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"Integrated Transportation Logistics: From Low Cost to High Responsibility"

15 – 18 October 2010 Chengdu, Sichuan, China

Edited by:
John Jianhua Liu
Xiaowen Fu
Tsz Leung Yip
Adolf K.Y. Ng

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

The roots of IFSPA can be dated back to 2006, starting as a workshop to bring together researchers in the fields of maritime and aviation studies with the objective to promote high-quality research papers. It had since made very good development in the past years, attracting over 400 participants from 17 countries and territories.

Preface

The Fourth International Forum on Shipping, Ports and Airports (IFSPA 2010) was successfully held from 15 to 18 October 2010, in Chengdu, Sichuan, China. This proceedings contains a collection of forty-two papers presented during the Conference. The topics covered include shipping economics, port strategy, airport management, logistics development in Asia, environmental issues in logistics, port efficiency and competition, and maritime safety and security.

This conference theme, "**Integrated Transportation Logistics: From Low Cost to High Responsibility**", is meaningful and timely in light of today's heightened concerns about global climate change. The governments, business community and green parties of different countries are all keen to address the associated issues with strong commitment to achieve a balance of economy, environment and social objectives for a sustainable society. China, parallel to the rapid economic development, is also determined to step up its efforts to boost low-carbon economy as part of its strategy of promoting the transformation of economic development pattern. Along the track, the booming Chinese transportation logistics will develop a more comprehensive and integrated system to modernize its logistics industry. We welcome more sharing on these evolving subjects.

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. It aims to provide an interactive platform for academics and industry practitioners to discuss and exchange views on contemporary issues facing the sectors, further advancing academia-industry cooperation. IFSPA 2010 was jointly sponsored by the Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University and School of Economics and Management, Southwest Jiaotong University. Following the success of previous IFSPAs which attracted more than 400 participants from different countries and territories, we are glad that the event has secured massive support from local governmental agencies and institutions on its coordination and implementation.

Chengdu is an important centre of commerce and finance as well as a regional hub of transportation and logistics in southwest China. In recent years, it has undergone fast-paced development, with a number of logistics centres and parks established, and the move-in of some of the world's top logistics companies.

We thank the 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, Joey Wong, Priscilla Lau, Justin Wong and Violette Wong.

Finally, we greatly appreciate the hard work and contribution of the paper authors, members of the Organizing Committee and Paper reviewers.

The Editors

John J. Liu
Xiaowen Fu
Tsz Leung Yip
Adolf K. Y. Ng

Hong Kong, November 2010

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Contents

Regulation, Privatization, and Aeronautical Charges: Panel Data Evidence from European Airports

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Abstract

This paper examines the determinants of airport aeronautical charges by employing a unique panel dataset covering sixty-one European airports over an eighteen year period. We are able to extend the literature on the role of airports as an essential element in transport infrastructure by offering the first analysis of the impact of different regulatory policies and privatization on airport charges in a panel data setting where fixed effects can be employed to mitigate endogeneity concerns. Our main empirical results indicate that aeronautical charges are lower at airports where single-till regulation is employed; at airports with ex-post price regulation; and at privatized airports. Furthermore, while hub airports generally set higher aeronautical charges, it appears that price-cap regulation and the presence of competing airports do not affect aeronautical charges.

Keywords: Airports; Airport Charges; Regulation; Privatization; Single-Till; Hubs

1. Introduction

Airports have always been viewed as an essential element in transport infrastructure, yet only over the last two decades have airports been increasingly recognized as full-fledged business enterprises that provide a number of different services to airline industry customers (Doganis, 1992; Winston and de Rus, 2008; Starkie, 2008). Despite the potential for airports to be innovative in providing services beyond take-offs and landings (e.g., parking, concessions, retail and other related services), it must be recognized that airports generally exhibit many of the classic properties of local monopolies. The natural monopoly tendency implies that leaving these businesses unregulated might not be the best course of action from a social welfare perspective. Nevertheless, some countries – such as Australia and the UK – have allowed airports to freely set charges in an unfettered manner; though, even in these instances, airport service pricing is subject to monitoring (an ex-post regulation) by industry regulators (Forsyth, 2008).

In light of the economic importance of the aviation industry and the relative maturity of research on the airline service industry (see Borenstein and Rose, forthcoming, for a recent review), the airport sector has recently experienced increased attention by scholars. For instance, Forsyth et al. (2004) provide a comprehensive overview of the history and practice of worldwide airport regulation. In addition to more traditional descriptive studies, we also see theoretical scholarship beginning to tackle some of the salient issues regarding airports. For example, Czerny (2006) considers the optimal form of airport regulation, while Brueckner (2002) and Basso and Zhang (2008) explore the airport-airline relationship concerning aeronautical charges in the peak/off-peak context. The existing empirical literature on airports, however, consists mostly of benchmarking studies that examine the factors determining airport productivity (e.g., Oum et al., 2003; Oum and Yu, 2004; ATRS, 2008).

While the benchmarking studies have begun to converge on the factors which enhance airport productivity and efficiency, empirical literature concerning the essential topic of what drives airport pricing is surprisingly scarce. We could only identify two empirical studies (van Dender, 2007; Bel and Fageda, 2010) focusing on the determinants of airport pricing. Such a relative scarcity of literature on airport pricing is all the more surprising when one recalls that pricing was the focus of the early empirical work on the airline industry (e.g., Keeler, 1978; Borenstein, 1989; Werden et al., 1991; Brueckner et al., 1992; Kim and Singal, 1993). This lack of empirical work on the drivers of aeronautical charges might be a function of the still prevalent view that airports are infrastructure objects rather than full-fledged businesses. Yet, providing substantive evidence on the impact of regulation and privatization policies on airport pricing is of particular interest to policymakers since many airport authorities in the cross-national environment have recently been experimenting with different regulatory regimes and privatized operations.

Accordingly, our aim here is to use empirical evidence to study the impact of different forms of regulation and privatization – as well as other factors – on the aeronautical charges manifesting at different airports. We employ a unique panel dataset covering sixty-one European airports: data that were collected within the framework of the German Airport Efficiency Project (GAP Project). The data from this project were compiled in order to allow the creation of a panel dataset with operating information on these sixty-one airports over a span of eighteen years (1990 to 2007). The panel nature of the data is one feature that distinguishes this study from that of Bel and Fageda (2010) – who use a cross-section of one-hundred large European airports. While van Dender's (2007) US-based study actually involves a cross-section of US airports spanning the 1998-2002 period, he is not able to fully employ panel-data econometric techniques (i.e., fixed effects) due to non-variation in some key variables. Furthermore, van Dender's study could not shed light on some of the issues we can examine since US airports strictly operate as public enterprises that in turn charge simple cost-based aeronautical fees. Accordingly, the European environment is the optimal context in which to study the impact of privatization and regulation on airport charges, as this is the environment where substantial variation in airport policies exists. Furthermore, the panel nature of the data allows us to fully exploit within-airport variation in the key variable constructs; thus, we are able to mitigate some of the endogeneity issues involved with the questions we address.

Our empirical findings indicate the following. First, *single-till regulation generates lower aeronautical charges* – in line with expectation. Second, *airports subject to ex-post regulation (i.e., monitoring and the threat of re-regulation) have lower aeronautical charges*. Third, *airport privatization leads to lower aeronautical charges*. Fourth, *hub airports have higher aeronautical charges*, thus suggesting that hubbing involves increased demand for airport services which naturally leads to higher prices. Fifth, the introduction of *price-cap regulation* and *increased airport competition do not significantly affect aeronautical charges*.

The rest of the paper is organized as follows. Section 2 considers airport regulation and privatization developments in the European context. Section 3 describes the data. Section 4 outlines the hypotheses and the methodology employed in the empirical analysis. Section 5 presents and discusses the panel-data empirical results. Section 6 concludes.

2. Airport Regulation and Privatization in Europe

Airports have traditionally been owned and managed as government entities. Yet, starting with the privatization of UK airports in 1987, many airports have been fully or partially privatized throughout the world—in particular, a number of airports in Europe, Australia, and New Zealand have been privatized. While there are gains to privatizing airports for local municipalities (removal of a fiscal burden and one-time government revenue boost via the purchase price for the assets), the concern has been that privatized airports will more fully utilize their market power and increase aeronautical charges. In fact, Bel and Fageda (2010) found higher aeronautical chargers at private unregulated airports. Accordingly, as the ownership of airports changes from public to private hands, economic regulation may become increasingly necessary due to the local monopoly nature of airports.

Two principal types of economic regulation have generally been practiced with respect to airport pricing: the traditional cost-based (i.e., rate of return) regulation and the more incentive-minded price-cap regulation. Under rate of return (ROR) regulation, the airport is allowed to charge a price that would prevail in a competitive market; i.e., the price equal to efficient costs of production plus a market-determined rate of return on capital investment. Price-cap regulation instead adjusts an airport's charges according to the price-cap index that reflects the overall rate of inflation in the economy and the ability of the airport to gain efficiencies relative to the average firm in the economy.

The exact form of price regulation appears to vary both across countries and over time. For example, a number of countries – including Germany and Canada – have adopted cost-based regulation, while price-cap regulation has been popular in countries such as the UK, Denmark and Australia. A major limitation of the cost-based approach is the well-known Averch-Johnson effect: i.e., if the allowable ROR is set too high, the regulated firm can increase its profit by enhancing capital assets, thus firms have a consequent tendency to over-invest (Averch and Johnson, 1962). In addition to the Averch-Johnson distortion, concerns also exist regarding productive inefficiency. In particular, the cost-based nature of ROR regulation suggests that airports would not benefit from cost reduction. Price-cap regulation has become popular because it is generally believed that this approach gives firms incentives to be cost efficient, thus price-cap regulation is often referred to as 'incentive regulation'. For example, while German airports have traditionally been regulated by cost-based regulation, price-cap regulation has been in place since 2000 for Hamburg airport. Niemeier (2002) argues that such a change improves the economic efficiency of airports.

An airport derives revenue from two facets of its business: the traditional aeronautical operation, and the commercial (concession) operation. The former refers to the aviation activities associated with runways, aircraft parking and terminals, whereas the latter refers to the non-aeronautical activities within terminals and on airport land, including terminal concessions (duty-free shops, restaurants, etc.), car rental, parking, and other activities. Over the last twenty-five years, commercial revenues have grown faster than aeronautical revenues and, as a result, have become the main source of income for many airports. For instance, van Dender's (2007) investigation of fifty-five large US airports found that concession revenue represents more than half of the total airport revenue during the 1998-2002 period (see Doganis, 1992, for figures on earlier years in the US). Note also that the commercial operations of European airports tend to be more profitable than aeronautical operations (see Jones et al., 1993; Starkie, 2001; and Francis et al., 2004) owing in part to the prevailing regulations and charging mechanisms (e.g. Starkie, 2001).

