuel fee	Lubricant	Consumables	Port	Administration	Total cost	NPV			
		cost	charge	cost					
\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000			
360.23	28.82	38.91	48.69	181.76	1208.65	4778.51			

Source: Clarkson Shipping Intelligence

Seen from Fig. 4, the whole time series should be decomposed into 18 intervals. The decomposition rule is that the oil price volatility should be under 20%. The average oil price in each interval and the duration of each interval are shown in Table 4.

Table 4: Intervals of On Frice Fluctuation (\$/barrer)								
Interval	Beginning - end	Duration/week	Average oil price					
$\mathbf{S}_0$	2001/1/1 - 2001/8/31	35	27.99					
$\mathbf{S}_1$	2001/9/7 - 2002/10/26	8	24.25					
$\mathbf{S}_2$	2002/11/2 - 2004/1/30	118	28.13					
$S_3$	2004/2/6 - 2004/12/31	48	42.08					
$\mathbf{S}_4$	2005/1/7 - 2005/5/20	20	50.53					
$S_5$	2005/5/27 - 2007/1/19	87	63.58					
$S_6$	2007/1/26 - 2007/4/20	13	60.08					
$S_7$	2007/4/27 - 2007/8/10	16	68.57					
$S_8$	2007/8/17 - 2007/9/21	6	75.39					
$S_9$	2007/9/28 - 2008/2/8	20	90.74					
$\mathbf{S}_{10}$	2008/2/15 - 2008/9/19	32	117.54					
$\mathbf{S}_{11}$	2008/9/26 - 2008/10/10	3	97.98					
$\mathbf{S}_{12}$	2008/10/17 - 2009/6/12	35	50.92					
<b>S</b> <sub>13</sub>	2009/6/19 - 2010/6/18	53	74.86					
$\mathbf{S}_{14}$	2010/6/25 - 2011/2/11	34	81.83					
$S_{15}$	2011/2/18 - 2011/9/2	29	97.94					
$\mathbf{S}_{16}$	2011/9/9 - 2011/12/16	15	91.20					
$S_{17}$	2011/12/23 - 2012/3/9	12	101.57					

### Table 4: Intervals of Oil Price Fluctuation (\$/barrel)

Assuming that the oil price are  $S_0$ ,  $S_1$ ,  $S_2$ ,  $S_3$ ,  $S_4$ ,  $S_5$ ,  $S_6$ ,  $S_7$ ,  $S_8$ ,  $S_{9}$ ,  $S_{10}$ ,  $S_{11}$ ,  $S_{12}$ ,  $S_{13}$ ,  $S_{14}$ ,  $S_{15}$ ,  $S_{16}$ ,  $S_{17}$ ; world crude oil 1 metric ton equals 7.35 barrel, then we can get the real oil price:  $S_0$ =205.73 \$/ton,  $S_1$ = 178.24 \$/ton,  $S_2$ =206.76 \$/ton,  $S_3$ =309.29 \$/ton,  $S_4$ =371.40 \$/ton,  $S_5$ =467.31 \$/ton,  $S_6$ =441.59 \$/ton,

 $S_7 = 503.99 \text{ (ton, } S_8 = 554.12 \text{ (ton, } S_9 = 666.94 \text{ (ton, } S_{10} = 863.92 \text{ (ton, } S_{11} = 720.15 \text{ (ton, } S_{12} = 374.26 \text{ (ton, } S$  $S_{13}=550.22$  \$/ton,  $S_{14}=601.45$  \$/ton,  $S_{15}=719.86$  \$/ton,  $S_{16}=670.32$  \$/ton,  $S_{17}=746.54$  \$/ton.

	Table 5: RFR in Each Interval (\$)								
]	$RFR_0$	$RFR_1$	RFR <sub>2</sub>	RFR <sub>3</sub>	$RFR_4$	$RFR_5$	RFR <sub>6</sub>	RFR <sub>7</sub>	
1	8.958	18.299	18.983	21.440	22.929	25.227	24.611	26.107	
]	RFR <sub>8</sub>	RFR <sub>9</sub>	$RFR_{10}$	$RFR_{11}$	RFR <sub>12</sub>	RFR <sub>13</sub>	$\mathbf{RFR}_{14}$	RFR <sub>15</sub>	
2	7.308	30.012	34.733	31.287	22.997	27.215	28.442	31.280	
F	RFR <sub>16</sub>	RFR <sub>17</sub>							
3	0.093	31.920							

Also, we assume that other factors change in the same way with the traditional method. We get the RFR in each phase, see in Table 5:

Considering the duration of each interval, we should get the sum of the RFR of each interval with the weight of each interval. Then we'll get the modified  $RFR = 0.060RFR_0 + 0.014RFR_1 + 0.202RFR_2 + 0.082RFR_3 + 0.082RFFR_3 + 0.082RFFR_3 + 0$  $0.034 RFR_{4} + 0.149 RFR_{5} + 0.022 RFR_{6} + 0.027 RFR_{7} + 0.010 RFR_{8} + 0.034 RFR_{9} + 0.055 RFR_{10} + 0.005 RFR_{11} + 0.005 RFR_$ + 0.060 RFR<sub>12</sub> + 0.091 RFR<sub>13</sub> + 0.058 RFR<sub>14</sub> + 0.050 RFR<sub>15</sub> + 0.026 RFR<sub>16</sub> + 0.021 RFR<sub>17</sub> = 24.649 \$/barrel.

Thus, with the modified RFR and the method of decomposition of oil price fluctuation time series, we can smooth the negative influence the fluctuating oil price taking to the vessel's RFR. And we can do the sensitive analysis under the drastic price volatility. To compare with the results of traditional sensitive analysis, we take the same volatility for example: 10% (assuming the other variables such as ship price, port fees et al. are stationary). The results are shown in Table 6.

Tak	Table 6: Contrast of Vessel's Economic Viability Sensitive Analysis								
Oil price	ARCH	Traditional	ARCH RFR	Traditional RFR					
change rate/%	RFR(\$/barrel)	RFR(\$/barrel)	Change Rate/%	Change Rate/%					
+10	25.687	27.607	+4.21	+12.00					
+5	25.157	26.128	+2.06	+6.00					
0	24.649	24.649	0.00	0.00					
-5	24.097	23.170	-2.24	-6.00					
-10	23.567	21.691	-4.39	-12.00					

As we can see from Table 6, the time series decomposition method provides better modified RFR which fluctuate much more smoothly than the traditional sensitive analysis. After we decompose the fluctuating oil price time series to several phases, we can get a more accurate assessment of vessels' economic viability. We have contractive the RFR interval of 23.567 to 25.687\$/barrel for the vessel. With the modified RFR, shipping companies can stabilize their freight rates in a light volatility (up to 5%) in case of 10% volatility of oil price to achieve the economic viability and gain more market share. For example, with a sudden 10% increase of oil price, some shipping companies may charge a freight rate with a 12% increase to 27.607\$/barrel, using the decomposition method, shipping companies can charge a freight rate of 25.687\$/barrel with only 4.21% increase. Thus this method can provide a good pricing strategy to shipping companies.

### 5. Conclusion

In this paper we introduced a modified method to examine vessels' economic viability with the influence of drastic oil price fluctuation. With an ARCH model, we confirm the similar findings in the literature that the volatility of oil price is time-varying, and the oil price volatility series exhibit clustering characteristics. Then we could decompose the observation time into 18 intervals that the price volatility in under 20% in each interval. This process can help to smooth the sharp volatility of oil price.

This paper provides an effective and simple way to examine vessels' economic viability against oil price fluctuation. It demonstrates that RFR is a proper economic indicator for vessels' economic viability

examination. With the decomposition of price time series into 18 phases, we could get a contractive interval of RFR against the extensive oil price volatility range. Shipping companies could appropriately adjust their freight rates according to RFR in a small volatility range when facing drastic oil price volatility to keep their leading place in market competition and achieve economic viability, as bunker fuel fee has become the major part of operational cost. The macro economy is still down going, the oversupply of shipping capacity is hard to ease, the bunker fuel price is still high and fluctuates drastically, how to keep vessels' economic viability under such a situation has long been a core objective to shipping companies. This paper provides a good way to deal with this problem.

However, further research still needs to be done to explore the multi-way sensitivity analysis of vessels' economic viability. In this paper, we assume that ship price, port fees et al. are all stationary, actually those fees are not stationary and may vary along with the oil price, future research needs to study the non-linear relationship between those factors.

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# Maritime Supply Chain Security: A Critical Review

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## Abstract

The importance of container security for international trade is well established and has been the subject of recent research in the follow up of the implementation of global security initiatives and the imperative of avoiding supply chain disruptions and reduce vulnerability. This article provides a review of the emerging literature on container security specifically in its interface with global logistics systems. The paper highlights the topics that have emerged as well-established research areas and indicates in what areas scholarly attention is most needed.

Keywords: Container Security; Supply Chain Security; Container Transportation.

# 1. Introduction

Container transportation is the backbone of globalization and international trade and has allowed countries and firms to improve efficiency and reliability of their supply chains. The development of the container has been the critical innovation responding to the requirements of a globalized world, as shown by the average double-digit growth rates of container transportation in the last half century. The development of containerization has allowed for increases in loading and unloading efficiency unimaginable before.

As container transportation increased and became more global, supply chains became more dependent on the box, with industrial processes deeply entwined with the global supply chain management strategies necessary to production and delivery of goods to markets worldwide. The benefits of such development are undeniable, but the dependence of modern industrial production to global supply chains has inadvertently exposed the world economy to a new source of risk: container supply chain vulnerability.

While on the one side the development of container transport has substantially reduced the risks of cargo damage and pilferage, which had been the predicament of transportation providers and cargo owners for centuries, on the other side, the resulting international nature of global supply chains as well as the relative lack of visibility of chains worldwide, has exposed container transport, and consequently supply chains, to the most diverse threats.

Contraband, smuggling of people and weapons, terrorist attacks and piracy are all too well-known criminal activities that can cause disruptions and costs increases in container-dependent transport chains. The very nature of globalized container transportation, with container boxes transiting the most remote corners of the world and the necessary reliance of logistics service providers on agents and operators often beyond the direct control of the cargo interest, have allowed criminal and terrorist organisations to interfere with container supply chains and make use of the world transport for malicious endeavours.

Organisations and governments have responded with policies and practices aiming at reducing the exposure of supply chains to voluntary acts of breach and intentional chain disruptions. The application of policies, procedures and technologies aiming at reducing such exposure and at protecting, people, goods, facilities and

equipment in the chain, as well as preventing malicious interferences on the normal flow of goods and information with the objective of allowing contraband or theft, are referred to as supply chain security (SCS) (Closs & McGarrell, 2004).

Ensuring security of maritime supply chains is critical to international trade (Closs & McGarrell, 2004). Although SCS is a rather developed area of research (Williams, Lueg, & LeMay, 2008), fewer studies have focused so far on maritime and container SCS (Barnes & Oloruntoba, 2005; Marlow, 2010; C. Yang & Wei, 2013). Container shipping and maritime security can be defined as "those measures employed by owners, operators, and administrators of vessels, port facilities, offshore installations, and other marine organizations or establishments to protect against seizure, sabotage, piracy, pilferage, annoyance, or surprise" (Hawkes, 1989: pg.9).

Nation State and firm responses to the increasing threats associated with global chains have been diverse and multifaceted, and only after the events of 9/11 has the global approach to SCS, somewhat under the stimulus of the USA foreign policy, been characterised by a renewed and coordinated international efforts. The results of such efforts have been controversial, and it is beyond the scope of this manuscript to review the global order approaches that have influenced international relations in the last decade and a half, nor, for that matter, to express any judgement on the success of such approaches in defeating terrorism or reducing supply chain vulnerability and disruptions. What can though be assessed is that such policies have stimulated global and interdisciplinary discourses on the importance of supply chain vulnerability and disruptions, and contributed defining SCS as an autonomous area of academic investigation in the broader domain of supply chain risk management.

The academic literature in the last fifteen years has highlighted the benefits of container security and a distinctive amount of analyses have been developed with the purpose of facilitating SCS initiatives, assess current practices and provide policy makers and the industry with scientific support on the elaboration of new security strategies. The area of container security is a dynamic and evolving discipline, shaped equally but governmental efforts to reduce security threats and industry practices to minimize security breaches costs and ultimately maintain or enhance the competitive position of the firm.

The multifaceted nature of supply chain security entails that the literature is often fragmented and it is challenging to identify clear research developments and trends (Williams, Lueg, & LeMay, 2008). Hence, a continuous effort to update and refine the frameworks and structures developed is imperative, and even more so for those research areas that are emerging and interdisciplinary in nature as SCS. Furthermore, the SCS literature had only recently started to focus in container transportation. Considering the pivotal role that container transportation has on global production systems, it has been recommended more attention be dedicated to this area.

This paper contribution to the existing discourses on SCS is two-folds. Firstly, it reviews supply chain security literature from the specific perspective of container security, highlighting the specificities of container transport with respect to SCS literature. This is important given the critical role that container transportation plays in the supply chain process (Closs & McGarrell, 2004; C. Yang & Wei, 2013). Secondly, by focusing on the literature of the last five years this review highlights how the conceptual structures and frameworks elaborated in the literature respond to the new developments in the discipline. Testing and reviewing conceptual and empirical frameworks is particularly important in container SCS, considering the dynamically evolving and often elusive nature of the discipline.

This review is structured in the six sections. This introduction provides the background for the analysis and highlights why a literature review in container SCS is expedient. Section two outlines the process and the overall structure used for the review. Section three focuses on the analysis of the antecedents to container SCS. Section four analysis the policy, practice and technological developments that have characterised the enhancement of container SCS in the last half decade. Section five reviews the organisation and process frameworks that have been used for maritime SCS. Section six reviews those contributions that have addressed the major outcomes to SCS. And finally section six summarises the major findings of the paper and indicates the areas where scholarly attention is most recommended.

# 2. Literature Review Structure

The SCS has increased substantially in the last decade and a half and has advanced the knowledge of SCS in multiple directions, but no specific attention has been dedicated to container SCS. In the search for a suitable container SCS security we have therefore looked at the recent SCS reviews and supply chain risk management. Previous literature reviews, such as Williams *et al.* (2008), Gould *et al.* (2010), and more recently Colicchia & Strozzi (2012) have employed different methods to summarise the existing literature. Williams *et al.* (2008) was one of the first papers to carry out a comprehensive and systematic literature review on SCS. They categorise SCS literature in four perspectives:

- An intraorganisational perspective
- An interorganisational perspective
- A combination of both perspectives
- An approach, that deliberately ignores security as an issue.

Intraorganisational approaches look at the supply chain from a single company perspective, presenting conceptual and practical approaches to prevention and response. Interorganisational approaches highlight the fact that supply chains are rarely managed within a single organisation and require the cooperation of multiple external parties, including governments. Some authors have highlighted the necessity to combine both approaches to reach SCS, and others pointed out the fact that some firm may reject taking any proactive attitude towards SCS, which are perceived to be ineffective and too expensive.

Gould *et al.* (2010) approach the review systematically but from a thematic point of view, subdividing the existing literature around three main research areas:

- SC efficiency despite security requirements
- Dealing with security risks in supply chains
- Improving response to a security event.

They also provide a review of the definition of the concept of SCS and argue that operationalization in SCS is among the least developed areas in the literature.

Colicchia & Strozzi (2012) approach the literature review combining a systematic review with a citation network analysis. Although the authors focus on the broader area of supply chain risk management, their findings are interesting in relation to the SCS literature, which is a subset of the supply chain risk management literature. They structure their systematic supply chain risk management literature using the approach illustrated by Denyer & Tranfield (2009) that consists of four categories: context (C), intervention (I), mechanism (M) and Outcome (O), from the acronym of which it takes its name (CIMO). The resulting structure of supply chain risk management literature is articulated according to Colicchia & Strozzi (2012) in four main research areas: complexity and uncertainty (context), practice and tools for supply chain risk management (intervention), organisation of supply chain risk management process (mechanisms), and increased supply chain resilience and robustness (outcomes).

A similar approach has been used in this manuscript for the categorisation of container SCS. The structure used in this literature review is:

- Vulnerability and potential for disruptions
- Policy, practices and technologies
- Organisation and processes
- Outcomes

In the case of container SCS the *context* is provided by the vulnerability and potential for disruptions of container supply chains because of increasing global container movement threats, mostly as a result of terrorism and piracy. The *intervention* category groups the literature that addresses practices, policies and technologies developed to enhance container SCS. The literature that focuses on how container SCS is likely to affect organisations and how organisations interact with each other, has been grouped under *mechanisms*. Under *outcomes* we collected the research contributions that investigate the possible outcomes of container SCS practices, such as decrease in vulnerability and disruptions but also cost increases.

# 3. Vulnerability and Potential for Disruptions

#### 3.1. Increasing vulnerability

In recent years, globalization and growth in seaborne trade have increased the vulnerability of supply chains to a series of international criminal activities that threaten the global movement of goods and may have significant impacts on economic activity and world trade. Piracy, people and drug trafficking, weapons smuggling, information security and, after the events of 11 September 2001, terrorism are all recognized as threats for supply chain security (see, among others, Closs & McGarrell, 2004; Lu, Chang, Hsu, & Metaparti, 2010; Thai, 2009; Van de Voort & O'Brien, 2003). A brief synthesis of literature related to threats in maritime supply chain is provided in this section, divided into two main areas dealing with piracy and terrorism.

#### 3.1.1. Piracy and maritime robbery

Maritime piracy is defined by the United Nations Convention of the Law of the Sea as "any criminal acts of violence, detention, or depredation committed for private ends by the crew or the passengers of a private ship that is directed on the high seas against another ship, or against people or property on board a ship". Although this definition is recognized in international law and accepted by the International Maritime Organization (IMO), several authors argued that it is inadequate, limiting the offence to the high seas (Bendall, 2010; Dillon, 2005; Marlow, 2010). In order to overcome the distinctions between high seas and territorial waters, the International Maritime Bureau (IMB) has provided a wider definition of piracy which includes maritime crimes in territorial waters but which is not recognized in international law.

Even if it is generally accepted that factors inspiring piracy have their origin in economic reasons (Talley, 2008), recently a nexus between piracy and terrorism, where pirates are also terrorist with ideological reasons, has been established (Bird, Blomberg & Hess, 2008; Fawcett, 2010; Garmon, 2002).

Data on piracy events are usually available from reports provided by maritime organizations (e.g. IMO and IMB), however these statistics should be read with care because many events result unreported. In fact, many shipping companies prefer to cover any losses out of their own resources rather than report the event and suffer delays and additional insurance cost (Marlow, 2010) and often there is no discrimination between major and minor attacks (Bateman, 2010; Chalk, 2009; Fawcett, 2010). These reports, however, show that undoubtedly acts of piracy are increasing in the last years and the most pirate-ridden area at this time are the coast of East Africa, the Gulf of Aden and nearby waters of the Indian Ocean (Axe, 2009; Fawcett, 2010; Hanson, 2009; Middleton, 2009; Murphy, 2010; Schiemsky, 2009; Waldron &Kimball, 2008; Wilson, 2009). The hotspot for piracy and maritime robbery has shifted from Indonesia to Somalia, but there has also been a worrying increase in the number of pirate attacks in the southern part of the South China Sea (Chow, 2009).

Literature dedicated to maritime piracy includes mainly legal review (see, among the most recent, Hong *et al.*, 2010; Kraska & Wilson, 2009) and descriptive studies (see, among others, Bateman, 2009; Bateman, 2010; Fawcett, 2010; He, 2009; Ho, 2009; Murphy, 2010; Nakamura, 2009; Onuoha, 2009; Shih *et al.*, 2010). These studies analyse the problem of maritime piracy and in many cases suggest measures for abating or containing it. Improved governance onshore, improvement of local security forces, cooperation between foreign navies engaged on counter-piracy operations and maritime law enforcement are among the most cited security measures proposed.

A limited number of studies deals with analysis aimed at investigating the economic effects of piracy. Mejia *et al.* (2009) perform an econometrical analysis identifying the types of vessels most likely being attacked by modern pirates. Whereas (Bendall, 2010; Fu *et al.*, 2010; Van der Meijden, 2008) investigate the impact of maritime piracy on supply chains due to the re-routing of liner service in the attempt to avoid areas with high piracy-risk, their findings highlight that even from a pure economic point of view, more efforts should be dedicated by International authorities to contain the piracy problem.

## 3.1.2. Terrorism

Maritime terrorism is defined as "...the undertaking of terrorist acts and activities within the maritime environment, using or against vessels or fixed platforms at sea or in port, or against any one of their passengers or personnel, against coastal facilities or settlements, including tourist resorts, port areas and port towns or cities" (CSCAP - Council for Security Cooperation in the Asia Pacific). Marlow (2010) expands this definition to include the use of the maritime sector to smuggle terrorist materials or personnel into a country.

Several authors observe that attacks aimed at disturbing the container supply chain have the potential of creating global chaos in that supply chain (Anderson, 2002; Chang, Chen, Lin, & Lin, 2008), but are less likely to inflict a high number of casualties (Van de Voort & O'Brien, 2003). On the basis of this consideration, Van de Voort & O'Brien (2003) propose a clear distinction in threat analysis between terrorists who want to target the maritime sector and terrorist who use the maritime sector to import/export terrorism, stating that threats are fundamentally different and require different solutions.

Even if maritime history reports terrorist activities prior to 2001, it is only after the events of 11 September 2001 that the awareness of terrorist actions has undoubtedly risen (Sheffi, 2001). In fact, the first phase after the 9/11 was characterized by heightened security threat perception (Metaparti, 2010) during which several regulatory measures (Bichou *et al.*, 2007; Hintsa *et al.*, 2009; Yang, 2010; Yang, 2011;) have been quickly introduced with the aim of enhancing maritime security. However, in some cases, the quick adoption prevented a complete examination of threats and responses resulting in security gaps (Marlow, 2010; Metaparti, 2010). Several studies state that security measures required by regulations should be determined only after appropriate risk assessment evaluations and economic considerations: any measures which cost more than resulting benefits should be discarded (Gkonis & Psaraftis, 2010; Marlow, 2010; Prentice, 2008).

## 4. Policy, Practices and Technologies

## 4.1. Policy

In the second half of the 20<sup>th</sup> century maritime security regulation has been moved to the top of the policy agenda. The need for increasing security measures in the maritime sector is founded on its high degree of vulnerability and in its crucial role for international trade: any disruption of the maritime supply chain could have drastic effects for the global economy. Since September 2001 governments, international organizations, customs and private firms have undertaken multiple types of responses and actions to enhance supply chain security (World Bank, 2009). Several studies provide a summary of existing initiatives, divided into voluntary programs and mandatory regulations (Hintsa *et al.*, 2009) or distinguishing among international security measures (e.g. International Ship and Port facility Security - ISPS code, International Maritime Organization – IMO code, International Labour Organization – ILO code, World Customs Organization framework, etc.), National initiatives (e.g. Container Security Initiative - CSI, 24-hour Rule, Customs-Trade Partnership against Terrorism C-TPAT, etc.) and Industry programs (e.g. ISO initiatives) (see, among others, Bichou *et al.*, 2007; Marlow, 2010; Metaparti, 2010; Yang 2010, 2011). A detailed review of security initiatives is provided by UNCTAD (2004) and OECD (2004).

The urgency of reinforcing security regulations has lead to a confused regulatory framework characterized by many initiatives not always coordinated and not derived from a process of negotiation and coordination among the multiple players involved (Helmick, 2008; Papa, 2013). This great variety of initiatives has been justified by the need to establish a multi-layer regulatory system in the attempt to fill potential security gaps (Flynn & Flynn, 2004; Willis & Ortiz, 2004), however, a closer analysis of the concrete security measures show that there are several areas in which they overlap or at least are interconnected (Bichou, 2008; Helmick, 2008; Hintsa *et al.*, 2009; Metaparti, 2010; Papa, 2013).

(Hintsa *et al.* 2009; Metaparti, 2010) in their studies state that a gap exists between theoretical supply chain security studies, emerging security standards and practical actions. Several solutions are proposed to overcome this gap. The academic community may overcome this gap via pragmatic case studies within real

world supply chains (Hintsa *et al.*, 2009). Whereas according to Metaparti (2010) this gap may be overcome reducing excessive bureaucratization, increasing International cooperation and making security integral to other activities of business.

Currently, the features of the maritime security policies vary from country to country. For example, (Papa, 2013) analyses the United States and the European Union approaches on maritime security observing that while US have adopted a series of initiatives aimed at ensuring internal security, Europe Union is more oriented towards a strategy aiming at balancing security needs with the minimization of their negative impacts. An analysis of European policies in maritime security is given also in Pallis & Vaggelas (2007).

The fragmented initiatives taken until now are not suitable with the internationalized nature of maritime sector and encourage the creation of an overregulated and bureaucratic scheme. The possibility in the future of identifying a competent international organization which could act as regulatory authority for maritime security at international level may allow to overcome the limits of the current fragmented regulatory framework (Allen, 2008; Papa, 2013).