In light of there being two main sources of airport revenue (aeronautical and non-aeronautical), airport regulation in the European context has varied in another dimension: whether airport charges are based on both aeronautical and non-aeronautical operations, or based strictly on aeronautical operations. More specifically, under the single-till approach, operating profits from both the aeronautical and non-aeronautical (concession) operations are considered in the determination of regulated aeronautical charges. Under the dual-till approach, the aeronautical charges are determined solely on the basis of aeronautical activities. The single-till and dual-till distinction can also carry over to cost-based regulation where the ROR can be set on the capital investment for both the aeronautical and non-aeronautical operations (single-till), or strictly on the aeronautical operations (dual-till).

A number of studies have compared the relative merits of these two different approaches. Czerny (2006) shows that at non-congested airports the single-till price-cap regulation dominates the dual-till approach in terms of welfare maximization. On the other hand, a major critique of the single-till approach is that aeronautical charges are set too low at congested and capacity-constrained airports, due to the cross-subsidy from the usually (non-regulated) profitable commercial operation. More specifically, as more concession revenue is derived from commercial activities, the aeronautical charges must be lowered to remain under the single-till price-cap. Thus, under single-till price-cap regulation, aeronautical charges are lowered at congested airports when economic efficiency of airport capacity requires them to be raised (Starkie, 2001; Gillen, 2009). It is generally believed, therefore, that dual-till price-cap regulation is more desirable at congested airports. Empirically, Oum et al. (2004) show that dual-till price-cap regulation provides a stronger incentive for capacity investment and cost reductions than does the absence of regulation.

Another more-recent regulatory mechanism that has been employed on the airport sector is ex-post regulation: which essentially involves price monitoring and the threat of re-regulation by authorities. More specifically, no regulation is applied to the airport unless the 'regulated' airport sets prices, earns profits, or reduces service quality beyond certain critical levels. If the thresholds are violated, then a long-term commitment to re-regulation is imposed; as such, this mechanism is sometimes referred to as conduct regulation, or 'light handed' price regulation (Forsyth, 2008). In short, this category includes all the airports that are not subject to prices being explicitly set by the regulator; instead, the charges proposed by these ex-post airports are subject to approval and/or monitoring by the regulator.

The ex-post approach is currently implemented in Australia, New Zealand and Switzerland, as well as some airports in the UK and Eastern Europe. For example, ex-post regulation has been applied to the small/medium-sized airports throughout the UK (excluding, of course, those airports designated for price-cap regulation in London and Scotland). The rationales for ex-post regulation include: (i) airports have incentives to lower aeronautical charges in order to attract more traffic and increase their concession revenues (Starkie, 2001); and (ii) the threat of re-regulation can help mitigate the potential exploitation of market power by privatized airports (Forsyth, 2008). The obvious danger is that the deterrence effect of re-regulation is insufficient to prevent airports from taking full advantage of their market power by setting relatively high aeronautical charges. Thus, it remains an empirical question as to whether ex-post regulation substantially affects airport pricing.

3. Data

In our analysis, we use the data collected and compiled by the German Airport Efficiency Project (GAP Project)—a partnership of three German Universities (FHV Berlin, Hochschule Bremen, and Internationale Fachhochschule Bad Honnef) supported by the Federal Ministry of Research and Technology. The project involved the collection of data on a number of airports across Europe. The data obtained included information on airports' annual basic operating results, such as total aeronautical revenue and non-aeronautical revenue, aircraft movements, number of passengers served, cargo transported, etc. Information on the institutional environment in which airports operate is also available—this includes the share of private ownership, as well as classification of airports by the type of regulation employed. The original dataset classifies airports as subject to cost-based regulation, price-cap regulation, and ex-post regulation. Further, we are able to observe whether airports are subject to single-till or dual-till regulation. Table 1 illustrates the pertinent descriptive statistics for the variables employed in our estimations.

Table 1: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.
Aeronautical revenue, thousand Euros (year 2000 prices)	103,907	39,385	1,287,187	3,633	176,848
Non-aeronautical revenue, thousand Euros (year 2000 prices)	77,286	28,151	889,370	627	144,556
Passengers	9,084,926	4,439,804	67,869,000	419,680	12,340,683
Cargo (metric tons)	135,769	19,678	2,190,461	0	318,072
Aircraft Movements	110,819	69,600	492,569	4,113	108,939
Charge per aircraft movement (year 2000 prices)	712.51	651.59	3,005.96	136.47	408.90
Cost-Based regulation	0.35	0.00	1.00	0.00	0.48
Price-Cap regulation	0.17	0.00	1.00	0.00	0.38
Single-Till regulation	0.34	0.00	1.00	0.00	0.47
Ex-Post regulation	0.48	0.00	1.00	0.00	0.50
Private ownership share	38.38	8.00	100.00	0.00	42.79

In addition to the above-mentioned airport characteristics, some additional features of the dataset are worth mentioning. The dataset classifies airports as either hubs or non-hubs (only about ten percent of our observations represent hub airports—the hub definition is given below). We also have information on the number of airports located within the airport's catchment area that serve over one-hundred thousand passengers; thus, we can test for airport competition effects. Furthermore, we adjusted aeronautical and non-aeronautical revenues for inflation – expressing them in year 2000 prices – before conducting the empirical analysis. Some demographics (population and per capita income) for the surrounding area of the airport were also included in the GAP data. We have supplemented this data by locating additional information, and/or by interpolating the numbers for a few missing years. In total, our unbalanced panel dataset (672 actual observations for the less exacting regression specifications) contains information on sixty-one airports from seventeen countries, and spans the time period from 1990 to 2007.

A merit of our sample is that we have a number of different airport types in our data: small airports, airports primarily used by low-cost carriers, airports specializing in cargo transportation, as well as large European hubs. This heterogeneity is somewhat in contrast to the study by Bel and Fageda (2010) which focuses on the one-hundred largest European airports, and the study by van Dender (2007) which focuses on the US airports specializing in commercial passenger operations. A quick glance at the descriptive statistics in Table 1 confirms that we are dealing with a diverse set of airports over many dimensions; thus, our sample involves the necessary amount of variation in order to employ panel-data econometric techniques. In particular, we will control for airport specific fixed effects and rely then on within-airport variation in making causal inferences. To add more specificity here, we observe regulation regimes changing in nine airports, till types changing in fourteen airports, and private ownership shares changing in nineteen airports. In short, our main explanatory constructs indicate a decent degree of within-airport variation.

In order to construct a measure of aeronautical charges – our dependent variable – we take the simple ratio of real aeronautical revenue over the number of aircraft movements: where either a landing or a take-off represents one movement. This is a rough proxy for average price since aeronautical charges consist of both weight-based take-off and landing fees (with the weight-charge relationship not always being linear), and per passenger charges. Note also that some airports set different charges for origin-and-destination passengers as compared to transfer passengers; set higher take-off and landing charges for noisier aircraft; and impose higher nighttime charges. At the same time, average revenue per aircraft is a good overall measure of the level of aeronautical charges, has been previously employed in the literature (van Dender, 2007), and the panel nature of our data allows controlling for airport-specific differences. Furthermore, our approach to constructing a measure of aeronautical charges is fundamentally different to that of Bel and Fageda (2010) who focus on the total airport charges for a particular type of aircraft (a narrow-bodied Airbus) assuming a certain load factor. While this approach is meticulous and appropriate for a cross-section of passenger-oriented airports, the use of our proxy enables taking full advantage of the data's panel nature.

4. Empirical Analysis

4.1. Methodology

In order to properly employ our data covering European airports over the 1990-2007 period, it behooves us to consider a few econometric issues. As already noted, the data's panel structure enables airport fixed-effects estimations that yield coefficient estimates based on within panel variation. Yet in the course of empirical analysis, we need to tackle some additional econometric issues.

First, our dependent variable – aeronautical charge per aircraft movement – may be simultaneously determined with a few of our independent variables. In particular, the number of aircraft movements, passengers, and cargo volume can all be considered measures of airport output; thus, we will effectively have three output measures on the right-hand side of our regression equation and price on the left-hand side. Technically, this means that the error terms in our regression equations may well be correlated with these independent variables. The classical approach to addressing this problem is to find variables correlated with the regressors but not with the error term, and then employ instrumental variable (IV) techniques. One could also use the panel properties of the data and assume that past values of the explanatory variables might be uncorrelated with current shocks. In our empirical estimations, we will combine these approaches by first lagging all of the independent variables in all of the regression specifications that we estimate in order to begin to mediate the endogeneity issue; and then by using twice lagged measures of an airport's output (aircraft movements, passengers, and cargo) in order to instrument for the once-lagged explanatory variables.

Second, the issue of autocorrelation needs to be addressed, as it can manifest due to the cyclical nature of the airline business. Autocorrelation may also manifest because airports are not able to immediately respond to a changing business environment (due to the regulated environment in which they operate) by adjusting prices for their services. We can address this issue by estimating a dynamic panel data model where the lagged dependent variable is introduced as a right-hand side regressor. Yet, dynamic panel data models can result in biased coefficient estimates due to the obvious endogeneity in the lagged dependent variable. In order to address this endogeneity threat, we will employ the Generalized Method of Moments (GMM) estimator for dynamic panel data. Specifically, we will use the system estimator proposed by Arellano and Bover (1995) which built and improved upon the Arellano and Bond (1991) GMM estimator. System GMM analysis is specifically designed to address endogeneity issues with dynamic panel data models (i.e., biases in the coefficient estimate for the lagged dependent variable). Moreover, GMM can also be used to address endogeneity in any additional explanatory variables; namely, the above mentioned measures of aircraft movements, passengers and cargo. Accordingly, we will use the System GMM procedure to estimate dynamic panel data models where we instrument for both the lagged dependent variable and the potentially endogenous explanatory variables.

Third, a few miscellaneous econometric issues also need to be addressed. For one, all the independent variables are lagged in all of the reported regression specifications in order to initially respond to the endogeneity issue. Furthermore, the IV regressions use twice lagged measures of airport output (aircraft movements, passengers and cargo) to respectively instrument for the once lagged measures of airport output that fall on the right-hand side of the regression specification. For the System GMM procedure, all available lags for aeronautical charges are employed as instruments for the lagged dependent variable, and twice lagged measures are employed as instruments for the once lagged output measures—akin to the IV estimations. This combination ensures no correlation between the instrumental variables and the error terms—a necessary condition for the GMM estimator to be valid. In addition, reported standard errors also account for heteroscedasticity both between and within cross sections (i.e., we allow for the error variance to differ not only across the airports, but also across time).