# 4.2. Best practices and existing models

Although many studies have focused on supply chain security (Banomyong, 2005; Yang, 2011), relatively few have empirically investigated the effect of supply chain security initiatives on supply chain performance and the relationship between security management and operating performance (Bennett & Chin, 2008; Yang & Wey, 2013; Voss *et al.*, 2009). Among the most recent, Yang & Wey (2013) have focused on the effect of security management on security performance in the container shipping sector in Taiwan, empirically identifying crucial security management factors and examining their effect on security performance.

In fact, although several security initiatives had been introduced during the past years, currently there is little empirical evidence about their impacts for the companies that have implemented them. Among the few works available in this regard we can cite (Gutierrez et al., 2007; Gutierrez et al., 2006; Martens et al., 2011; Talley & Lun, 2012; Yang, 2010, 2011). Gutierrez et al. (2007; 2006) analyse the impact generated by BASC (Business Alliance for Security Commerce), a private voluntary security programme created in Latin America, for the companies that have implemented it. Authors, through a questionnaire survey answered by BASC member companies, identify which supply chain security standards have been implemented by BASC companies, detect the most and the least efficient security measures implemented and provide a qualitative analysis of the cost and effectiveness of security measures implemented. Talley & Lun (2012) investigate the effect of security inspections on the quality of the port's interchange services and, through an empirical analysis based on a e-questionnaire, find that an increase in security measures can also result in improvements in the quality of container port interchange service. Yang (2010, 2011) investigates through an empirical evaluation, based on data collected by questionnaire survey and a risk management matrix, the impact of risk factors from the Container Security Initiatives on Taiwan's shipping industry and provide several risk management alternatives for shipping industry. Whereas Martens et al. (2011) use multiple regression analysis to investigate the antecedents to supply chain effectiveness.

Another area of empirical studies in maritime security is represented by works that propose management framework with the aim of ensuring at the same time operating efficiency and compliance with regulations (Bichou *et al.*, 2007a-b; Bichou & Evans, 2007; Bichou, 2004; Thai, 2009). Bichou *et al.*, (2007a-b) propose a conceptual framework for managing quality in the context of maritime security regulations and state that current regulatory requirements can be implemented in line with the principles of quality management, satisfying at the same time legal requirements and operational aims. Specifically, they discuss the application with a shipping company of a 10-step conceptual quality management framework to implement the 24-hour Advance Vessel Manifest Rule. Bichou (2004) proposes a conceptual framework to port security integrating and optimizing three initial models relating, respectively, to channel design and process mapping, risk assessment and management, and cost control and performance monitoring. Thai (2009) investigates how to enhance security while not putting at risk organizational efficiency and effectiveness and proposes a conceptual model of effective maritime security, including 13 dimensions and 24 associated critical success

factors. The author suggests that managers can use the model to develop a checklist of essential components for their company's security management policies.

These empirical studies may represent a roadmap for the future of maritime sector to formulate quality standards so that the requirements of both regulators and customers can be equally satisfied.

# 4.3. Technologies

Considering the costs and complexity associated with increasing maritime security, it is to be expected that efforts have been made to reduce such costs by means of new technologies. SCS technologies can be subdivided on the basis of the purposes that such technologies have and can be grouped in monitoring, prevention and forecasting.

Monitoring technologies are those aiming at increasing the visibility of the chain or at the facilities and at reducing thereby the risk of malicious interference with the cargo or at certain facilities. Typical examples of monitoring technologies are cameras and RFID tags. A large amount of literature has emerged on the effectiveness of RFID tagging (Sarac, Absi, & Dauzère-Pérès, 2010) or have focused on the benefits of such technology (e.g. Chin & Wu, 2004; Huang, Lee, & Gong, 2012; Rizzo, Barboni, Faggion, Azzalin, & Sironi, 2011; Roberti, 2005)

Prevention technologies can be used to prevent interference with the chain and ensure full visibility of the various parties involved. RFID has also such function, but in this are we can include fencing and data management technologies. Container scanning by means of x-rays, gamma ray, and pulsed neutron scanners is now available (Frankel, 2005).

Seals have also become a valuable aid in preventing interference with the container. But, as noted by Frankel (2005), "*The principal container security issue is: what has been loaded into the container? not what does someone say was loaded in the container, and not whether the seal on the container is intact.*" Frankel recommends the use of technologies that allow, without opening the container, to inspect its contents, as the nature itself of the container, that is not used on closed or dedicated services does not allow any other form of reliable security technology to be particularly effective.

Apart from the evident benefits of better insight on what the contents of containers are, a combination of various systems might in the end be the most appropriate solution, and indeed, container security technologies are moving towards a combination of various systems employed simultaneously. The literature seems to advise for intelligent container seals, or pre-scanning, that allow identifying suspicious containers, that can be then scanned, non intrusively with x-rays or gamma-rays, or opened if necessary (Bakshi, Flynn, & Gans, 2011; Frankel, 2005).

One of the main issues related to inspections is the inefficiency deriving from the necessary limited capacity of scanners and inspectors (Bichou, 2004; Kumar & Vellenga, 2004; Yeo, Pak, & Yang, 2013). Acceptance of security measures is also important but only a handful of research contributions addressed such issue (Chao & Lin 2009).

Among the forecasting technologies this review considers the various methods that are used to assess the impacts of supply chain disruptions. This area of research overlaps with the models developed to maximise supply chain performance by means of simulation or other OR techniques. Without broadening the scope of the review too much it is worth mention the book by Bichou, Bell & Evans (2007) where various contributions investigate by means of forecasting and simulation the impacts of various approaches to assess resilience of networks.

## 5. Organisation and Processes

Several studies have focused on the organisational and managerial aspects relevant for maritime SCS. The focus of this section is to highlight the mechanisms that allow certain practices to be successful in terms of

increasing maritime SCS. In order to structure such analysis we proceed by discussing the mechanisms that have focused on the individual components of the maritime chain and then on those that have focused on the complete supply chain. As far as the specific maritime supply chain components we will limit the review to the literature on ports, the shipping segment and the interfaces with hinterland transport and logistics systems, such as rail, road and inland waterways. When looking at the complete maritime supply chain we will follow the approach of Williams *et al.* (2008) and consider the intraorganisation, interoganization and combined perspective.

# 5.1. Security of single maritime supply chain components

Yang & Wei (2013) distinguish between separate risk elements in container supply chains, namely: cargo, vessels, ports, people, information and financing. As discussed in the previous section, existing security initiatives, such as ISPS and the C-TPAT have different focus areas and aim at addressing security concerns arising from various risk elements. Some of these interventions focus on the cargo, while other on the port or the vessel. Most of the literature surveyed focused on chain mechanisms but does not discuss in detail how the initiatives will impact the individual risk elements. Frankel (2005) reviews the developments of maritime supply chain security highlighting the importance of technology and the impacts of various initiatives on tightening maritime supply chain security.

Several contributions have addressed maritime security mechanisms that impact trade, although the focus has been mostly on US led initiatives, such as the container security initiative (CSI) discussed above. Other studies (Bichou & Evans, 2007) have focused on shipping and in particular vessel network resilience for supply chain security risks reduction. These studies though appear more applications of simulation or network analysis, where the security issues are only instrumental to show the value of the network simulation models.

As far as ports are concerned Yang (2010) illustrates how the ISPS code impacts the Keelung Port in Taiwan. Lirn & Whang (2010) focus on the Kaoshung port also in Taiwan. Bakshi *et al.* (2011) analyse the impact of alternative scanning procedures in terms of congestion in two large container ports, highlighting that, while full 100% scanning will not be feasible, a combination of pre-scanning with more detailed inspections would reduce the costs and inefficiencies deriving from congestion. Bichou (2011) analyses a panel of 470 container terminals and observes that security impacts on operational efficiency, although the relevance of such effects depends substantially on the type of regulation and terminal. There is evidence though that targeted inspections focusing only on those containers that appear suspicious as a result of cargo pre-screening would greatly benefit the efficiency and effectiveness of security operations in port. A large part of the literature (Lewis, Erera, & White, 2003; Y. Yang, 2010; Yeo, Pak, & Yang, 2013) has focused on optimization of port and terminal links under security threats or with the objective of assessing the resilience of the system.

Very few papers have focused on the links between port and maritime security and the hinterland transportation networks (Schilk, Blumel, Recagno, & Boevé, 2007). Schilk *et al.* (2007) highlight how security at a chain level for European transport requires further work both in terms of the policy and organisational concepts. They argue that while for the maritime segment, including ports, policy and practices are well underway, for hinterland transportation little directions exist with reference to hinterland transportation (road, rail and inland waterways) and recommend the development of innovative security strategies and concepts combining maritime with hinterland transport to crate seamless security processes.

Some studies have also assessed data information requirements for security such as Chao & Lin (2009), highlighting how security perception affects the adoption of new technologies. This area, though, still require further analysis.

## 5.2. Security mechanisms at a supply chain level

As mentioned in the introduction, extensive literature has emerged in the area of SCS (Williams, Lueg, & LeMay, 2008), but not in particular on maritime supply chains (Yang & Wei, 2013; Frankel, 2005). Following Williams *et al.* (2008) in the case of maritime supply chains we can use three perspectives; the intraoriganisational perspective, focuses on the mechanisms that can be used by SCS within an organisation,

with respect to those organisational functions such as marketing, purchasing and distribution. A supply chain security orientation is considered important for successful security practices (Autry & Bobbitt, 2008), and this includes information exchanges with external partners (Russell & Saldanha, 2003).

These approaches tend to focus on prevention and response measures that can be adopted within an organisation. Considering that the maritime supply chain typically require the involvement of several parties, an intraorganisational perspective to maritime supply chain security appears insufficient. Sheffi (2001) suggest that leveraging relationships with suppliers and governmental agencies is necessary to improve SCS and supply chain continuity. Several authors suggest that these partnerships should include governmental agencies as well as private firms (Prokop, 2012; Russell & Saldanha, 2003; Sheffi, 2001).

As supply chains have become more integrated they have shifted from exclusively intraorganizational coordination to coordination with other external organizations involved in the flow of product, information, and finances from raw material to end consumer. It would be valuable to investigate whether security initiatives are better handled by integrated ocean carriers, non-vessel operating common carriers (NVOCC), or freight forwarders. An increasing role of SCS could at least in theory favour integrated carriers.

In a recent review (Gould, Macharis, & Haasis, 2010), four main mechanisms are identified for dealing strategically and operationally with SCS issues, specifically terrorisms, and impacts and costs of compliance. Firstly, communications among suppliers appear to be critical (Autry & Bobbitt, 2008), which is also beneficial in improving information sharing among supply chain partners (Peleg-Gillai, Bhat, & Sept, 2006). A second strategy involves the development of a framework for security based on adherence to regulation (Gould, Macharis, & Haasis, 2010), and includes QM approaches (Bichou, Lai, Lun, & Cheng, 2007a; Bichou, Lai, Lun, & Cheng, 2007b; Lee & Whang, 2005).

A third strategy entails a reorganization of logistics operations and warehousing to reduce dependence on overseas sourcing, but also securing alternative suppliers and increasing inventories (Sheffi, 2001). Ensuring that alternative transport modes are available is one of the suggestions made by Russell and Saldanha (2003). A fourth strategy refers to the development of mitigation measures to build up flexibility and resilience. Flexibility is often traded off for efficiency gains, e.g. by reducing inventories, but it can be maintained if alternative avenues are available to perform business and processes, transportation and access distribution facilities (Autry & Bobbitt, 2008; Russell & Saldanha, 2003). Resilience on the other hand is the ability of a system to recover after a disruption or a security incident, or in other words as the ability of the supply chain to return to normal standards of operations following a failure in one or more of its components (Willis & Ortiz, 2004).

# 6. Outcomes

# 6.1. Costs and benefits

Is fairly well known that implementing security measures may lead to extra costs and delays and result in potential liabilities (Chang, Chen, Lin, & Lin, 2008; Kumar & Vellenga, 2004). Several attempts have been made to calculate the cost impacts and financial implications of the introduction of new security regulations. For example, a summary of ISPS cost estimates as calculated by various regulatory risk assessment tools is reported in Bichou & Evans (2007). HPC (2010) provides an evaluation of the impact of additional terminal operations required for 100% scanning of containers in terms of investments and operation costs necessary to perform the additional terminal operations. Whereas the results of a global study based on a questionnaire-survey conducted by UNCTAD (2007) in the attempt to acquire a better understanding of economic implications of security measures are presented in Benamara & Asariotis (2007).

Quantify the economic impact of maritime security measures is difficult and subjects involved are traditionally reluctant in sharing sensitive information. Brooks & Button (2006) in their work try, through interviews with cargo operators, to investigate the economic impacts of security regulations from a cargo interest perspective. Banomyong (2005) explores some of the financing implications of the security initiative,

distinguishing two possible sources for financing container security initiatives: payment by users and public sources.