With the above econometric issues in mind, we estimate the following regression specifications. Specification 1 is a simple fixed effects estimation that does not employ a dynamic panel data model (i.e., no lagged dependent variable). Specification 2 is a similar fixed effects specification that introduces instrumental variable (IV) procedures for the three explanatory variables with potential endogeneity: aircraft movements, passengers and cargo volume. Specification 3 introduces the lagged dependent variable into a simple fixed effects specification where no instrumentation takes place. Specification 4 does the same as specification 3 except it instruments – via the IV procedure – for the three explanatory variables (aircraft movements, passengers, cargo) of concern. Specification 5 employs the GMM procedure where only the lagged dependent variable is instrumented for with the System GMM technique. Finally, specification 6 employs the System GMM procedure to instrument for both the clearly endogenous lagged dependent variable and the potentially endogenous explanatory variables (aircraft movements, passengers, cargo).

4.2. Hypotheses and regression specification

Our research focus is the effect of regulatory environment changes and private ownership changes on aeronautical charges; yet, here we will discuss *a priori* expectations for both the main explanatory variables and the key control concepts.

The expected effect of private ownership is uncertain due to the potential for multiple causal paths. On one hand, we can expect private owners to exercise their market power, thus yielding higher aeronautical charges. In line with this view, Bel and Fageda (2010) found higher charges at private unregulated airports. On the other hand, we can offer three explanations for a possible negative privatization–charges relationship. First, the general theory of principal-agent relationships in publicly owned enterprises suggests that such managers may have an incentive to emphasize what could be perceived as correlates of social welfare, namely quality (Lindsay, 1976). This could yield overinvestment in quality (manifested through, for instance, keeping traffic low to avoid congestion). As private owners strive to make the airport more (technically) efficient, they may be able to reduce operating costs and pass the savings along to customers in the form of lower aeronautical charges. The second explanation relates to the fact that private ownership brings investment to the airport; hence, the timing of privatization might be related to the airport's need to attract investment. Accordingly, those airports that are in need of investment might be the ones getting privatized; meaning that at the time of privatization these airports are expanding their capacity, and a capacity expansion will clearly entail lower prices. A third possible explanation is that a private airport may be more innovative in its approach to, and management of, commercial operations than a public airport. As a result, it would have a higher commercial profit per passenger than a public airport. Due to this, the private airport would have a greater incentive to lower aeronautical charges so as to attract more passengers and earn greater commercial profit. In short, the relationship between privatization and aeronautical charges is complex, and the coefficient estimates for the privatization variable may potentially reflect the net-effect of these different elements.

As far as regulation is concerned, we specifically examine three different dimensions of regulatory policy: price-cap, ex-post and single-till regulation. In order to identify the three regulatory variables and avoid collinearity, we omit the indicators of cost-based regulation and dual-till regulation. Omitting these indicators – and thus setting them up as the empirical benchmark – is in line with cost-based and dual-till regulation representing traditional regulatory practice for airports, while price-cap, ex-post and single-till regulation all represent innovations in regulatory policy. Accordingly, our *a priori* expectation regarding price-cap regulation is for lower aeronautical charges at airports which practice price-cap regulation as compared to cost-based regulation. Price-cap regulation should provide airports with the necessary incentives to increase efficiency, since cost-based regulation has been deemed to lack sufficient incentives. It should be noted, however, that Starkie (2004) suggests an equivalence between price-cap and cost-based regulation; furthermore, Bel and Fageda's (2010) empirical study of aeronautical charges found no difference between these two regulations. Second, we can formulate a clear hypothesis regarding the effect of single-till – as compared to dual-till – regulation on aeronautical charges: we expect lower aeronautical charges at airports introducing single-till regulation as a substitute for dual-till regulation, because airports can cross-subsidize between aeronautical and non-aeronautical activities under single-till regulation. Third, and as already noted, the expected effect of ex-post regulation is *a priori* uncertain, as it is an open question as to whether the airports will use their freedom to exert market-power or instead attempt to lower charges in order to attract more traffic.

In order to make better causal inferences regarding the above explanatory variables of principal interest, we will introduce a number of control constructs. While not the focus of this study, the influence of these controls on aeronautical charges is also of some interest. The following represent the control variables we employ in all of the reported regression specifications:

- Hub airport dummy: Hub status should bring with it a greater demand for flight frequencies and airport services; thus, hub status should translate into higher aeronautical charges.
- Natural logarithm of non-aeronautical revenue per passenger: We expect the effect of this variable to be negative, due to the potential for cross-subsidization between aeronautical and non-aeronautical revenues.
- Natural logarithm of real GDP per capita: Wealth in an airport catchment area should be associated with higher aeronautical charges, due to the obvious demand-side forces reflected in this variable.
- Natural logarithm of population: Akin to GDP per capita, this variable is also likely to be positive due to demand-side forces. Both per capita GDP and population are routinely found to be associated with higher airfares.
- Number of airports serving over 100,000 passengers located within an airport's catchment area: The presence of competing airports should reduce aeronautical charges.
- The three measures of airport operational performance: the natural logarithms of the number of aircraft movements, number of passengers, and volume of cargo transported.

Beyond knowing whether the airport is a hub for a particular airline, we do not have any additional information on the downstream airline market. This is clearly an omission in our study, as van Dender (2007) and Bel and Fageda (2010) have information on the downstream market. Yet, the relevant data for all the years in our sample of European airports are simply not readily available. This data deficiency also makes it impossible to test the implications of recent airport-pricing theoretical studies that incorporate airline market structure (e.g., Brueckner, 2002). Nevertheless, it is important to underscore that both Bel and Fageda (2010) and van Dender (2007) found airport level HHI to be an insignificant determinant of aeronautical charges. Thus, omitting downstream market structure may not be of serious consequence.

5. Results

Table 2 presents the estimation results for the six regression specifications previously outlined in the methodology sub-section (see 4.1). It is important that the regressions be well-specified in order to yield confidence in interpreting our variables of principal interest. The adjusted R-squares in regression specifications' 1-4 range from .8611 to .9284, thus indicating that the model is reasonably well specified. Another striking result from a first glance at Table 2 is that our key variables of interest (indicators and measures of regulation and privatization) exhibit a substantial degree of consistency when we consider signs and significance across the six different regression specifications. In particular, the coefficient estimates for hub status and airport competition – in addition to price-cap, single-till and ex-post regulation – are generally consistent across the different treatments: i.e., non-dynamic and dynamic panel data models, not-instrumenting and instrumenting (with both IV and GMM) for the three output measures, and not-instrumenting and instrumenting (with GMM) for the lagged dependent variable.

Table 2: Estimation Results

	Base Model		Dynamic Panel Data Model		System GMM Dynamic Panel Data Model	
Regression Specification:	#1 FE	#2 FE + IV	#3 FE	#4 FE + IV	#5 IV for Y_{t-1}	#6 IV for Y_{t-1} and more
Price-Cap regulation	-0.0005 (0.0332)	0.0222 (0.0368)	-0.0139 (0.0219)	0.0101 (0.0276)	0.0219 (0.0450)	0.0010 (0.0408)
Single-Till regulation	-0.1264** (0.0515)	-0.1219** (0.0612)	-0.0636** (0.0289)	-0.0848** (0.0349)	-0.0854** (0.0301)	-0.0748* (0.0417)
Ex-Post regulation	-0.2473** (0.0957)	-0.2554** (0.1102)	-0.0842 (0.0849)	-0.1662** (0.0758)	-0.1042** (0.0438)	-0.1500** (0.0764)
Private Ownership Share	-0.0025** (0.0004)	-0.0026** (0.0006)	-0.0011** (0.0003)	-0.0013** (0.0005)	-0.0009** (0.0001)	-0.0012** (0.0003)
Hub	0.1301** (0.0526)	0.1701** (0.0430)	0.0602** (0.0236)	0.1030** (0.0307)	0.0933** (0.0274)	0.0809** (0.0371)
Airports within catchment area	0.0019 (0.0304)	-0.0093 (0.0366)	0.0237 (0.0252)	-0.0037 (0.0329)	0.0121 (0.0159)	0.0131 (0.0175)
Log(non-aeronautical revenue per pax)	0.0800 (0.0511)	0.1042 (0.0727)	-0.0051 (0.0319)	-0.0048 (0.0528)	0.0192 (0.0201)	-0.0044 (0.0387)
Log(Real GDP per capita)	0.2479** (0.1192)	0.2652** (0.1063)	0.0391 (0.0865)	0.1204 (0.1022)	0.0679 (0.0463)	0.0914 (0.0702)
Log(Population)	0.0580 (0.1018)	0.3565** (0.0800)	0.0406 (0.0326)	0.2230** (0.0780)	-0.0268 (0.0299)	0.1296 (0.0994)
Log(aircraft movements)	-0.2618* (0.1383)	-0.4835* (0.2981)	0.3984** (0.1450)	-0.2604 (0.4423)	0.3602** (0.0300)	0.2678** (0.0826)
Log(cargo volume)	-0.0027 (0.0091)	0.0382** (0.0194)	-0.0039 (0.0060)	0.0274* (0.0153)	-0.0046** (0.0020)	0.0115 (0.0121)
Log(passengers)	0.1956** (0.0960)	0.2542* (0.1559)	-0.1842** (0.0767)	0.0941 (0.2319)	-0.1459** (0.0244)	-0.1658** (0.0525)
Lagged dependent variable	---	---	0.8275** (0.0391)	0.5613** (0.2187)	0.8465** (0.0350)	0.7652** (0.0602)
Constant	3.1297** (1.4051)	-0.5691 (1.5631)	-1.4169** (0.6757)	-0.4620 (1.5272)	---	---
Observations	672	614	672	614	611	553

Adjusted R-squared	0.8611	0.8624	0.9284	0.9102	---	---
Durbin-Watson statistic	0.9168	0.9252	---	---	---	---
Hansen J statistic (p-value)	---	---	---	---	35.77 (0.9969)	32.77 (0.9969)

Notes:

1. Dependent variable is natural logarithm of aeronautical revenue per aircraft movement.
2. All independent variables are lagged one year.
3. White robust standard errors in parentheses.
4. Year dummies included in all regressions, but not reported.
5. In regression specifications' 2, 4, and 6, twice-lagged aircraft movements, cargo, and passengers were used to instrument for the same once-lagged explanatory variables.
6. In regression specification 5, the second-to-last lags of the dependent variable were used as instruments for the lagged dependent variable; in regression specification 6, third-to-last lags were used as instruments for the lagged dependent variable.
7. Significance: * = 10 percent; ** = 5 percent.