# 6.2. Security as a source of competitive advantage

One of the most relevant outcomes of maritime security is that it can contribute to generate competitive advantage. Although so far most firms have seen security as a cost element, mostly as a result of the focus on direct expenses following security initiatives (Peleg-Gillai, Bhat, & Sept, 2006), there is increasing evidence that collateral benefits can be obtained through maritime SCS. Among these, Peleg-Gillai *et al.* (2006) indicate:

- Higher supply chain visibility;
- Improved supply chain efficiency;
- Better customer satisfaction;
- Improved inventory management;
- Reduced cycle time and shipping time; and
- Cost reduction following the above-mentioned collateral benefits.

If looked in this sense, then supply chain investment contributes then positively to the competitive position of the firm and is not only a cost.

In the specific case of maritime transport, voluntary logistics security programs, such as C-TPAT, by improving collaboration among logistics service providers, shippers and carriers can bring substantial improvements to the chain. Maritime supply chain security can be then interpreted as a parameter of quality of service, and take advantage of the concepts developed in the "total supply chain" approach (Sheu *et al.*, 2006). This change in perspective is particularly important as a supply chain that is based on strong relationships will be the supply chain that is more likely to be effective, efficient, and relevant (Bowersox *et al.*, 1999)

# 7. Conclusions and Directions for Further Research

This paper presented an updated literature review centred on the maritime and container supply chain security, mostly on articles appeared since 2007. The review is structured in four parts:

- Contributions related to vulnerability and potential for disruptions;
- Contributions on policy, practices and technologies;
- Contributions on organisation and processes; and
- Contributions on the outcomes of maritime supply chain security initiatives.

From this review the following observations can be made. Maritime supply chain security is an important research area, and considering the strategic role of maritime transport and container shipping on international trade, as well as the transnational nature of container shipping, would deserve more attentions from practitioners and researchers. There seem to be sufficient analysis on the antecedents of maritime supply chain security (e.g. terrorisms and piracy) although most of these contributions are theoretical and qualitative. Less attention has been dedicated to pilferage and smuggling activities among the main reasons for improving container security.

Several contributions have focused on policy, technologies and best practices. Also in this case most of the analysis is of a theoretical and qualitative nature. Systematic reviews of security practices and cross sectional studies are by the nature of the subject difficult, but surveys can provide a wealth of information (e.g. Bichou *et al.*, 2007). Furthermore as far as the initiatives are concerned, most literature made use of simulation and analytic methods that focus on liner shipping network reliability and container terminals, few on ports a whole, and only a handful on the interfaces between ports and other modes of transport (Schilk, Blumel, Recagno, & Boevé, 2007), or overall on the total maritime supply chain (Barnes & Oloruntoba, 2005).

As far as processes and organisation studies, there is substantive literature on ports and to some extent on maritime networks. Few studies have addressed organisational issues in maritime and terminal operators from an organisational point of view. Also in this case further empirical analyses would be useful. This is

interesting as a large number of contribution I the broader area of supply chain security makes use of surveys and has been able to provide useful recommendation in the industry on the evaluation of existing inter- and intraorganisational practices. A useful avenue for expanding research would be to investigate the applicability of some of the main findings in the SCS literature to shipping, ports and in general maritime supply chains.

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# **Common-pool Marine Resources Management on Fisheries**

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# 1. Introduction

Marine resource is a typical common-pool resource<sup>i</sup> that likely will fall prey to the "*tragedy of the commons*". Aristotle made such observations about two thousands years earlier by saying that "*which is common to the greatest number has the least care bestowed upon it*" (Aristotle, edited by Everson, 1996). To avoid the tragedy of collapsing the marine environment, we need to keep consumption to a sustainable level - whether through property rights, community norms, or government regulation on preventing the grave danger of depletion that beyond hope for commercial use in the near future.<sup>ii</sup> This paper is organized as follow:

# 2. Literature and Cases Review

The inefficiencies of managing common-pool resources, such as fisheries in the high seas are of continuing concern to both maritime economists and lawyers.

During the 1950s, the unique nature of common-pool resources concerning fisheries in the high seas started to attract the attentions of some political economists, such as Scott Gordon (Gordon, 1954) and Anthony Scott (Scott, 1955) began to investigate the economic behaviors in high seas fisheries.

Another event that happened in 1950s shaped the analysis of fishery management from the perspectives of both law and economics. The specific event was the collapse of the California sardine fishery in 1950s. In the 1930s, the California sardine fishery could yield over 500,000 tons of fish per year. By the early 1950s, however, the annual catch had dropped to under 20,000 tons (a drop of 96 percent in twenty years). As one researcher summarized that *"the pressures on the fishery were too great, and by 1952 for all practical purposes, the commercial sardine fishery was finished."* (Libecap, 1989) The event attracted the attentions of legal scholars because there was a legal case which decided in 1941, which seemed to serve as an important contributing factor to the collapse of the California sardine stocks.

In the 1930s, fisherman Frank Manaka chartered a boat to fish for sardine off the coast of Monterey in California; however, he found that he could not market his catch. All local canneries refused to purchase fish from him. He filed suit against two entities: (a) the Monterey Sardine Industries, Inc., a cooperative association of fishing boat owners, and (b) the Del Mar Canning Company. He claimed that the two entities acted to set prices and restrict entry into the California sardine fishery – in other words, they engaged in a conspiracy to restrain him from fishing and marketing his products.<sup>iii</sup>

In court, the fishing boat owners association admitted that it did set the price about its members' fish that sold to canneries. The canneries, in turn, agreed to purchase fish exclusively from its members (Fee, 1941). Since Mr. Manaka was not a member, so he could not sell his fish to the canneries. In court, the association opined that on the surface, the price setting seemed like the typical collusive cartel, but its very purpose is not for eliminating competition, but for conservation purpose: it restricted entry by non-local fishermen, so that it helped to conserve fish stocks by limiting the harvest. However, the court found that the association was guilty of conspiracy in restraint of trade under the Sherman Act (Fee, 1941), and the judge reasoned that two involved entities were "not freed from the restrictive provisions of the antitrust act" merely because they sought "the conservation of important food fish" (Fee, 1941). The subsequent overfishing of California sardines and eventually collapse of the sardine stocks were correlated with the Manaka decision, which makes the case a popular cite in literatures discussing the concept of "tragedy of the commons" (Seth Korman, 2011).

Economists have pointed out that the mere condition of open-access to a common resource does not

necessarily produce the tragedy Aristotle describes. The tragedy only occurs when there is sufficient exploitation that threatens the sustainability of the resource. For example, when local populations are relatively small, aggregate catch levels are not large enough to cause fishery depletion, the tragedy would not present as a problem irrespective of its open-access nature. The "race to fish" only arises after there is sufficient demand for fish that makes it economically scarce (Scott, 1955). For centuries, the oceans were widely viewed as providing an inexhaustible supply of fish. However, starting from the 1950s, intensive industrial fishing began employing new surveying and harvesting technologies, which rapidly have increased the scale and geographic range of fishing. With this dramatic technological development, the international community began to consider whether conservation standards be carried out by national jurisdictions. It is because large scale fishing began to take place on the high seas beyond areas of national jurisdiction. Two responses took place in reaction to these changes, one in the international level, and one in the academic level:

- (a) In 1958, the United Nations issued the Convention on Fishing and Conservation of the Living Resources of the High Seas ("<u>1958 Convention</u>")<sup>iv</sup>, which represented the first attempt of establishing global regulatory standards on conservation obligations aiming at high seas fisheries.
- (b) In the academic circle, Garrett Hardin published his influential essay *The Tragedy of the Commons* (Hardin, 1968) in 1968, which popularized the concept of managing common-pool resource that fishery economists, such as Scott Gordon and Anthony Scott articulated over a decade earlier. Hardin described the fate of a common pasture that was owned by no one but available to all. Hardin observed that since there is no owner to own or protect the common pasture, each herdsman will maximize his use of the commons at the expense of the community at large, and the cost to the pasture, in the form of overgrazing, is dispersed among all of the users. Since the cost of adding the additional animal to the herd of individual herdsman will be distributed equally among all pasture users, so that the individual herdsman has little incentive to exercise restraint. When all the herdsmen act in this fashion, the commons becomes overgrazed and tragedy results. Hardin summed up the implications of such collective behaviors, "*[E]ach man is locked into a system that compels him to increase his herd without limit--in a world that is limited*" (Hardin, 1968) To prevent the overexploitation, Hardin suggested that there must be a system to prevent overuse, otherwise, "*freedom in a commons brings ruin to all*" (Hardin, 1968).

# 3. To Prevent Overuse by Assigning Property to the Common-Pool Resource

This section devotes to discuss the likelihood of preventing overuse by assigning property right to the common-pool resource. The discussion can be divided into two parts: (a) assigning right by the local government, and (b) assigning property right by fishermen unions. The overuse of marine fishery is indicated in Figure 1, which shows that in terms of annual million tones captured, regardless of the modern advance in capturing technologies, the captured stocks did not show any increase from 2005 to 2010.



Figure 1: World Capture Fisheries Production, Rome, 2012

Source: FAO Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, http://www.fao.org/docrep/016/i2727e/i2727e.pdf

#### 3.1 Assigning Property Right by Local Government

Economists build up models of fishery exploitation in high seas, and one shared assumption is that the fish

stocks in the waters are subject to no property owners. Then, the models predict that fishery exploitation under such open access condition will continue until the average cost of fish catching equals the market price in the same unit. Once reaching this point, the economic rent of the fishery is dissipated. Figure 2 shows the standard textbook model of fishery economics, which was originated by Gordon (1954).



Figure 2 Gordon model of fishery economics

The model illustrates that the factor of annual fishing effort (E) will determine the positions of both the annual revenue (R) from fishery and the annual cost (C) associated with it. The factor E can be defined operationally, for example, as the number of standard-vessel days of fishing per year. From figure 2, it shows that the cost C is proportional to the fishing effort, but why does the revenue decline at a high effort level? Gordon believes that the behavior of the revenue curve is also affected by biology - if fishing effort is kept at a high level, then the fish stock becomes depleted. This explains why the annual catch declines when fishing effort exceed the point *EMSY* in figure 2. Therefore, the point of overfishing can easily be determined in this simple model, once the fishing effort is greater than the MSY level, then it reaches the point of biological overfishing of the stock. Gordon predicts that in the absence of property rights to the fish stocks, unregulated fishery stop at *EO* rather than *EMSY*, and at *EO* level, all potential economic "<u>rents</u>" from the fishery are dissipated. In practice, when a fish stock that is severely depleted for certain duration, it may collapse entirely. Then, the question is: how to reduce the fishing effort?

One may investigate the solution by taking one step backward and ask: If the absence of property rights to the fish stocks is the source of the problem, then will the assignment of property right to the stocks solve the common-pool resource management problem? What is the government position in assigning property right to fish stocks?

Common law jurisdictions tend to reject sole fishing right, seeing it as a direction to monopoly control of the fishery.<sup>v</sup> For example, in the twentieth century, aboriginal use rights to Alaskan salmon were outlawed by the 1924 White Act which provided that "*no exclusive or several right of fishery shall be granted therein...*" (Rogers, 1979). White Act provisions were later incorporated in the Alaskan constitution, which made the non-resident control of the salmon fishery be challenged by the native aboriginals. The following important court decisions invalidated any attempts by the local legislatures to form government ownership of fisheries for their common use by local citizens, which set the subsequent direction of case laws:

- <u>McCready v. Virginia</u> 94 U.S. 391 (1887),
- <u>Stephenson v. Wood</u> 34 S.W. 2nd 246 (1931)
- Toomer v. Witsell 334 U.S. 385 (1948)
- <u>Dodgen v. Depuglio</u> 209 S.W. 2nd 588 (1948).

Case laws after 1950s basically followed the same direction. For example, the Texas Supreme Court in 1950 rejected state legislation to limit entry in Texas coastal waters: "If allowed to stand, the statute and action already taken under it are reasonably calculated to perpetuate in effect a monopoly of commercial fishery for the favored class" (Dobard v. State, 233, S.W. 2nd 440). In other words, the courts have not allowed state

governments to set up regulatory scheme that will discriminate against out-of-state fishermen. Limited entry arrangements for inshore and state territorial waters must include all U.S. citizens. What are the economic implications of these court decisions? They effectively reduce the incentive of state legislatures to regulate fisheries, since any resulting gains must be shared with outsiders and cannot be restricted to voting residents.

# 3.2 Assigning Property Right by Fishermen Unions

From time to time, fishermen unions along the U.S. coasts negotiated price agreements and entered into informal agreements with fish wholesalers and canneries so as to limit outsiders' entry to the local fishery resource.

The <u>Gulf Coast Shrimpers and Oystermens Association v. U.S.</u>  $(1956)^{vi}$  case is of particular interest because of unique price setting strategy in relation to a marine common-pool resource - shrimping. The union attempted to regulate shrimping and to set prices along the Mississippi coast, and its members included practically all commercial shrimp and oyster fishermen operating from the five major ports in Mississippi, which included about 1,800 fishermen with 600 boats. The union set a floor price, and their members could only be permitted to sell "at or above" the floor price, and only to packers who agreed to the union rules.

The union argued that the shrimps were sold in a national market, and according to the 1951 statistics collected by the U.S. Department of Commerce, the Mississippi shrimps only accounted for 3.8 percent of total Gulf catch, therefore, the floor price could not create any substantial effect on limiting competition. The union further argued that the floor price was established with the primary objective of protecting the baby shrimps, so that they could have a chance to grow up into larger shrimps.<sup>vii</sup> The floor price was set according on shrimp size, and the price only applied to smaller shrimp. Court testimony showed that whenever the market price for small shrimp fell below the union's floor price, shrimpers just stopped fishing.<sup>viii</sup> The higher price for smaller shrimp would act as a conservation measure by reducing catches of smaller, immature shrimp, so that they could grow into larger shrimps later in the season. Economically speaking, with the price floor, it reduced the quantity of reducing supply of small shrimps in the market and together with Mississippi's small share of the national market, the union's action in effect established a quasi quota for small shrimp on the Mississippi coast.

In addition, the union pointed out that the floor price based on shrimp size was in line with the Mississippi government regulation which specified in 1934 that a legal minimum size for Mississippi shrimp be larger than the 4 inches.<sup>ix</sup> The union floor price was thus an attempt to enforce the government legislation.

The price per pound for larger shrimp was at least double that for smaller shrimp, and union minimum prices for larger shrimp were generally at or below the market price in adjoining states.<sup>x</sup> To make sure the implementation of the legislation, the union required that all fishing captains for small shrimp carry a purchase contract from a buyer at the association price. Fines and suspension from fishing were levied for failure to comply.<sup>xi</sup> The union's efforts were directly aimed at obtaining larger shrimps.

The union enforcement can only be successful if it could exclude the fishermen from Louisiana, where the government defined the shrimps in a larger size. In other words, there existed a strong economic incentive for the Louisiana shrimps fishermen to catch the shrimps in Mississippi and have them sold in Louisiana. As a response, the union pressured material suppliers to deny ice and fuel to nonunion shrimpers outside Mississippi.

However, the union lost the case on legal ground. Both in the trial level and in the appeal level, the judges took the view not in the conservation standpoints, but on the status of the union itself. The judges looked to the facts that Mississippi fishermen were either owned their own boats or worked for shares, and these two facts made them independent entrepreneurs. Therefore, the entire matter should not be considered a legitimate labor dispute. The judge repeated the position of the law embodied in 15 U.S.C.A. Sec. 522 that "A cooperative association of boat owners is not freed from the restrictive provisions of the Sherman Anti-trust Act, section 1-7 of this title, because it professes, in the interest of the conservation of important food fish, to regulate the price and the manner of taking fish unauthorized by legislation and uncontrolled by proper

authority."

One researcher summed the legal implication of "share basis" payment: "*The roots of the legal problem of fishermen's unions lie in the nearly universal practice of compensating fishermen on a share or 'lay' basis*" (Crutchfield, 1955).

# 4. Professor Elinor Ostrom's Views on Managing Common-Pool Resources

In previous discussion, it seems that assigning property rights to common-pool resources will not be a feasible solution because of the legal obstacles it encounters. In this section, the author turns to the findings of economists, primary the contributions by professor Elinor Ostrom.

The purpose of this section is to give a brief introduction about the economic ideas of Professor Elinor Ostrom (August 07, 1933 – June 12, 2012) on managing common-pool resources, which made her the 2009 Nobel Prize winner (the first woman to be awarded Nobel Memorial Prize in Economic Sciences).

Professor Ostrom traveled around the world to observe the different ways of managing the natural resources by local communities. Instead of focusing solely on economic efficiency as most traditionally trained economists of her time, she moves the world's attention to the following question: If a local community has a fishery or pastureland or forest area, of which the local people's livelihood is relying on it, how such a common-pool resource shall be managed sustainably, so that it can renew itself.

The author intends to contribute something positive to maritime research in Hong Kong by giving a brief introduction of Professor Ostrom's ideas, and let more researchers to see their research findings in light of Ostrom's framework. The author conducted a search in the literatures done by the maritime researchers in Hong Kong (as of April 2013), and found very little application of Professor Ostrom's ideas in maritime related researches.

When Ostrom's work *Governing the Commons* (Ostrom,1990) celebrated its 20<sup>th</sup> anniversary in 2010, the author took a stock count about the university researchers in Asian region who cited the *Governing the Commons* during the period from 1996 to 2010, and summarized the findings in the following *Table 1*, which shows that of these few researchers, only one (Professor Yoshiaki Matsuda) was from Department of Marine Social Sciences.

Researchers	# of	Faculty/Department.	University		
	citations.				
Lam, WF	5	Dept of Politics & Public Administration	University of Hong Kong, China		
Matsuda, Y	5	Dept of Marine Social Sciences	Kagoshima University, Japan		
Satria, A	5	Faculty of Human Ecology	Bogor Agricultural University, Indonesia		
Tang, CP	5	Dept of Political Science	National Chung Cheng University, Taiwan		
Webb, EL	5	Dept of Biological Sciences	National University of Singapore, Singapore		

Table 1: University researchers of Asian region citing Governing the Commons (1996–2010)

## 4.1 Non-productive Rent Seeking Activities

Professor Elinor Ostrom uses the level of non-productive rent seeking activities as a measure to evaluate how successful a common-pool resource is being managed. She uses rent seeking activities to judge the two approaches this paper discusses in Part III.

The two popular approaches were (a) public ownership and (b) private ownership with legally specified property rights. Under the public ownership approach, the government should own and manage the common-pool resources. The rationale is that only under a benevolent government with perfect knowledge, it could develop the rational rules to prevent overuse of the common-pool resources, for example, the control and management of fisheries in the European Union is more or less a manifestation of such an economic approach. However, the rationale is losing its ground when the control and management is subject to

lobbying – the rule making body is not benevolent.

Under the private ownership and control approach, the role of government is not to own or to control, but to provide a legal system to adjudicate disputes and specify the property rights of the common-pool resources by issuing guidance judicial decisions. Thus, free economic actors are central to the management and control of the resources. The problem of this approach is that: it could not handle a situation where the resource is not subject to a clear boundary, especially when there exists a large-scale and diverse population of resource users who located in more than one single country. Under such situation, the transaction costs of enforcing decentralised solutions may be prohibitive (Hardin, 1968). One example is the problem of trans-boundary ocean pollution.

Although both approaches were very different from the perspective of the entity which owns and manages the common-pool resources, they were grounded in the same rational-choice tradition economic theory. The rational man theory assumes that all players are rational actors, with the same information, and will make their decisions and actions in responding to costs and benefits calculations.

Researchers observed that both approaches were affected by the "rent seeking" behaviors of the economic actors (Buchanan, Tollison, and Tullock, 1980). The term was first used by Anne Krueger (Krueger, 1974). Rent seeking theory explains the behaviors of deploying interest group power to manipulate government with the intent to obtain special advantages. The rent seekers with similar interests invest real resources in the expectation of - obtaining an increase income or avoiding a decrease in their income wealth by either (a) securing changes in legal rights to their favor, or (b) blocking unfavorable legal reforms.

Researchers observe that the resources used in seeking these advantages are essentially wasted, because they result only in redistributing the existing wealth, but not in creating new wealth. A copious body of theoretical literature has developed that maintains that rent-seeking activity inhibits economic growth by diverting resources from productive uses (Buchanan,1980; Tollison,1982; Olson, 1982; Murphy, Shleifer, and Vishny, 1991). Murphy et al.(1991) examined the effect of the allocation of human talent between entrepreneurship and rent seeking on economic growth, they collected data from 91 countries, using data on college enrollment in engineering as a measure of talent allocated to entrepreneurship. Then, they collected data on law school enrollment as a measure of talent allocated to rent seeking. Their research findings indicate that when talented people become entrepreneurs, it is good for economic growth. Laband and Sophocleus (1988), using time series data (1947–83) on the number of U.S. lawyers as a proxy of rent-seeking activity and cross-sectional data on the number of state law firms per capita, found such activity to have a negative impact on both the growth in GNP and state per capita income.

# 4.2 Professor Ostrom's Intellectual Contributions

Professor Ostrom's research interests in fisheries and forest management took her around the world to countries as diverse as Australia, Bolivia, Indonesia, Japan, Mexico, Nepal, Nigeria, Philippines, Poland, Spain, Sweden, and Switzerland. The different case studies created a large database, and as Ostrom has often emphasized, in order to come up with reliable conclusions, it is necessary to study a large number of diverse cases.

One of Ostroms' contributions is to challenge the conventional economic presumptions about the supposed efficiency of centralized administration, she found that

- 1. The presumption that economies of scale were prevalent was wrong
- 2. The presumption that you needed a single police department was wrong
- 3. The presumption that individual departments wouldn't be smart enough to work out ways of coordinating is wrong
- 4. The conventional wisdom about important ecological matters has also been overturned, especially with regard to the supposed inability of communities to self-organize to create collective rules for punishing free-riders on common-pool resources.

Ostrom's research findings support the view that actors at the local level can perform better than decision-makers in the higher institutional levels. Observed Ostrom: 'For patrolling, if you don't know the neighborhood, you can't spot the early signs of problems, and if you have five or six layers of supervision, the police chief doesn't know what's occurring on the street' (Elinor Ostrom, cited in Zagorski, 2006).

# 4.2.1 Ostrom's research findings on fisheries management

Professor Ostrom conducted researches of fisheries management around the world, and she uncovered some interesting new findings. For example, contrary to most economists' expectations, communities often do not regulate the quantity of fish that people are allowed to harvest, which can be too difficult to monitor (Ostrom, 1999). The most common used proxies are:

- (a) fishing time (for example, banning fishing during spawning periods),
- (b) fishing location (for example, banning fishing at the upper end of a river) and
- (c) fishing technology (for example, not allow the use of 'overly efficient' technologies).

When Professor Ostrom studied the lobster fisheries in Maine, she discovered that the lobster resources were severely depleted in the 1920s, as the local communities failed to implement their rules. Subsequently, the state intervened by threatening some of the fisheries with closure. The intervention was by nature not a top-down comprehensive policy, it was merely taking a supportive role for the 'informal local enforcement efforts'. The intervention was successful and 'by the late 1930s, compliance problems were largely resolved and stocks had rebounded'.

Another interesting example was Pacific salmon fisheries management in Washington State. Prior to the mid-1970s, salmon fisheries were centrally managed, and it faced a typical knowledge problem – measure the measurable. The centrally regulated system had focused on aggregations of salmon species, and it spent little time on the freshwater habitats that are essential to maintain the viability of salmon fisheries over the long term. In the mid-1970s, the U.S. court decided to grant those Indian tribes that had signed treaties more than a century before, 'the right to 50 per cent of the fish that passed through the normal fishing areas of the tribes.' This changed the centralized management because it required the development of a "co-management" system that involves both the state of Washington and the 21 Indian tribes in diverse policy roles related to salmon'. The change created a new system of incentives at the local level. The co-management system gave individual tribes an economic incentive to increase the total stock of the salmons, which, in turn, stimulated them to protect those freshwater habitats that salmon fisheries depend over the long term.

## 5. Conclusion

The focus of this paper is on the common-pool property nature in fisheries and the nature of the regulatory response to them. It outlined why the methods of sole ownership and union efforts to control entry have been rejected as illegal. Without the helps of unions of local fishermen and local suppliers, the central administration of a fishery conservation program would incur a high cost, both in terms of information collection and measurements. Biological knowledge of the fish stocks is uncertain, it is difficult to measure the effectiveness of a fishery conservation program, the recovery may be contributed by the program or forces outside the program, such as the impact of environmental changes.

Why some activities should not be the subject of contracts? Ronald Coase gives an explanation: pointed out: for some matters, contractual arrangements are commonly unsatisfactory, *"it would cost too much to put the matter right*" (Coase, 1960).

In studying the <u>Gulf Coast Shrimpers and Oystermens Association v. U.S.</u> (1956), one may wonder why the union established restrictions on outsiders (setting a floor price to protect the small shrimps) and did not institute any special controls on its members, such as the internal catch restrictions. The answer is simple: applying self restrictions is costly for heterogeneous fishermen – even with the same size of fishing boats and same capacity of equipment, skillful fishermen can catch more, and a standardized quota restriction would hurt them the most.