In light of the qualitatively similar findings for our variables of interest in the six different econometric treatments, we take a variable-by-variable approach here to analyzing the results. First, the coefficient estimates for price-cap regulation are statistically insignificant in all six regression specifications, thus suggesting that price-cap regulation is not superior to cost-based regulation when it comes to aeronautical charges. Second, the coefficient estimates for single-till regulation are negative and statistically significant in all six regression specifications, thus it appears that the onset of single-till regulation leads to lower aeronautical charges. Third, the coefficient estimates for ex-post regulation are negative in all six specifications and significant in every specification except for regression 3, thus the onset of ex-post regulation appears to lower aeronautical charges. Fourth, the coefficient estimates for privatization are negative and significant in all six regression specifications, thus privatization appears to lead to lower aeronautical charges. Fifth, the coefficient estimates for the Hub variable are positive and significant in all six regression specifications, thus it does appear that hub airports charge higher prices than do non-hubs. Sixth, the coefficient estimates for the number of airports in the catchment area are insignificant in all six regression specifications, thus the presence of competitor airports does not seem to influence aeronautical charges.

While the effects of the privatization and regulation measures are qualitatively consistent, we should point out that their magnitudes vary across the six regression specifications. In particular, the introduction of dynamic panel data analysis leads to diminishing magnitudes for the effects of our key drivers of aeronautical charges. Specifically, single-till regulation yields a 12 percent decrease in aeronautical charges in the base model specifications (#1 & #2), but only a 7.5 to 8.5 percent decrease in charges when considering the System GMM specifications (#5 & #6). Ex-post regulation shows a remarkable 25 percent decrease in average aeronautical charges in the base model (specifications' #1 & #2), but the size of that effect is brought down to a more modest 8-15 percent once a dynamic structure is introduced. A similar reduction in magnitude is exhibited when one considers the impact of private ownership on aeronautical charges: with the effect of privatization being more than halved once a dynamic structure is introduced in regression specifications' 3-6.

We now take a similar variable-by-variable approach to consider the impact of the additional control variables on aeronautical charges. First, all six regression specifications yield no support for non-aeronautical revenue per passenger having a significant impact on aeronautical charges. Second, Real GDP per capita and population are generally associated with higher aeronautical charges; though, these coefficient estimates are insignificant in many specifications. While studies of the airline industry routinely detect positive relationships between these measures of potential market size and airfares, it is important to point out that our employing a panel-data methodology omits the between-panel variation that may drive that standard result. Third, the three measures of airport operating performance (aircraft movements, air cargo volume, and passenger traffic) yield mixed results (differences in both signs and significance) across the six regression specifications. In part, these mixed results indicate the potential endogeneity in these variables, and suggest the advisability of not interpreting these coefficient estimates with any degree of confidence. Note, however, that consistency in the coefficient estimates for the variables of principal concern suggests that any endogeneity in these output measures does not spillover and affect the inferences on our key constructs. Finally, the coefficient estimates in regression specifications' 3-6 do indeed suggest that previous levels of aeronautical charges influence current levels of aeronautical charges.

While this analysis represents the first comprehensive empirical study (comprehensive in that we have a sample involving heterogeneity in regulation and privatization, employ panel data techniques, and factor the potential for inertia in the regulation process by using dynamic panel data models) of the factors driving aeronautical charges, it is important to compare our results with the pre-existing empirical literature (e.g., van Dender, 2007; Bel and Fageda, 2010). A comparison of the above results with the prior empirical literature on airport pricing yields the following observations. First, our finding that both privatization and ex-post regulation lead to lower aeronautical charges contradicts Bel and Fageda's results which suggested that these types of airports have higher charges. In contrast to their approach, however, we employ panel data methods and use a different measure of aeronautical charges. Second, our finding a statistically significant negative relationship between single-till regulation and aeronautical charges confirms Bel and Fageda's similar (though insignificant) empirical finding. Third, our finding that price-cap regulation is equivalent to cost-based regulation when it comes to setting aeronautical charges confirms Bel and Fageda's similar finding. Furthermore, while our finding hub airports to have higher aeronautical charges is clearly intuitive, it is nevertheless a novel result in the sense that Bel and Fageda did not include this variable in their regression specification and van Dender's study did not find hub airports to generally have higher charges.

6. Conclusions

This study examines the impact of airport regulatory policy and airport privatization on the prices that airports charge their customers (i.e., the aeronautical charges faced by airlines). In particular, we are able to explore the effects of privatization and different regulatory policies on European airports using a new panel dataset collected by the German Airport Efficiency Project. The European context is the ideal environment in which to study these relationships, as a substantial degree of variation exists in both the regulatory framework and the degree of privatization found in Europe as compared to US airports. Accordingly, the strength of our analysis resides in our ability to comprehensively analyze the impact of varied regulatory policies and different degrees of privatization on aeronautical charges. In addition, our study is able to employ panel data methods and thus elicit stronger causal inferences that are less subject to the usual endogeneity concerns.

Our empirical results can be summarized as follows: single-till regulation, ex-post regulation, and privatization all tend to lower aeronautical charges at airports. Interestingly, we do not find price-cap regulation to substantially decrease aeronautical charges. In addition to the above core results concerning regulation and privatization, we find that hub airports tend to have higher aeronautical charges, while the presence of competing airports in the catchment area does not significantly affect airport charges.

Accordingly, our empirical results suggest the following interpretations and implications. First, price-cap regulation does not appear to generate lower aeronautical charges as compared to cost-based regulation: while this result is somewhat surprising, it is in line with Starkie's (2004) ideas concerning the equivalence of cost-based and price-cap regulation, and with the empirical results of Bel and Fageda (2010). Second, the regulatory practice of single-till regulation – as opposed to dual-till regulation – appears to lead to lower aeronautical charges, as the consideration of non-aeronautical revenues lowers the optimal aeronautical charge due to the potential for cross-subsidization of non-aeronautical revenues via increased aeronautical traffic. Third, the presence of ex-post regulation generates lower aeronautical charges; thus, it appears that airports generally resist the lure of fully exerting their market-power when liberalized from regulation. Instead, liberalized airports attempt to attract increased traffic via lower aeronautical charges. Fourth, our results suggest – in contrast to Bel and Fageda (2010) – that privatized airports do not tend to increase aeronautical charges, but rather tend to decrease aeronautical charges. Accordingly, it appears that airport privatization may lead to efficiency gains which are passed off to airlines in the form of lower aeronautical charges, and/or may allow airport managers to be more innovative in attracting additional customers via lower aeronautical charges. Fifth, hub airports – per expectation – involve higher aeronautical charges than non-hub airports; though, it should be noted that we have only a few instances of airports changing from hub to non-hub status in our sample. Fifth, our results indicate that any changes in the number of nearby airports competing with the focal airport do not significantly affect aeronautical charges; thus, competition between airports does not seem to involve pricing discipline at this point.

In terms of future work, we see a few different areas for potential extensions of this study. For one, the lower aeronautical charges associated with ex-post regulation is one finding that merits further investigation. Many of the airports in our sample subject to ex-post regulation are located in the UK, and it was believed by local authorities that these airports faced a significant degree of competition for their services. Yet, the monitoring role of local authorities and the potential threat of re-regulation may also be the source of lower charges under ex-post regulation. Accordingly, a study that identifies the actual mechanisms via which ex-post regulation leads to lower charges would be of significant merit. A second area of fruitful research may be in further understanding the impact of privatization on aeronautical charges. As noted, the privatization/aeronautical-charges relationship is complicated due to it potentially involving multiple effects; thus, there may be merit in uncovering and identifying these different effects and determining the conditions which explain when one effect dominates others. For instance, under what conditions might privatization lead to higher aeronautical charges? A third area for future empirical work could be in extending this analysis to Oceania and Asia where – like in Europe – a degree of policy experimentation has been undertaken concerning airports.

Understanding the link between changes in airport regulation and privatization is crucial from a policy perspective, as regulatory authorities throughout the world are increasingly experimenting with both the form of ownership and the form of regulation for airports. Despite this experimentation, a particular concern has been whether liberalization of regulatory policy and ownership conditions might lead to airports increasingly exercising their market power vis-à-vis the airlines which use airport facilities and services. Such an exercising of market power would clearly be at the ultimate detriment to the travelling public. The empirical results we present suggest that experimentation in airport regulation and privatization has not come at the expense of increased market power and lower social welfare. For one, far from charging higher prices for aeronautical services, privatized airports tend to have lower aeronautical charges. Furthermore, while our evidence suggests that experiments with price-cap regulation have not led to significantly lower aeronautical charges, the single-till and ex-post regulatory innovations have succeeded in that they have generally lead to lower aeronautical charges. These results suggest that airport regulatory authorities do not need to consider social welfare losses via higher aeronautical charges as a necessary tradeoff when allowing private sector investment and altered regulatory frameworks. Thus, these early empirical lessons yield important first-order policy implications as airport authorities continue to search for the optimal mix of public policies concerning regulation and privatization.

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Appendix

List of Airports

IATA Code	Airport / Country	IATA Code	Airport / Country
ABZ	Aberdeen, UK	LHR	London Heathrow, UK
AHO	Alghero, Italy	LIL	Lille, France
AMS	Amsterdam, The Netherlands	LJU	Ljubljana, Slovenia
ATH	Athens, Greece	LPL	Liverpool, UK
BFS	Belfast, UK	LTN	London Luton, UK
BHX	Birmingham, UK	LYS	Lyon, France
BLQ	Bologna, Italy	MAN	Manchester, UK
BRE	Bremen, Germany	MLA	Malta International, Malta
BRS	Bristol, UK	MME	Durham Tees Valley, UK
BRU	Brussels, Belgium	MRS	Marseille, France
BTS	Bratislava, Slovakia	MUC	Munich, Germany
CAG	Cagliari, Italy	NAP	Naples, Italy
CGN	Cologne/Bonn, Germany	NCE	Nice, France
CPH	Copenhagen, Denmark	NCL	Newcastle, UK
CTA	Catania, Italy	NUE	Nuremberg, Germany
CWL	Cardiff, UK	OLB	Olbia, Italy
DTM	Dortmund, Germany	OSL	Oslo, Norway
DUS	Düsseldorf, Germany	PMO	Palermo, Italy
EDI	Edinburgh, UK	PSA	Pisa, Italy
EMA	East Midlands, UK	RIX	Riga, Latvia
FLR	Florence, Italy	SCN	Saarbruecken, Germany
FRA	Frankfurt, Germany	SOU	Southampton, UK
GLA	Glasgow, UK	STN	London Stansted, UK
GOA	Genoa, Italy	STR	Stuttgart, Germany
GVA	Geneva, Switzerland	SZG	Salzburg, Austria
HAJ	Hanover, Germany	TRN	Turin, Italy
HAM	Hamburg, Germany	TRS	Trieste, Italy
LBA	Leeds Bradford, UK	VCE	Venice, Italy
LCY	London City, UK	VIE	Vienna, Austria
LEJ	Leipzig, Germany	ZRH	Zurich, Switzerland
LGW	London Gatwick, UK		

A Robust Approach for the Airport Gate Assignment

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Abstract

Airport gate assignment is a critical issue for the operation management of an airport. Airport gate assignment is to assign flights to gates according to their real-time arrival time and departure time, such that each flight is assigned to exactly one gate, and there is no conflict be- tween two consecutive flights assigned to the same gate. We formulate the airport gate assignment as a stochastic binary integer programming, in which the real-time arrival and departure time are stochastic parameters. Concerning the real-time flight disturbance, a robust approach is introduced to protect the airport gate assignment from flight disturbance such as flight delay or early arrival. Instead of making strong assumption on the distribution of the real-time arrival and departure time of a flight, we assume that they belong to pre-specified uncertainty sets. The robust approach is to make sure that the airport gate assignment is feasible for all possible value for the real-time arrival and departure time within their uncertainty sets. Under these uncertainty sets, we can transform the stochastic binary integer programming to a mix integer programming. The computational re- sults on the real-life test data from Hong Kong International Airport demonstrate that our robust approach can avoid realtime gate conflict efficiently.