Professor Ostrom advocates the idea of social cooperation on managing common-pool resources. Although her theoretical development is just an extension of previous theories in the fields of sociology and political science, especially public choice theory, as she reflected one can find her analytical roots in Buchanan and Tullock's *Calculus of Consent* (Ostrom and Ostrom, 2004); she presents a full-blown economic theory in management common-pool resources from a social perspective. In fact, there is one crucial advantage offered by social cooperation on managing common-pool resources over government regulation: they will internalize the costs of regulation.

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<sup>i</sup> This paper uses the terms common pool resource and open access interchangeably, which refers to a situation where no property rights or individual owner exists for the resource.

<sup>ii</sup> The 1998 from The Food and Agriculture Organization (FAO). The State of the World Fisheries, available at http://www.fao.org/docrep/w9900e/w9900e02.htm (Dec. 20, 2000).

<sup>iii</sup> *Manaka v. Monterey Sardine Indus., Inc.*, 41 F. Supp. 531, 532 (N.D. Cal. 1941)

<sup>iv</sup> Law of the Sea: Convention on Fishing and Conservation of the Living Resources of the High Seas, Apr. 29, 1958, 17 U.S.T. 138, 559 U.N.T.S. 285.

<sup>v</sup> In non-common law jurisdiction, such as Japan, inshore fisheries customary rights are recognized and enforced by the government.

<sup>vi</sup> Gulf Coast Shrimpers and Oystermens Association v. U.S., 236 F. 2nd 658 (1956)

vii Transcript of Record, Gulf Coast Shrimpers and Oystermen's Association v. United States, pp. 51-53.

<sup>viii</sup> Testimony of Joe Castigliola, a packer (Transcript of Record from *Gulf Coast Shrimpers and Oystermen's Association v. United States*, pp. 78-99).

<sup>ix</sup> For Mississippi size regulations, see Food Commission, State of Mississippi, Ordinance #3, 1934.

<sup>x</sup> Oliver Clark, a packer, testified that his prices for large shrimp were above the association floor price (Transcript of Record from *Gulf Coast Shrimpers and Oystermen's Association v. United States*, p. 174).

<sup>xi</sup> Gulf Coast Shrimpers and Oystermen's Association By-Laws, p. II (Transcript of Record, from *Gulf Coast Shrimpers and Oystermen's Association v. United States*).

# Application of Forecasting Container Throughputs for Port Planning: Case of Bangkok Port

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## Abstract

Containerization is an important transportation system in the rapidly growing international trade, especially in the country like Thailand that is very active in both import and export. However, forecasts of container growth and trade development of Bangkok Port, the main river port of Thailand, are scant and the findings are divergent. The aim of this paper is to forecast container throughputs of Bangkok Port by an integrated model of time series forecasting for predicting relevant economic factors and cause-and-effect forecasting for predicting future container throughput and to apply the results for planning port operations. In order to determine the benefits or the contributions of forecasting container throughput in Bangkok Port, this paper develops a best-fit forecasting method for Bangkok Port. The forecasting accuracy of the future throughput is crucial to Bangkok Port for planning and managing their container volumes in the future. Finally, the forecast container throughputs are used to assist the port planning which include terminal layout and yard crane planning. The yard layout is reprovisioned according to forecast container throughputs. Both types of Rubber Tyred Gantry (RTG) and Rail Mounted Gantry (RMG) Crane are considered in this paper.

Keywords: Forecasting, Time series forecasting, Cause-and-effect forecasting, Container throughput, Terminal layout, Yard crane

## 1. Introduction

Maritime transportation is an important part of international trade. This transport is composed of the maritime shipping and the ports dimensions. That is the key element for creating an economic growth (UNCTAD, 2011). Container transportation give an effect to international economic, 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, 2011). 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.

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. The aim of this paper is to forecast container throughputs of ports by an integrated model of both techniques: time series forecasting for predicting all the economic factors and cause-and-effect forecasting methods for predicting future container throughput at Bangkok Port and to apply the results for planning port operations. Finally, the

result of forecasting container throughputs will be used to assist and plan the port operations of which include terminal layout, yard equipment and human resources.

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, Section 5 presents application of forecasting for port planning: Case of Bangkok Port and finally, some conclusions are provided in Section 6.

# 2. Literature Review

This section is devoted to forecasting techniques and maritime forecasting.

# 2.1 Forecasting techniques

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. There are two types of quantitative forecasting models: Time Series and Cause-and-Effect (Armstrong, 2001).

# a. 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 (Armstrong, 2001). The example of time series methods are Simple Moving Average, Exponential Smoothing and Holt winters methods.

# b. Simple Moving Average

That is calculated by adding the closing price of the security for a number of time periods and then dividing this total by the number of time periods.

$$MA_{n} = \frac{\sum_{i=1}^{n} D_{i}}{n}$$
(1)

# c. Exponential Smoothing

This is a procedure for continually revising in a forecast in the light of more recent experience.

$$F_{t+1} = a D_t + (1 - a) F_t$$
(2)

Where,

 $F_{t+1} =$  forecast for next period  $D_{t} =$  actual demand for present period  $F_{t} =$  previously determined forecast for present period a = weighting factor, smoothing constant

## *d. Holt Winters Methods*

This method is appropriate when trend and seasonality are present in the time series.

$$E_{i} = \alpha(y_{1}/S_{i-c}) + (1-\alpha)(E_{i-1} + (T_{i-1}))$$
(3)

$$T_{i} = \beta (E_{1} - L_{i-1}) + (1 - \beta)T_{i-1}$$
(4)

$$S_{i} = \gamma (y_{i} / L_{1}) + (1 - \gamma) s_{i-c}$$
(5)

$$yhat_{i+1} = (E_i + T_1)s_{i+1-\alpha}$$

(6)

Where  $\gamma$  is another smoothing constant between 0 and 1, this means that Holt Winters' smoothing is similar to exponential smoothing if  $\beta$  and  $\gamma = 0$ . It will be similar to double exponential smoothing if  $\gamma = 0$ .

#### e. 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).

#### f. 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. 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 general linear regression model, with normal error terms, simply in terms of X variables, is shown in Equation 1.

$$Y_{i} = \beta_{0} + \beta_{1} X_{i1} + \beta_{2} X_{i2} + \dots + \beta_{p-1} X_{i,p-1} + \varepsilon_{i}$$
(7)

Where  $\beta_0, \beta_1, ..., \beta_{p-1}$  are parameters,  $X_{i1}, ..., \beta_{p-1}$  are unknown constants,  $\varepsilon_i$  are independent  $N(0, \sigma^2)$ , i = 1, ..., n

#### g. Multilayer perceptrons (MLPs)

Multilayer perceptrons (MLPs) are feed-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). 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 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.





Source: Skapura (1996)

#### 2.2. Maritime Forecasting

Forecasting of the volumes of imports and exports container is the central to the planning and the operation of

port authority and government offices. The result of forecasting container throughputs will be used to assistand plan the port operations of which include building new container terminals, operation plans, marketing strategies, as well as finance and accounting. The other is the government offices level, forecasts of containers volumes also provide basis for regional and national transportation plans. (Chou et al., 2008).

Many researchers have been interested in the relationship between 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 the exports 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, exchange rate, rate of return on stock public, unemployment rate, oil price, GDP and money supply.



# Figure 2: Determinants of Port Throughput

Source:Meersman (2009)

From figure 2 and 3, International trade is influenced by economic activity, competitive position, trade policy and structure shifts. The economic growth and macroeconomic policy impact to international trade and also maritime trade.

Tuble IT Examples of Tupers in Murthine Torecusting and Economics Tuetors							
Authors	Year	Economics Factors	Methodology	Contributions to research			
Seabooke	2003	Macroeconomics	Regression Analysis	Predict cargo growth of the port			
et al.				of Hong Kong			
Syafi et	2005	GDP, Population, Exports	Unit Root Test	Container throughput in			
al.		and Imports Volume		Indonesia			
Chou et	2008	population, industrial	Modified regression	forecasting container in			
al.		production index, GDP		Keelung Port, Taichung Port			
		and GNP		and Kaohsiung Port			
Lattila	2009	GDP, exchange rate and	Combined both of	combined advanced forecasting			
		inflation	ARIMA and regression	methods with system dynamic			
				of Finish Seaports			
Hui et al.	2010	Estate price, trade	Autoregressive time	Port cargo forecasting of Hong			
		activities and GDP	series	Kong			
Yip	2012	GDP, GDPPC and	traditional gravity	Cereal trade between			
		Population	model and gravity	developing countries			
			model				

Table 1: Examples of Papers in Maritime Forecasting and Economics Factors

# 3. Research Methodology

Forecasting methodologies includes four steps following as,

*Step 1: Defining the problem,* forecasting container throughput in Bangkok Port. Study factors influencing container throughput. The factors are selected from the results of researches as Greenway and Nam (1988), Ram (1985), Chou et al. (2008), Lattila (2009), Hui et al. (2010) and Yip (2012). The others are Thailand's Economic indicators and both of importing and exporting factors, and also from figure 2 and 3 about international trade and container throughput.

*Step 2: Collecting data*, Dependent Factors, from year 2001-2012 (Number of Container Throughput in Bangkok Port) and Independent Factors, from 2001-2012 (GDP, Exchange rate (compared to U.S. dollars), World GDP, Population, Inflation rate, Fuel price and Interest rate. The data are collected in 12 years (144 months or 144 sets). The sources of data are from the Bank of Thailand, Office of the National Economic and Social Development Board, World Bank, Ministry.

Fastara	Period						
ractors	Monthly	Quarterly	Yearly				
GDP		Х					
Exchange rate	Х						
World GDP			Х				
Population			Х				
Inflation rate	Х						
Fuel price	Х						
Interest rate	Х						

**Table 2: The Optimized Period of Economics Factors** 

Step 3: Choosing the fitting model, integrated model of time series forecasting for predicting relevant economic factors and cause-and-effect forecasting for predicting future container throughput. *Time Series:* Time series is an ordered sequence of values of a time intervals. Most of researches are proposed by this technique. Cause-and-Effect: The purpose of this model is to discover the form of the relationship and to

forecast future the variable.

*Step 4: Evaluating a forecasting model,* in this study, we consider two accuracy measurements to the neural networks model and linear regression. They are the root mean squared error (RMSE) and the mean absolute error (MAE) defined as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{n}}$$
(9)

$$MAE = \frac{\sum_{i=1}^{n} |y_i - \hat{y}_i|}{n}$$
(10)

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 < r < +1. The + and – signs are used for positive correlations and negative correlations respectively.

	Factors							
Total of Container	CDP	Exchange	World	Population	Inflation I	Fuel Price	Interest	
	ODF	Rate	GDP		Rate		Pate	
Container Throughput	0.35	-0.43	0.35	0.7	0.24	0.29	-0.02	

 Table 3: Correlation between dependent (Container Throughput) and independent factors

## 4. **Results and Discussion**

**Ex-post forecasting**, find the lowest error of forecasting both of time series model and cause-and-effect techniques. The lowest error of time series forecasting is Holt Winters Methods, while the lowest error of cause-and-effect forecasting is Multilayer Perceptron (MLP).

Table 4: Performance of forecasting the number of contain	er in Bangkok Port
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Time Series methods	Multivaria	te Regressio	n	Multilayer Perceptron		
Time Series methous	MAE	RMSE	Correlation	MAE	RMSE	Correlation
Moving Average	13318.34	17579.11	0.53	8698.1	11150.66	0.88
Exponential Smoothing	13174.19	17382.59	0.56	9602.53	11187.64	0.92
Holt Winter Methods	13217.01	17224	0.56	7357.18	9573.13	0.9

**Table 5: forecasting number of container by monthly in 2013** (*Compare both of forecasting and actual number: Bangkok Port*)

		· · · ·	55	0			0	/	
Year 2013	GDP	Exchange rate	World GDP	Population	Inflation	Fuel price	Interest rate	Forecast BKP	Actual number in BKP
January	4.62	30.17	4.33	65925427	3.04	29.98	6.62	128563	120758
February	5.14	30.08	3.83	65925427	3.06	30.21	7	99978	104737
March	6	31.07	3.78	65925427	2.96	30.21	7.29	124784	128146
April	6.76	30.63	3.77	65925427	3.14	30.19	7.31	126128	115031
May	4.88	30.36	3.77	65925427	4.04	30.17	7.56	130826	
June	7.49	30.16	3.78	65925427	4.33	30.15	7.58	138828	
July	7.22	30.39	3.78	65925427	4.25	30.14	7.7	120800	
August	7.57	30.57	3.78	65925427	4.23	27.15	7.95	130450	
September	8.66	29.92	3.78	65925427	4.41	27.43	7.97	125890	
October	3.45	30.06	3.79	65925427	4.12	27.87	8.08	126350	
November	1.11	31.44	3.79	65925427	4.28	27.93	8.09	136635	
December	-2.22	31.14	3.79	65925427	4.29	27.94	7.96	128450	

**Ex-ante forecasting**, the predictions for port operations are usually made on a long-term basis, but short-term forecasts are also important (Franses and Dijk, 2005). This paper forecasts the number of container throughput monthly in 2013, cover period of one year. Because the forecasting in short-term is forecasting is relatively simple, practical and highly accurate (Peng and Chu, 2009). This paper applied both of Multiple Linear Regression and Multilayer Perceptron technique to predict container throughput volumes in Bangkok Port.