Keywords: airport gate assignment, robust optimization, uncertainty set

1. Introduction

Airport gate assignment (AGA for short) is a critical issue for the operation management of an airport. In practice, flights are assigned to airport gates according to their schedule, i.e., their scheduled arrival time and departure time. Table 1 illustrates the scheduled arrival and departure time, and the real-time arrival and departure time for six flights in the Hong Kong International airport.

Table 1: Arrival and departure time of six flights of Hong Kong International Airport

Flight	Arrival	Departure	Real-time Arrival	Real-time Departure	Route	Airline
CA101/102	11:25	12:45	11:23	12:50	Beijing-Hong Kong	Air China
LH738/739	11:30	13:10	11:31	13:30	Frankfurt-Hong Kong	Lufthansa
TG600/601	11:45	12:45	11:50	12:55	Bankok-Hong Kong	Thai Airway
JL710/702	13:15	15:00	13:15	15:14	Osaka-Hong Kong	Japan Airlines
BR869/870	14:25	15:30	14:23	15:32	Taipei-Hong Kong	EVA Air
SQ862/861	14:20	16:00	14:22	16:10	Singapore-Hong Kong	Singapore Airlines

The airport operation center normally locks the gate for a flight at its arrival time and release the gate at its departure time. Thus, a feasible airport gate assignment must satisfy the following two constraints:
1. Each flight is assigned to exactly one gate.
2. No two flights can be assigned to the same gate concurrently. In other words, if a gate is locked for one flight, it can not serve another flight until it is released.

However, in real-time operation, flight delays or early arrivals often occur. According to the schedules of two flights assigned to the same gate, even though there is no overlap of time durations they occupy the gate, there may be conflict between the two flights due to flight delay or early arrival. For example, according to the scheduled arrival and departure time, flight LH738/739 and flight JL710/702 can be assigned to the same gate without gate conflict, but due to the flight delay of LH738/739, there is gate conflict in real-time operation. After JL710/702 arrives at Hong Kong International Airport, it is forced to wait on the ramp or even in the air. Therefore, considering the real-time flight disturbance, we should consider the arrival time and departure time of a flight as random parameters rather than deterministic ones, and design a robust airport gate assignment (RAGA for short) framework to protect the system from uncertainty in the operation.

Consider n gates, in which all gates have a uniform service starting time s and service finishing time t ($0 \leq s < t \leq 24$). Consider a flight set $F = \{1, . . . , m\}$ of m flights, in which each flight i has a scheduled arrival time a_i and a scheduled departure time d_i ($s \leq a_i < d_i \leq t$).

Let $\tilde{a}_i$ denote the real-time arrival time for flight i and let $\tilde{d}_i$ denote the real-time departure time for flight i. Accordingly, let $\tilde{l}_{ij} = \tilde{a}_j - \tilde{d}_i$ denote the real-time gap between any two flights. We can thus define a feasible solution to the AGA as: n sequences $\{S_1, . . . , S_n\}$ which consist of all elements of F , and each element of F appears exactly once in a sequence; there is no gate conflict between two consecutive flights which are assigned to the same gate, which means, for any two consecutive elements i and j in a sequence, the real-time gap $\tilde{l}_{ij} \geq 0$.

Related Work

In the literature, the airport gate assignment problem which is to minimize the total walking distance of customers has been deeply researched. This kind of problem has been studied by Babic et.al [1], Xu and Bailey [10], and Zhu et.al [13] with binary integer program-ming, tabu search, and generic algorithm, respectively. Furthermore, airport gate assignment problem with multiple objective was formulated by Yan et.al [11] as a multi-commodity network flow model, and was solved by Lagrangian Relaxation.

For deterministic airport gate assignment problem, buffer time between two flights was adopted by Hassounah and Steuart [8], and Yan and Chang [11] to avoid real-time flight con- flicts. Buffer time is not flexible enough to address the flight disturbance in the real-time opera- tion. Therefore, Yan and Tang [12] considered stochastic flight delays and provided a gate-flow network model.

Robust airport gate assignment was initiated by Lim and Wang [9]. They modeled the robust airport gate assignment as a stochastic programming model and transformed it into a binary programming model by introducing the un-supervised estimation functions without knowing any information on the real-time arrival and departure time of flights in advance. In their paper, due to the NP-hardness of the graph coloring model, they proposed a hybrid meta-heuristic combining a tabu search and a local search to solve their model.

Recently, Ben-Tal and Nemirovski [2–4] provided a framework for convex optimization prob- lems for which the data is not specified exactly and it is only known to belong to a given uncertainty set. Moreover, Bertsimas and Sim [5, 7, 6] developed a robust approach for linear optimization and extendeded it for discrete optimization. Based on their work, we can assume that the real-time gap between two flights belongs to a pre-specified uncertainty set and establish our robust approach for the AGA.

Our Results and Significants

The main results of this paper and their significants are as follows:
1. We give a new formulation for the AGA. Compared to the graph coloring model raised in Lim and Wang [9], our model determines not only the flights to be served by a gate but also the order of these flights to be served within a gate.
2. Based on the formulation of the AGA, we further develope the formulation for the RAGA, which takes the uncertainty sets of the random parameters into consideration. Based on the weak duality, we can transform the AGA with random parameters into a mix integer programming.
3. The RAGA model can help the airport operation center to evaluate the gate capacity when there is new flights to be added to the airport.

4. The RAGA model also has high impact to help airlines to estimate how many fixed gates should buy or rent from airport to serve their own flights.

Organization

Section 2 introduces a "general" AGA model defined on a set which consists all the gates and flights. Based on a feasible solution to the "general" AGA, a feasible solution to the AGA can be obtained. In Section 3, the robust airport gate assignment (RAGA) is introduced. In section 4, numerical experiments based on the data collected from Hong Kong International Airport are conducted to show the efficiency of our RAGA model. Finally, this paper is concluded in Section 5.

2. Preliminaries

Since each gate has a service starting time s and a service finishing time t, then it can be considered as a flight with real-time arrival time t and departure time s, which indicates that each flight i can be arranged after the gate if $\tilde{a}_i \geq s$ and each flight i can be arranged before the gate if $\tilde{d}_i \leq t$. Therefore, let us consider a general flight set $F' = \{1, \ldots, m, m+1, \ldots, m+n\}$ which consists m flights and n gates. For $m+1 \leq i \leq m+n$, we define $\tilde{a}_i = t$ and $\tilde{d}_i = s$. We can then give the formulation of the general airport gate assignment (GAGA).

$$\sum_{i=1}^{m+n} y_{ij}=1, \forall i \quad (1)$$

$$\sum_{j=1}^{m+n} y_{ij}=1, \forall j \quad (2)$$

$$\sum_{j=1}^{m+n} y_{ij}\tilde{l}_{ij} \geq 0, \forall i \quad (3)$$

$$y_{ij} \in \{0,1\}, \ \forall i \ \forall j \quad (4)$$

in which y_{ij} is the decision variable representing that whether or not flight i is followed immediately by flight j in the same gate. Constraint (1) and (2) indicate that each flight follows one flight and is followed by one flight. Constraint (3) indicates that any two consecutive flights which are assigned to the same gate must have non-negative real-time gap.

Based on a feasible solution $y = \{y_{ij} : 1 \leq i \leq m+n, 1 \leq j \leq m+n\}$ which satisfies constraints (1)-(4), we define a mapping $\sigma : F' \rightarrow F'$, in which $\sigma(i) = j$ if $y_{ij} = 1$. Since y satisfies constraint (1) and (2), it is easy to verify that σ is bijective. We can then construct a feasible solution to the AGA from y by Algorithm 1.

Algorithm 1

Input: *A feasible solution y to the GAGA, in which the general flight set consists of m flights and n gates.*

Output: *A sequence set* $S = \{S_1, \ldots, S_n\}$ *which consists of m flights.*
1. *Set* $i = m+1$.
2. *Repeat the following while* $i = m+n$.
(a) *Set* $S_i = \emptyset$, *set* $k = i$
(b) *Repeat the following until* $\sigma(k) \in \{m+1, \ldots, m+n\}$:
i. *Add* $\sigma(k)$ *to* S_i *as the last element.*
ii. *Set* $k = \sigma(k)$
(c) *Set* $i = i+1$.
3. *Return* $S = \{S_1, \ldots, S_n\}$.

In Algorithm 1, for each gate i, where $m+1 \leq i \leq m+n$, we find the flight immediately follows i and add it to the sequence S_i, and in each iteration of step 2(b), we find the flight which immediately follows the last element of sequence S_i until the last element of S_i is directly followd by a gate. In the following theorem, one can see that the sequence set $S = \{S_1, \ldots, S_n\}$ returned by Algorithm 1 is a feasible solution to the AGA.

Theorem 1. *Given a feasible solution y to the GAGA, Algorithm 1 returns a feasible solution to the AGA.*

Proof. Since y satisfies constraint (3), we can prove that in each iteration of Step 2(b) of Algorithm 1, the element $\sigma(k)$ added to Si is different from all elements which have already existed in Si as follows. By contradiction, suppose $\sigma(k)$ is added after the element t, and $\sigma(k)$ appears before t in the sequence Si.