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. Population, GDP and World GDP are important factors affected to volume of container throughput in Bangkok Port.

# 5. Application of Forecasting for Port Planning: Case of Bangkok Port

Many container terminals have become excessively utilized. The expanding of terminal area will improve the overall productivity. The building capacity on the existing operating area might be more suitable. Terminal expansion might be an option to add capacity and improve productivity of terminal. A better design of yard capacity and yard cranes are the ways of terminal expansion (Niswari, 2005). This section explored the current capacity of Bangkok Port and improved productivity of the terminal in Bangkok Port.

# 5.1 Calculate Yard Capacity in Bangkok Port

The yard capacity is measured as the total TEU visits. The factors effected to terminal capacity (Wiegmans, 2003).

- 1. The available terminal ground slots (TGS)
- 2. The average dwell time (the days within which containers are stored in the terminal) Peak factor (a factor of which the highest volume of container moves might be realized by the terminal).
- 3. Stacking height (how high the containers are stacked for each type of container) Stacking density (how heavily is the container yard being utilized).

The formula is:

$$TEU Visits = \frac{TGS X Stacking Density X Stacking Height X 365 (days)}{Dwell Time (days) X Peak Factor}$$
(11)

# 5.2 Number of Container throughput in Bangkok Port by forecasting

Total = 1,517,682 TEU

Number of Import = 801,184 TEU (about 52% of container throughput) Terminal expansion is one option to add capacity and improve productivity of the terminal. (Niswari, 2005)

To main factors are needed to be investigated:

- 1. The current situation of the terminal and yard capacity
- 2. The foreseen capacity requirements
- 3. The possible expansion alternatives
- 4. Equipment and layout for each alternative
- 5. Financial analysis for each alternative
- 6. An analysis of all alternatives
- 5.3 Proposal of Four models

This paper will propose four alternatives. The general description of each model will explain as follow.

**Case 1:** Current Layout but more stacking (1 over 4 stacks), this model is same as current layout, but will extend more stacking as 1 over stacks.

**Case 2:** RTG 4+1, 1 over 4, this model adopt all Rubber tyred gantry crane (RTG 4+1) for container terminal. **Case 3:** RTG 6+1, 1 over 4, this model adopt all Rubber tyred gantry crane (RTG 6+1) for container terminal.

Case 4: RMG 6+1, 1 over 4, 1 over 4, this model adopt all Rail mounted gantry crane (RTG 6+1) for container terminal.

Parameter	Both of RTG 4+1, 6+1	RTG 4+1	RTG 6+1	RMG
Stacking	4 Stack	4 Stack	4 Stack	4 Stack
Block	18,536 TEU	18,160 TEU	21,048 TEU	21,048 TEU
Annual yard capacity	872,985 TEU	855,277 TEU	991,292 TEU	991,292 TEU
Compare to current capacity	+267,192 TEU	+250,084 TEU	+386,099 TEU	+386,099 TEU
Forecasting container throughput (Importing)	801,184 TEU	801,184 TEU	801,184 TEU	801,184 TEU
Equipment cost	39.2 M US \$	53.2 M US \$	57 M US \$	76 M US \$
Economic life of equipment	15 Years	15 Years	15 Years	20 Years
Container yard development cost	20.27 M US \$	27.26 M US \$	17.92 M US \$	18.79 M US \$
Equipment cost + Container yard development	59.47 M US \$	80.46 M US \$	74.92 M US \$	94.79 M US \$

Table 6: The comparison of four model layout

From Table 6, all of four models are four stacks high. This paper is calculated both cost of equipment and cost container yard development. Case 3 and 4 are expanded the most volume of container, while case 2 is expanded the lowest number of container. Case 1 is the lowest cost both equipment cost and container yard development, while Case 4 is the highest cost.

## 6. 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. The forecast number will assist Bangkok Port to manage and develop the main infrastructures and equipment for supporting the country's competitiveness. Moreover, the Bangkok Port 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. Population, GDP and World GDP are important factors that effected to volume of container throughput in Bangkok Port.

The forecasting accuracies from RMSE and MAE are satisfactory, and the values of correlation coefficients are more than 75%. In this research, MLP is the most valuable tool for forecasting. 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. Time series forecasting is adopted to forecast all of Economics factors for this research, the most accuracy method is Holt Winters Methods, while cause-and-effect forecasting methods for predicting future container throughput in Bangkok Port. Multilayer Perceptron (MLP) is the most valuable tool for forecasting.

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. The detail of four alternatives are explained as Case 1 is the lowest cost both equipment cost and container yard development, while extended capacity to more 267,192 TEU, Case 2 is the worst case. High cost and lowest extended capacity, while Case 3 is the average case and Case 4 is the highest cost, but extended capacity the most of 386,099 TEU and life time of equipment is 20 years.

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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# Substitution and Complementarity Effect of Railway Improvement on China's Airport Passenger Traffic

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## Abstract

The recent development of railway brings great challenges for air passenger traffic in China. This paper aims to analyze the impact of railway improvement on the airport passenger traffic. Panel data models are applied to estimation using the data of passenger traffic of main airports and rail stations during 1998 to 2009 in China. The empirical results show that the speed acceleration of railway has a substitution effect on the growth of air passenger traffic. However, improvement of rail does not reduce the airport passenger traffic as a whole, which is inconsistent with expectation. The increase of passengers at rail stations has a positive effect to the concentration at hub airports but a negative effect to regional airports. These findings fill in the research gap left over by previous empirical studies of air-rail competition which has focused on mode-based competition and show some policy implications for air transport network.

Keywords: Airport passenger traffic, Railway improvement, Substitution and complementarity effect, Panel data

## 1. Introduction

In China, rail transport is becoming a viable alternation for air passengers. The recent development of railway brings great challenges for air transport, especially after the construction of High-Speed Railway (HSR). Rail is also an environmentally acceptable alternative to air transport, and efforts are made to encourage passengers to move from air to rail. Meanwhile, rail is also a necessary complement for air transport. Different modes of transport can be seen as simultaneous complements and substitutes. The objective of this study is to examine the impact of railway improvement on airport passenger traffic in China.

Since the civil aviation reforms started in 1987, China has experienced considerable average annual growth rate of air passenger volume and great expansion of air transport network. Despite the rising role of air transport in China, the air transport network is characterized by regional inequality and still at the initial stage of a hub-and-spoke system (Wang et al., 2010). First, the spatial distribution of passenger traffic is concentrated in China's eastern large cities. Moreover, the air transport network continues to feature connections between city pairs with undeveloped sub-networks and insufficient feeder lines. In addition, the air passenger traffic is highly correlated with geo-economic and competitiveness factors from the other transport alternatives (Jin et al., 2004; Liu et al. 2013). Figure 1 shows a historical trend of passenger throughput at airports in Northern China compared with that at rail stations. China is now undergoing a HSR building boom. The largest, advanced HSR system in the world will appear in China by 2020, with a total length of 16,000 miles. HSR service will be competitive in city-pairs of short to medium distance due to the network connectivity, total travel time and cost efficiency (Fu et.al., 2012). It can be expected that the rapid development of railway will bring strong impact on the traffic pattern of air passenger transport.



Figure 1: Historical Trend of Passenger Throughput in Northern China: Rail Station vs. Airport

Most of the studies on determinants of air travel demand were conducted using the city-pair data of certain routes (Fridström and Thune-Larsen, 1989; Rengaraju and Arasan, 1992; Jorge-Calderon, 1997; Yao and Morikawa, 2005). In general, the literature categorized the driving factors into two groups: service-related factors and geo-economic factors (Jorge-Calderon, 1997). The service-related factors refer to the quality and price characters of airline products, while the geo-economic factors are elements outside the control of airlines. The latter describes the economic activities and locational characteristics of the areas around the airports involved. The common economic-activity variables in the literature include population, gross domestic product (GDP) and income. As for locational factors, the most common factors concerned are distance, intra-modal and inter-modal competition. More recently, some studies have gone into greater detail on inter-modal competition factors. A series of studies were conducted to estimate the impact of HSR on domestic air travel demand in different regions, using different forms of discrete choice models (Mandel et al., 1994; González-Savignat, 2004; Park and Ha, 2006). But most of the transport literature from a mode choice view only looks at mode alternatives in competition with each other, while neglecting the complementarity effect in terms of intermodal cooperation between them.

Concerning the substitutive and complementary relationships between air transport and rail transport, we focus on the examining the impact of railway improvement on the airport passenger traffic. Different from the city-pair transport demand analysis, this study focuses on airport and rail station passenger traffic based on the aggregate model. With an aggregate demand model at the airport and rail station level, it would be easier to illustrate the overall impact of railway improvement on the pattern of airport passenger traffic.

This paper is organized as follows: Section 2 interprets complementarity and substitution effects of railway to air transport and also plays a role of literature review. In Section 3, the econometric models are specified based on the development of hypotheses. Section 4 presents the data description and estimation results. Section 5 concludes the paper, and we briefly discuss some policy implications.

# 2. Complementarity and Substitution Effects of Railway on Air Transport

There is compatibility for passengers to choose between air and rail transport or both. This compatibility was regarded as simultaneous complementarity and substitution (European Commission, 1998). From the perspective of the travelers, the ability to choose one mode in preference of the other mode of transport is referred as substitution. Two modes of transport are regarded as complementary when their successive utilization is either necessary or simply preferred to the utilization of a single transport mode for a journey between two cities. In this sense, rail is a necessary complement to and occasionally a substitute for air transport to travelers. Moreover, the relationship between air and rail passenger transport is in dynamic due to the modification of transportation products and changes of related environment factors. Shocker et al. (2004) discussed that the complementarity and substitution relationships between products in different but related categories and pointed out that such relationships are in transition over time. It meant that complements might become substitutes for the original products or originally imperfect substitutes become to coexist as
#### complements.

On one aspect, rail transport competes with air transport within certain distance ranges (generally accepted travel distance is from 350 km to 1, 000 km). It is also considered as a substitute of feeder air services to main hub airports, especially after the development of HSR. From the historical experience, a transport modal shift is expected to happen due to rapid development of HSR. González-Savignat (2004) investigated the effect of a HSR corridor between Barcelona and Madrid in Spain and concluded that HSR would obtain an important diversion of air travelers. Park and Ha (2006) forecasted the market share of airline and HSR after the introduction of the Korea Train Express (KTX) on the Seoul-Deagu route in 2004. Both the estimated result and actual revealed demand showed a significant decline of aviation demand, over 70 percent in that year. Behrens and Pels (2012) studied the inter- and intra-modal competition in London–Paris passenger market. HSR is a competitor for both conventional and low-cost airlines.

On the other aspect, railway interconnections supplies airports with concentrated passenger flows and complement the air travel service with the expansion of platforms. The last two decades witnessed many airports get interconnected with the rail network to extend the catchment area. The COST 18 study (European Commission, 1998) examined the effects of railway stations at airports to investigate the interactions between HSR and air passenger transport. By using four case studies and expert interviews of European HSR corridors, the results indicated that the improved rail access showed positive social benefit for large hub airports but balanced or negative for the medium-sized airports. Givoni and Banister (2006) investigated the intermodal integration of air and rail transport and suggested that airlines could be benefited from the freed slots as a result of using railway services instead of the existing feeder airline services.

## 3. Hypothesis Development and Model Specifications

To measure the effect of enhancement of railway on air passenger transport, we choose the change of aggregate demand at airports and rail stations for econometrical analysis. The change of annual airport passenger throughput is taken as the explained variable. The explanatory variables are chosen from two categories: geo-economic factors and locational factors. The geo-economic causal variables are specified as provincial GDP, provincial population density, average provincial transport expenditure and average travel times. By checking the result of correlation matrix, the list of variables is narrowed down to the GDP and average transport expenditure. The breakout of SARS epidemic in 2003, which is presumably has a negative impact on the air travel passenger, is also taken into consideration. Based on the existing literature and above analysis, we present two hypotheses below and develop two models to test the hypotheses accordingly.

Hypothesis 1: The speed acceleration of railway has a negative impact on the growth of air passenger traffic.

The inter-modal competition is considered to be one type of locational factors influencing the growth of airport passenger traffic. The nationwide rail speed acceleration is added as a dummy to the explanatory variables. Another explanatory variable is the change of passenger traffic of the nearby rail station. It reflects the changing travel demand of residents and thus presumably affects the passenger traffic at the airport in the same city. Based on the above discussion, Model 1 is specified to estimates the impact of rail improvement on the change of air passenger traffic.

$$\Delta AIRPASS_{it} = \beta_0 + \beta_1 \Delta GDP_{it} + \beta_2 \Delta EXPENSE_{it} + \beta_3 D \_ SARS + \beta_4 \Delta RAILPASS_{it} + \beta_5 D \_ SPDACCE_t + v_i + u_{it}$$
(1)

**Hypothesis 2**: The increase of passengers at rail stations has a positive effect to the concentration at hub airports but a negative effect to regional airports.

Spatial variation of airports which forms the hub-and-spoke system is also a crucial determinant for air passenger traffic as another type of locational factors. In Model 2, hub airport is included as dummy that reflects the difference between the hub airports and regional airports. Moreover, the increase of rail travel passenger is hypothesized to affect the changes of air passengers of hub airports and regional airports in a

different way.

$$\Delta AIRPASS_{it} = \beta_0 + \beta_1 \Delta GDP_{it} + \beta_2 \Delta EXPENSE_{it} + \beta_3 D \_SARS + \beta_4 \Delta RAILPASS_{it} + \beta_5 D \_SPDACCE_t + \beta_6 D \_REG_t + \beta_7 D \_REG_t \times \Delta RAILPASS_{it} + v_t + u_{it}$$
(2)

where subscript *i* denotes the *i*-th airport, and *t* the year. The  $\beta$ 's used to represent the coefficients give an indication of the way in which the variable is hypothesized to affect the changes of air passenger. Table 1 lists the measurements of variables in models and the expected sign.

Table 1: Variable definition			
Variables	Measurement		
	Explained variable		
$\Delta AIRPASS_{it}$	Annual change in the number of air passenger throughput at the <i>i</i> -th airport.		
Explanatory variables			
$\Delta GDP_{it}$	Annual change in the Gross Regional Product of the province where the <i>i</i> -th airport is		
	located in. (+)		
$\Delta EXPENSE_{it}$	Annual change in the residents' expenditure on travel of the province. It is calculated by		
	per capita annual household transport expenditure by region divided by CPI (Consumer		
	Price Indices) of intercity traffic fare by region. (+)		
D_SARS	Year=2003; the breakout of SARS (Severe Acute Respiratory Syndromes) (-)		
$\Delta RAILPASS_{it}$	Annual change in the number of rail passenger throughput at the rail station nearby the <i>i</i> -		
	th airport. (+ or -)		
$D\_SPDACCE_t$	1 if the year is under the influence of the rail speed acceleration, 0 otherwise. (-)		
$D\_REG_i$	1 if the airport is a regional airport, 0 otherwise. (-)		
$D\_REG_i$	The difference of impact of the rail passenger growth on the hub airports and regional		
$\times \Delta RAILPASS_{it}$	airports.		
i	Airport index (1 to 24)		
t	Year (1997 to 2009)		

#### 4. Data description and estimation results

## 4.1 Data description

This study uses annual data from 1997 to 2009 that consist of 24 major airports. We select airports that locate in cities currently ranked Top 40 in China by both air and rail passenger throughput. Most of the airports chosen are in the capital of province and located respectively in six regions shown in Table 2.

Table 2:	Sample	airports
I abit II	Sample	an por os

Region	Hub airport	Regional airports
Northern China	Beijing (PEK)	Tianjin (TSN), Shijiazhuang (SJW), Taiyuan (TYN)
Fastern China	Shanghai (SHA	Nanjing (NKG), Hangzhou (HGH), Nanchang (KHN),
Lastern China	and PVG)	Jinan (TNA)
Southern China	Guangzhou (CAN)	Shenzhen (SZX), Zhengzhou (CGO), Wuhan (WUH),
Southern China		Changsha (CSX)
Northeastern China		Shenyang (SHE), Haerbin (HRB), Changchun (CGQ)
Southwestern China	Chengdu (CTU),	Chongqing (CKG), Guiyang (KWE)
Southwestern China	Kunming (KMG)	
Northwestern China	Xi'an (SIA)	Urumchi (URC), Lanzhou (LHW)

*Note: The airports are categorized according to the 12th Five Year Plan of CAAC (2010). Airport code in parentheses.*  The passenger traffic data used come from the terminal passenger throughputs of *China Aviation Statistics* and *China Railway Yearbook*. The data for GDP and EXPENSE were gathered from the *Yearbook* and the *Survey of Family Income and Expenditure of China* from 1998 to 2010. From 1997-2009, there are six nationwide railway speed acceleration launched in April 1997, October 1998, October 2000, October 2001, April 2004 and April 2007 respectively. The speed acceleration is assumed to have major influence on the current year if performed in April and on the next year if performed in October. The hub airports are selected according to the 12th Five Year Plan of CAAC (2010). They contain three national hubs, i.e. Beijing (PEK), Shanghai (SHA and PVG) and Guangzhou (CAN), and regional hubs in the western region including Chengdu (CTU), Kunming (KMG) and Xi'an (SIA).

## 4.2 *Effects of rail acceleration*

Table 3 presents the estimation results of Model 1 for the effect of railway improvement. Hypothesis 1 is tested through fixed effect (FE) Model 1C, and Model 1A and 1B are basic models for comparison. The *F*-statistics are all significant at the 1% level that indicates the fixed effects model is preferred to pooled regression. Further, the result of Hausman test indicates that there is no systematic difference between random effects (RE) and fixed effects and thus the fixed effects model is more feasible.

	Explained variable	$\therefore \Delta AIRPASS_{it}$		
	F	Random Effect (RE)		
Explanatory variable	1A	1B	1C	1
$\Delta GDP_{it}$	5.360***	4.142***	3.489***	2.835***
	(5.68)	(4.41)	(3.78)	(3.53)
$\Delta EXPENSE_{it}$	9.010*	7.044*	8.138*	14.77***
	(2.21)	(1.79)	(2.13)	(3.92)
D_SARS	-900.498***	-443.022	-810.690**	-781.016**
	(-3.45)	(-1.66)	(-2.97)	(-2.72)
$\Delta RAILPASS_{it}$		0.110***	0.122***	0.150***
		(4.88)	(5.55)	(6.94)
$D\_SPDACCE_t$			-626.423***	-674.098***
			(-4.26)	(-4.35)
Constant	369.270**	281.736*	701.013***	624.825***
	(2.79)	(2.20)	(4.43)	(3.57)
Observations	288	288	288	288
$\mathbf{R}^2$	0.487	0.530	0.561	
Adjusted R <sup>2</sup>	0.435	0.481	0.513	
F-statistics for FE	6.386***	4.896***	4.976***	
Hausman test ( $\chi^2(4)$ )				155.200***

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Note: t-statistics in parentheses.

\*\*\* Significant at the 1% level, \*\*at the 5% level, \* at the 10% level

The goodness-of-fit statistics  $R^2$  and adjusted  $R^2$  of Model 1 are all above 43%. Hypothesis 1 is confirmed according to the results of Model 1. The speed acceleration of railway diverts passenger throughputs from air transport. Therefore, it has a negative and highly significant impact on the growth of airport passenger traffic. As indicated by the statistically significant of  $\Delta$  GDP and  $\Delta$  EXPENSE for all specifications, the growths of GDP and average travel expenditure have positive and strong influence on the increase of air passenger traffic. The negative sign of D\_SARS denotes a negative impact of infectious diseases to the public air travel.

What we are interested in is the positive sign of the variable  $\Delta$  RAILPASS. As discussed in Section 2, railway has both substitution and complementarity influence on air passenger transport. The negative effect is represented by the competition of the two alternatives for attracting passengers, while the positive effect is derived from two components. First, the airport and rail station passenger throughputs generally have the same

growth tendency due to the influences from economic environment and other unobserved factors. Second, the rail station is a necessary complement to air transport network from the view of intermodal transfer. Such contradictory effects will be further determined in Section 4.3.

## 4.3 Estimation of hub concentration

Model 2 assumes that differences across airports have some influence on the passenger throughput, such as the obvious distinctions of function and on-service airlines between the hub and regional airports. Thus we consider the random effects model. Moreover, random effects which assume error term is not correlated with the predictors allow for the D\_REG dummy as a time-invariant variable to be an explanatory variable. To justify whether random effects exist, we conduct Breusch-Pagan Lagrange multiplier test and verify the preference of RE specification.

Hypothesis 2 relating to the hub concentration effect is tested through Model 2 and the results are reported in Table 4. RE model 2A is the estimate using GLS method and RE model 2B is the estimate by FGLS method.

Table 4: Estimates of the hub concentration model (Model 2), 1998-2009				
	Explained variable: AAIRI	PASS <sub>it</sub>		
	Fixed Effect (FE)	Random Effect (RE)		
Explanatory variable	2	2A	2B	
$\Delta GDP_{it}$	4.645***	3.549***	$2.471^{***}$	
	(5.02)	(5.04)	(8.63)	
$\Delta EXPENSE_{it}$	7.447*	14.005***	5.667***	
	(2.03)	(4.07)	(4.05)	
D_SARS	-1030.449***	-1063.832***	-216.777**	
	(-3.85)	(-3.88)	(-2.73)	
$\Delta RAILPASS_{it}$	$0.172^{***}$	$0.186^{***}$	$0.186^{***}$	
	(7.21)	(8.40)	(3.95)	
$D\_SPDACCE_t$	-591.7***	-639.6***	-269.1***	
	(-4.17)	(-4.39)	(-6.52)	
$D\_REG_i$		-941.1***	-720.9***	
		(-4.86)	(-3.44)	
$D\_REG_i \times \Delta RAILPASS_{it}$	-0.194***	-0.192***	-0.153**	
	(-4.57)	(-4.60)	(-3.17)	
Constant	710.2***	$472.8^{**}$	223.6***	
	(4.66)	(3.06)	(5.31)	
Observations	288	288	288	
Wald $(\chi^2(7))$		264.680***	$262.410^{***}$	
B-P test $(\chi^2(l))$		7.24**		

*Note: t-statistics in parentheses* 

\*\*\* Significant at the 1% level, \*\*at the 5% level, \* at the 10% level

The variable D\_REG is negative and significant at 1% significance level. It indicates that regional airports have significant gap in the growth of air passenger traffic from hub airports. Accordingly, the total increase of airport passenger throughput is greatly contributed by hub airports. The interaction term D\_REG  $\times \Delta$  RAILPASS, which captures the difference of impact of the rail passenger growth on the hub airports and regional airports, also shows a negative sign. That means the passenger traffic of regional airport will decrease with the increasing traffic at the nearby rail station. It is partially resulted from the shift of passenger from air to rail transport for feeder service as the railway improvement. From the operators' perspective, it can be viewed as an extension of competition of the airline and railway at the terminals. Since the variable  $\Delta$  RAILPASS is positive and clearly significant to the explained variable  $\Delta$  AIRPASS, it can be inferred that the air passenger traffic at the hub airports will also increase if passenger flow keeps growing at the nearby rail stations. As a consequence, the rail station accompanying with the improvement of railway

services enhances the traffic concentration of hub airports.

#### 5. Conclusion and Implications

This study examines the impact of railway improvement on the airport passenger traffic in China, taking into account the railway speed acceleration and the effect of passenger traffic at neighbored rail stations. Panel data models are applied to estimate on the aggregate terminal passenger traffic data. Empirical results show that the speed acceleration of railway has a negative impact on the passenger growth of air transport, while improvement of rail does not reduce the airport passenger traffic as a whole, which is inconsistent with expectation. More specifically, the increase of passengers at rail stations has a positive effect to the concentration at hub airports but a negative effect to the regional airports. It indicates that the improvement of railway encourages the passenger traffic to converge on hub airports and enhances the passenger concentration of hub airports.

These findings show some policy implications for air transport network. In an emerging and rapid-developing market of high speed rail like China, a transport modal shift is expected to happen due to the increased speed and service of railway. On one aspect, for the airlines, some routes of feeder service linking of regional airports will be negatively influenced by the operation of HSR. Due to the regional development inequality and high construction cost of HSR, there left more expansion space for airlines to develop domestic feeder service in the Northwestern and Southwestern regions. On the other aspect, the passenger traffic in hub airports will continue to rise contributed by the development of HSR. The concentration of passenger traffic will put great pressure on the hub airports. The potential problems such as capacity constraints, distribution of public resources and airport congestions should be taken into consideration.

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