According to constraint (3), we have $\tilde{l}_{\sigma(k)t} \geq 0$, i.e., $\tilde{a}_t - \tilde{d}_{\sigma(k)} \geq 0$, and we have $\tilde{l}_{t\sigma(k)} \geq 0$, i.e., $\tilde{a}_{\sigma(k)} - \tilde{d}_t \geq 0$. Since $\tilde{a}_t < \tilde{d}_t$, we can conclude that $\tilde{a}_{\sigma(k)} \geq \tilde{d}_{\sigma(k)}$, which is a contradiction. Since in each iteration of Step 2(b) of Algorithm 1, a new element of of $\{1, \ldots, m\}$ is added to Si, there are at most m iterations for each i. Since the mapping σ is bijective and a new element is added to Si in each iteration of Step 2(b), we can see each element of $\{1, \ldots, m\}$ appears exactly once in a sequence. Due to constraint (3), we can see that any two consecutive element i and j in the same sequence satisfies that $\tilde{l}_{ij} \geq 0$. Therefore, the sequence set $S = \{S1, \ldots, Sn\}$ is a feasible solution to the AGA.

Example 1

We use the following example to show how to transform a feasible solution y of the GAGA to a feasible solution of the AGA by Algorithm 1. Consider an airport with two gates and three flights. The general flight set can be constructed as $F' = \{1, 2, \ldots, 5\}$, in which flight 4 and 5 in F' represent the two gates. If there is a feasible solution y to the GAGA as listed in Table 2

Table 2: A feasible solution to the GAGA

yij	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$
$i = 1$	0	0	0	1	0
$i = 2$	0	0	1	0	0
$i = 3$	0	0	0	0	1
$i = 4$	1	0	0	0	1
$i = 5$	0	1	0	0	0

For Algorithm 1, since $m = 3$ and $n = 2$, in step 1, set $i = m + 1 = 4$. In the first iteration of step 2, we find all flights which are served by the first gate. Since $\sigma(4) = 1$, in step 2(b), add 1 to $S1$ as the last element and set $k = \sigma(4) = 1$. Since $\sigma(1) \in \{4, 5\}$, then set $i = 5$ and Algorithm 1 goes to the next iteration of step 2. Since $i = 5 = m + n$, then Algorithm 1 goes to step 3 after this iteration. In the second iteration of step 2, we find all flights which are served by the second gate. Similarly, since $\sigma(5) = 2$, add 5 to $S2$ as the last element and set $k = 2$. Since $\sigma(2) = 3$, add 3 to $S2$ as the last element and set $k = 3$. Since $\sigma(3) = 5 \in \{4, 5\}$, then this iteration of step 2 terminates and Algorithm 1 goes to step 3. In step 3, return $\{S1 = \langle 1 \rangle, S2 = \langle 2, 3 \rangle\}$.

3. Robust Airport Gate Assignment

Based on Theorem 1, we can only consider the general flight set F with $|F| = m$ which consists all the gates and flights, and base the robust airport gate assignment on the GAGA. Note that the real-time arrival time $\tilde{a}i$ and the departure time $\tilde{d}i$ of the flight i are random parameters. Clearly, if flight i in the general flight set F represents a gate, we have $\tilde{a}i = t$ and $\tilde{d}i = s$. Instead of making a strong assumption on the distribution of the real-time gap between two flight, we assume that $\tilde{l}ij = \tilde{a}j - \tilde{d}i$ belongs to a symmetric interval $[\bar{l}ij - \hat{l}ij, \bar{l}ij + \hat{l}ij]$, where $\bar{l}ij$ is the mean for $\tilde{l}ij$, and $\hat{l}ij$ is the worse-case deviation from its mean. Let $\tilde{l}i = (\tilde{l}i1, \ldots, \tilde{l}im)$. We can define the uncertainty set Li for $\tilde{l}i$ as

$$L_i = \{\tilde{l}_i : \tilde{l}_i \in Z^m,\ \bar{l}_{ij} - \hat{l}_{ij} \leq \tilde{l}_{ij} \leq \bar{l}_{ij} + \hat{l}_{ij}\} \quad (5)$$

Since Li is the worse-case uncertainty set for $\tilde{l}i$, it is conservative to consider all possible value in this uncertainty set. Instead, let

$$z_{ij} = \frac{\tilde{l}_{ij} - \bar{l}_{ij}}{\hat{l}_{ij}}$$

denote the deviation of $\tilde{l}_{ij}$ from its mean $\bar{l}_{ij}$. Accordingly, let $z_i = (z_{i1}, \ldots, z_{im})$. Restrict the norm of z_i as $\|z_i\| \leq \Gamma$. We can obtain a uncertainty set $L_i(\Gamma)$ as follow

$$L_i(\Gamma) = \{\tilde{l}_i : \tilde{l}_i \in Z^m,\ \bar{l}_{ij} - \hat{l}_{ij} \leq \tilde{l}_{ij} \leq \bar{l}_{ij} + \hat{l}_{ij},\ \|z_i\| \leq \Gamma\} \tag{6}$$

Recall that the AGA requires any two consecutive flights which are assigned to the same gate to have non-negative real-time gap. Since the real-time gap $\tilde{l}_i$ is a random vector, under the assumption that $\tilde{l}_i$ belongs to the uncertainty set $L_i(\Gamma)$, our robust approach for the AGA is to ensure that constraint (3) is not violated for any possible value in $L_i(\Gamma)$, which means, for any possible value in $L_i(\Gamma)$, flight i and the flight which follows i have no gate conflict.

Furthermore, since the norm Γ of z_i is the budget of uncertainty, to maximize the reliability of the airport gate assignment is to guarantee that there exists a solution which is feasible for all possible value in the largest uncertainty set. Thus, the goal of the RAGA is to maximize the budget of uncertainty Γ. Therefore, we can define our robust airport gate assignment (RAGA) as follows:

$$max\Gamma \tag{7}$$

$$\sum_{i=1}^{m} y_{ij}=1, \forall i \tag{8}$$

$$\sum_{j=1}^{m} y_{ij}=1, \forall j \tag{9}$$

$$\sum_{j=1}^{m} y_{ij}\tilde{l}_{ij} \geq 0, \forall i, \forall \tilde{l}_i \in L_i(\tilde{\Gamma}) \tag{10}$$

$$y_{ij} \in \{0,1\}, \forall i, \forall j \tag{11}$$

Since $\tilde{l}_{ij} = \bar{l}_{ij} + z_{ij}\hat{l}_{ij}$, then constraint (10) is equivalent to

$$\sum_{j=1}^{m} y_{ij}\bar{l}_{ij} - max_{z_i}\sum_{j=1}^{m} z_{ij}y_{ij}\hat{l}_{ij} \geq 0 \tag{12}$$

$$\|z_i\| \leq \Gamma \tag{13}$$

How to choose the norm $\|\cdot\|$ is closely related to the tractability of the RAGA. By choosing $\|z_i\| = \|z_i\|_1 = \sum_j |z_{ij}|$, we can transform the RAGA to a mix integer programming (MIP).

Theorem 2. *Under the uncertainty set $L_i(\Gamma)$, the RAGA can be transformed into a MIP by* replacing constraint (10) as the constraints below

$$\sum_{j=1}^{m} y_{ij}\bar{l}_{ij} - \Gamma p_i - \sum_{j=1}^{m} q_{ij} \geq 0, \forall i \tag{14}$$

$$p_i + q_{ij} \geq \hat{l}_{ij}y_{ij},\ \forall i, \forall j \tag{15}$$

$$p_i \geq 0,\ \forall i \tag{16}$$

$$q_{ij} \geq 0,\ \forall i, \forall j \tag{17}$$

Proof: Considering the problem

$$max_{z_i}\sum_{j=1}^{m} z_{ij}y_{ij}\hat{l}_{ij} \geq 0$$
$$\|z_i\|_1 \leq \Gamma,$$

Since $y_{ij}\hat{l}_{ij} \geq 0$, for all $1 \leq i, j \leq m$, it is equivalent to

$$max_{z_i} \sum_{j=1}^{m} z_{ij} y_{ij} \hat{l}_{ij} \geq 0,$$

$$\sum_{j=1}^{m} |z_{ij}| \leq \Gamma$$

$$0 \leq z_{ij} \leq 1 \ \forall j.$$

Its dual problem is $\min (\Gamma p_i + \sum_{j=1}^{m} q_{ij})$

$$p_i + q_{ij} \geq \tilde{l}_{ij} y_{ij}, \ \forall i, \forall j$$

$$p_i \geq 0, \ \forall i$$

$$q_{ij} \geq 0, \ \forall i, \forall j.$$

Thus, due to the weak duality, for the RAGA, constraint (12) and (13) are equivalent to constraints (14)-(17) under $\| \cdot \|1$, which in turns implies that constraint (10) is equivalent to constraints (14)-(17).

In order to construct the RAGA, it is necessary to estimate the parameters $\bar{l}ij$ and $\hat{l}ij$. Suppose we have N historical data $l_{ij}^{(k)} = a_j^{(k)} - d_i^{(k)}$ for $\tilde{l}_{ij}$, for $1 \leq k \leq N$. Thus, we can use the sample mean for $\tilde{l}ij$ to estimate $\bar{l}ij$. Furthermore, according to the 3σ principle, for the random parameter $\tilde{l}ij$, the probability that $\tilde{l}ij$ deviates from its mean more than three times the variance is less than 0.003. Thus, we can use three times the sample variance for $\tilde{l}ij$ to estimate the worse-case deviation $\hat{l}ij$.

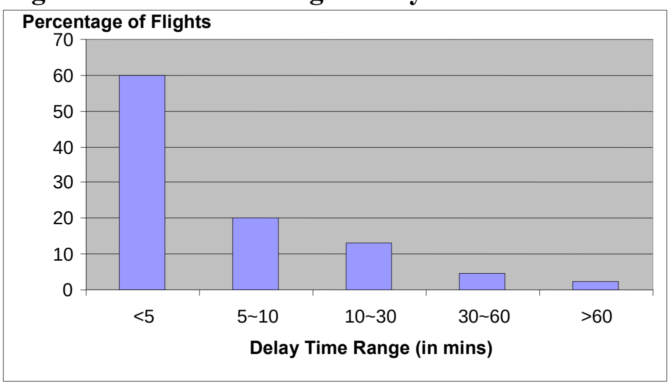
After we specify all the parameters of the RAGA, we can not solve the RAGA directly because both Γ and pi are decision variables, which indicates that the RAGA is a quadratic programming. It is observed that for any given Γ, the RAGA is a linear programming. Therefore, since Γ belongs to a bounded interval [0, 1], a binary search is conducted to obtain a close optimal value for Γ. The optimal $\Gamma *$ is returned as the greatest $\Gamma \in [0, 1]$ such that the RAGA has a feasible solution.

4. Numerical Experiments

The data from Hong Kong International Airport is collected as the test data. The data consists of all records of real-time arrival time and departure time of all flights for 2 weeks. There are 255 flights to be served in the test data. There are in total 48 frontal gates and 27 aprons for Hong Kong International Airport.

Figure 1 shows the distribution of flight delay in the test data. For all records in the 2 weeks, 60% of flights delay less than five minutes, and 20% of flights delay from five to ten minutes, and 13% of flights delay from ten to thirty minutes, and only 4.5% flights delay from half an hour to one hour.

Fig. 1: Distribution of flight delay



We use all records for $\tilde{a}_j$ and $\tilde{d}_i$ to estimate $\bar{l}_{ij}$ and $\hat{l}_{ij}$, and solve the RAGA by ILOG CPLEX 9.0 to obtain a airport gate assignment. It takes 1.618 seconds for ILOG CPLEX 9.0 to obtain a feasible solution to the RAGA. We use the data in the two weeks to test the efficiency of the airport gate assignment. First, the average gate conflict and stand deviation of gate conflict under our proposed RAGA model are calculated. Second, we solve the AGA model according to the scheduled arrival time and scheduled departure time, and calculate the average gate conflict and the standard deviation of the gate conflict. Figure 2 compares the average gate conflict of these two approaches, and Figure 3 compares the standard deviation of gate conflict of these two approaches.

From these two figures, we can conclude that: our proposed RAGA model can develop robust airport gate assignment to deal with real-time flight disturbance. Only 60 gates are sufficient for the airport to avoid real-time gate conflict for most of the test data while there are in total 78 gates in the Hong Kong International Airport. When we solve the AGA according to the scheduled arrival and departure time of all flights, the the real-time flight disturbance is ignored.

Fig. 2. Average of gate conflict of RAGA and AGA (schedule)

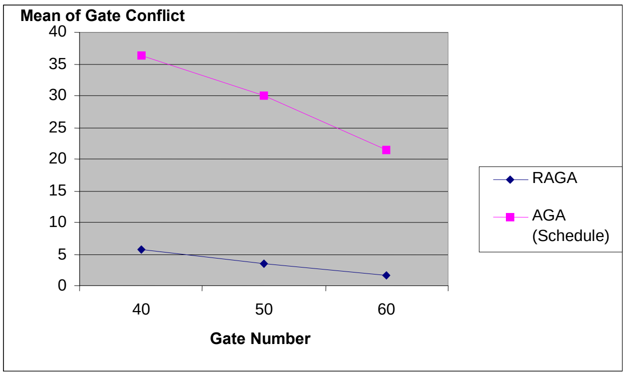
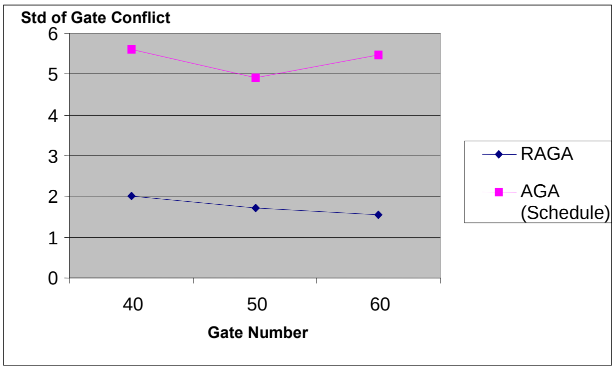


Fig. 3. Standard deviation of gate conflict of RAGA and AGA (schedule)



Our proposed RAGA model performs better than AGA model without considering uncertainty. Moreover, when the RAGA model is restricted on flights belonging to a airline, the minimum number of gates which can serve all the flights without gate conflict can be estimated. Thus, airlines can evaluate the minimum number of gates they should buy or rent from the airport according to our proposed RAGA model. On the other hand, our proposed RAGA model can be used to evaluate the gate capacity when there are new flights to be added in the airport.

In addition, we will compare our proposed RAGA model and the approach proposed by Lim and Wang [9]. They define $p(i, j)$ as the probability distribution function on gate conflict between two flights i and j if they are assigned to the same gate. In their work, they assign flights to airport gate without determining the sequence of all flights assigned to the same gate. Therefore, they formulated the airport gate assignment as a graph coloring model, in which all flights are colored by different colors. Flights with the same color are assigned to the same gate, and the total expected probability of gate conflict within all the flights assigned to the same gate is calculated. The goal is to minimize the total expected probability of gate conflict for all the gates. Since the graph coloring model does not determine the sequence of all flights assigned to the same gate, the expected probability of gate conflict is calculated by summing up the expected probability of gate conflict for every two flights assigned to the same gate. However, for airport gate assignment, the probability of gate conflict between two consecutive flights is much more important. The drawback of the graph coloring model lies in that the objective function does not estimate the expected probability of the gate conflict accurately. Therefore, we combine the definition of the $p(i, j)$ and our AGA model to establish the following stochastic programming model for the robust airport gate assignment which minimizes the total expected gate conflict probability (RAGA-Lim and Wang):

$$max \sum_{i,j} E(p(i,j))\, y_{ij} \qquad (18)$$

$$\sum_{i=1}^{m} y_{ij}=1\ \forall i \qquad (19)$$

$$\sum_{j=1}^{m} y_{ij}=1\ \forall j \qquad (20)$$

$$\sum_{j=1}^{m} y_{ij}\tilde{l}_{ij} \geq 0\ \forall i, \forall \tilde{l}_i \in L_i\tilde{(}\Gamma) \qquad (21)$$

$$y_{ij} \in \{0,1\} \forall i \forall j \qquad (22)$$

It is noticed that for this model, the objective function consists of the expected probability of gate conflict for consecutive flights which are assigned to the same gate.

Lim and Wang introduced an estimation function $e(i, j)$ to estimate the expected value of the probability of the gate conflict between flight i and j based on lij . This un-supervised estimation function $e(i, j)$ is only based on the scheduled time gap between flight i and j without considering the historical data. In their work, they set $e(i, j) = exp(-\beta lij)$, where $\beta = -0.03$, and they set

$$E(p(i,j)) = \frac{max\{e(i,j)\} - e(i,j)}{max\{e(i,j)\} - min\{e(i,j)\}}$$

Figure 4 compares the average gate conflict of these two approaches, and Figure 5 compares the standard deviation of gate conflict of these two approaches.

Fig. 4: Average of gate conflict of RAGA and RAGA-Lim and Wang

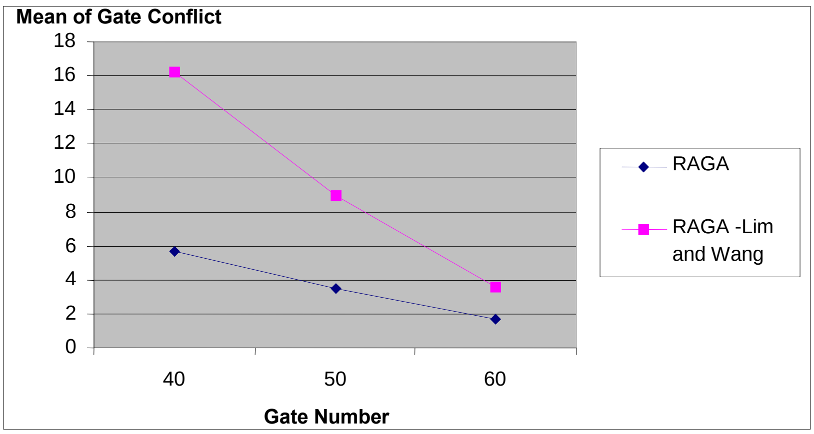
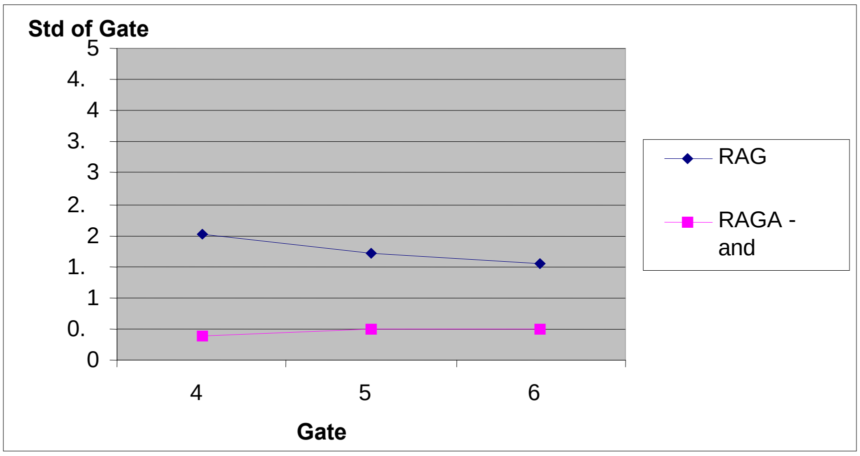


Fig. 5: Standard deviation of gate conflict of RAGA and RAGA-Lim and Wang



From these two figures, we can conclude that: both of the two approaches have small standard deviation which indicates that these two approaches have stable performance. Moreover, our proposed RAGA model has a better average gate conflict than RAGA-Lim and Wang, especially when the numer of gate is small.

5. Conclusion

In this paper, we proposed a new robust approach for the airport gate assignment, which can deal with the real-time flight disturbance. Computational results on real-life data demonstrate that the proposed RAGA model can efficiently avoid gate conflict.

Since the worse-case deviation is to some extend conservative for the uncertainty set of the real-time gap between two flights, in practice, more related features such as weather, air traffic control, peak time should be considered for a more accurate estimation of the uncertainty set for the real-time gap. Our future research will focus on constructing more accurate estimation of the uncertainty set for the real-time gap.

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Spoke-Entry and Airline Network Reformation

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Abstract

A major carrier uses city H as its hub to link multiple non-hub cities A, B, etc. Given an entry on its spoke AH, it considers whether or not to reform its network partially by starting to offer nonstop services on its rim route AB while (i) continuing to operate on; or (ii) withdrawing from the entered spoke AH. Under a schedule competition model, the analysis shows that reformation (i) is profitable if connecting passengers' hub-through additional time cost is sufficiently large. However, reformation (ii) could be profitable if and only if the entry/exit costs and the mentioned time cost are sufficiently small. Otherwise, continuing to operate its initial hub-spoke network is reasonable. The welfare analysis shows that reformation (ii) is welfare-improving in a certain large range. However, the network carrier has less incentive to do so. This suggests the necessity for a transport policy to encourage this type of network reformation.

Keywords: airline network, spoke-entry, secondary hub

JEL: L13, L93

1. Introduction

After airline deregulation, major carriers have transformed their networks into the hub-spoke type. The economic efficiency of hub-spoke networks may generate from economies of traffic density on cost side and/or from flight frequencies effects on demand side. These are known as "hub-spoke network effects" in the industry. On the other hand, regional carriers as well as low-cost carriers had successfully entered some spoke routes (the routes link a hub city) of major carriers. Doubtlessly, this spoke-entry weakens major carriers' hub-spoke network effects, and it may compel major carriers to reform their networks.

Dunn (2008, Table 1) showed that US hub carriers had an entry rate of 49.15% in non-hub city pair markets from 1996 to 2000. Bamberger and Carlton (2006, Figure 7) also showed overwhelmingly large number of entry to non-hub city pair markets by US major carriers from 1991 to 2003. In addition, some major carriers (e.g., Delta and US Airways, in 2000) offered nonstop services between their own non-hub cities (see Dunn, 2008 for the corresponding markets). This type of nonstop entry links the related cities directly and hence, leads a partial fully-connected network of major carriers.

This movement of nonstop entries arise the issue of the efficiency between hub-spoke and fully-connected network, which has been intensively debated by previous works. Another straightforward question arises here is that, suppose if the nonstop entry to rim routes is considerable, then why not major carriers also consider withdrawing the entered spoke routes, so as to drive the hub-spoke network effect, again. This paper investigates the partial network reformation of a major carrier, which may be stimulated by the spoke-entry.

In the previous studies, the issue of entry is popular (see footnote 2) whereas the issue of exit is spare. Hendricks et al. (1997) consider a hub carrier's exit from one spoke route where a competitor exists. They demonstrated that as long as the network size is large enough, it is a dominant strategy for the hub operator not to exit from. However, the nonstop entry to rim routes is no included in their model. As an essential differentiation from the previous studies, this present paper investigates major carriers' network reformation including entry in and exit from different routes on its network. The relevant impacts on social welfare are also examined.

To address this issue, consider a major carrier who uses city H as its hub to link multiple destination cities and highlight on cities A and B only. In this (partial) network, there are two spokes AH and BH and one rim market AB where the two direct flights connect at the hub. An entrant enters one of the two spokes (specified as AH). In response to the spoke-entry, the network carrier is considering whether or not to reform its network. Three plausible networks could be formed as follows:

network-SE (spoke-entry): the initial hub-spoke network with spoke-entry.

network-FC (fully-connected): the network carrier continues to offer direct flights AH and BH while starting to operate direct flight AB.

network-NH (new-hub): it starts to operate direct flight AB while withdrawing direct flight AH, and this creates a secondary hub B.

One major feature of the paper is the schedule competition. There is a fixed entry (exit) cost for operating new (withdrawing existing) direct flights on a certain route. Symmetric market size and identical operating costs are assumed. Three critical but realistic assumptions for passengers are imposed. A connecting passenger might incur a higher additional travel time cost by flying through a hub city than if there were direct flights at their disposal (see Oum et al., 1995 and Kawasaki, 2008). If there is a nonstop service in a particular market, then passengers do not use the one-stop service of the same carrier. Connecting passengers do not use inter-line connecting flights.

The analysis first shows that, including the entry cost consideration, shifting network-SE to FC is profitable if connecting passengers' hub-through additional time cost is sufficiently large. This theoretical finding is intuitive and it may provide a reasonable justification of nonstop entries by network carriers. However, shifting network-SE to NH could be profitable if and only if the entry and exit costs and the mentioned time cost are sufficiently small. This finding supports the indication by Dunn (2008) that the US hub carriers at their hub only had an exit rate of 1.33% in their spoke markets from 1996 to 2000.

The intuitions behind the second finding are sensible. The network carrier benefits from the flight frequencies effect under both hub-spoke type networks. However, the interesting difference is that the entrant operates on its spoke (rim) route in network-SE (NH). The shift allows the network carrier to operate spoke BH and AB which are monopolized by itself, but it induces a tough competition on market AH because its connecting flight BH-AB competes with the entrant's direct flight AH. In other words, the shift gives its competitor a competitive advantage by the existence of the mentioned time cost. As a consequence, the network shifting could be profitable only if the time cost is small enough to lead larger connecting passengers who use both the monopolized HB and AB routes (which increases the frequencies greatly) and this frequencies effect dominates its competitive disadvantage on market AH.

The second finding might be meaningful as it offers a theoretical explanation of why network reformations along with exit from primary spoke routes are less observed in the real world. In particular, the finding asserts that, even though the entry and exit costs are ignorable and the market size of the rim is symmetrically large, network reformation by using another airport as its (secondary) hub cannot be profitable, except its connecting passengers' time cost by flying through the airport is sufficiently small.

Furthermore, the welfare analysis finds that given an appropriate entry/exit costs, the socially superior network is network-FC (could be either network-SE or NH) when the mentioned time cost is large (small). Interestingly, network-NH is socially preferable to network-SE in a certain large range. However, the network carrier has less incentive to do so. The reason is that from the viewpoint of social welfare, the network reformation does not lose the frequencies effect (but quantitatively moved from AH-BH to BH-AB spokes) and it saves some of the mentioned time cost by the entrant direct flights (whereas there is no direct flight AB in network-SE). The network carrier has no concerns on the latter effect which is welfare-improving, and therefore the divergence emerges.

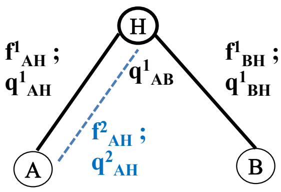
Section 2 presents the network structures and basic assumptions. Section 3 derives the outcomes. Section 4 compares the outcomes of the three networks. Section 5 investigates the optimal network structure for major carriers. Section 6 presents the social welfare analysis. Section 7 details the conclusions.

2. The Model

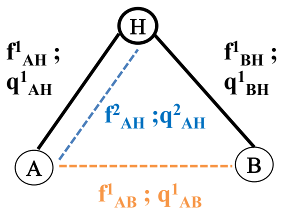
2.1. Network structures and carriers

Figure 1. Network structures

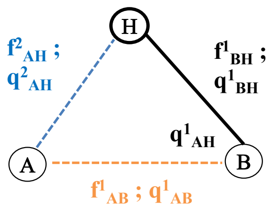
1-a. network-SE (Spoke-entry)



1-b. network-FC (Fully-connected)



1-c. network-NH (secondary new-hub)



Let us consider a partial network of a major carrier (Airline 1), in which its hub H links two non-hub cities A, B. Individuals living in each city wish to travel to other cities. All travel is assumed to be round trip. Therefore, there are two spoke markets (AH and BH) with direct flights and one rim market (AB) in which the two direct flights connect at its hub H. To make our analysis tractable, it is assumed that the two spoke markets are symmetric and that the potential demands for the three markets are the same.

Following the previous studies (e.g., Oum et al., 1995, Zhang, 1996, Hendricks et al., 1997, and Lin, 2005; 2008), it is supposed that a carrier (Airline 2) enters one of the spoke markets with nonstop services. Without loss of generality, the entered spoke is specified as the AH route. This spoke-entry gives Airline 1 an incentive of considering whether or not to reform its network. Three plausible networks are considered in our model.

network-SE: Airline 1 does not reform its network (Figure 1-a)

network-FC: it continues to operate direct flights AH and BH while starting to operate direct flight AB (Figure 1-b)

network-NH: it starts to operate direct flight AB while withdrawing direct flight AH, and this creates a secondary new hub B (Figure 1-c)

In each network, the two airlines compete by simultaneously choosing the flight frequency and quantity (the total traffic) of the corresponding market(s). Throughout the analysis, the airfares of Airlines i (i=1, 2) for city pair g-h (g, h = A,B,H, $g \neq h$) are represented as p^i_{gh}; the flight frequency and quantity of Airline i for city pair g-h are represented as f^i_{gh} and q^i_{gh}, respectively.

Following Brueckner (2004), operational costs of airlines services are captured on per direct flight basis. The operational cost per flight generally entails a fixed cost (e.g., landing fee, fuel cost, personnel cost, etc.) and a marginal cost per passenger. Following Brueckner and Zhang (2001) and Kawasaki (2008), the marginal cost is assumed to be constant and zero for simplification. Then, the operational cost per flight, which is assumed to be symmetric, can be captured as a fixed cost K. Furthermore, the fixed entry (exit) cost for operating new direct flights (withdrawing existing direct flights) on a certain route is denoted by F.

2.2. Passengers

Each passenger gains a benefit from using the airline service. Following Brueckner (2004), this benefit is assumed to be the sum of a travel benefit and a reduction in schedule delay cost. A travel benefit, which varies among passengers, is represented by w. The travel benefit w is assumed to be uniformly distributed over the interval $[-\infty, W]$ with density unity on each market. The passenger who evaluates a travel benefit as W prefers air travel and is willing to travel by air, while the passenger who has $w = -\infty$ might be a person who is afraid of flying and who will never fly on an aircraft.

The schedule delay cost crucially depends on flight frequencies. As a reasonable assumption that has been done by a number of airline studies (among others, Oum et al., 1995, Brueckner, 2004, Brueckner and Flores-Fillol, 2007, Kawasaki, 2008), this paper assumes that an increase of flight frequencies reduces the schedule delay cost, which in turn, benefits the passengers. Following Kawasaki (2008), the benefit from the frequency-increase on route j-h, is expressed as $\sqrt{f_{jh}}$ in our model. Hereafter, let us refer to this effect as the "frequencies effect" (or f-effect).

In addition, this paper formulates a benefit function for connecting passengers, which differs from that used in previous studies. For passengers traveling between cities j-k through hub-city h, the direct flights on route j-h and k-h are necessary for connecting. Consequently, their benefits depend on the frequencies on the two routes f_{jh} and f_{hk}. Following Oum et al. (1995), this paper assumes that the total reduction in the schedule delay cost is the sum of the reduction on each route. That is, if the reduction on route j-h is written as $d(f_{jh})$, then the total reduction for connecting j-k passengers will be denoted as $d(f_{jh}) + d(f_{hk})$.

This analysis further specifies a benefit function for connecting passengers as $d(f_{jh}) = (1/2)\sqrt{f_{jh}}$. This formulation includes the assumption that the marginal f-effect on spoke passengers is greater than that on connecting passengers. This assumption appears to be reasonable because connecting passengers must wait to change aircraft at a hub airport. Namely, if f_{jh} increases but f_{hk} does not, then the benefit (convenience) for the connecting j-k passengers cannot increase as large as that for the spoke j-h passengers.

Moreover, the described hub-through additional time cost is denoted by T. It is assumed that T is not extremely large so that a passenger who has at least w = W travels on the airline.

Finally, two critical but realistic assumptions are imposed in the analysis. First, given the existence of T, it is assumed that if there is nonstop service in a particular market, then passengers do not use the one-stop service of the same carrier. Second, connecting passengers do not use the inter-line connecting flights. The reason is that when connecting passengers change airlines at the hub airport, they incur a heavy dis-utility from moving to a different terminal, repeated check-in procedures, or an excessively long waiting time.
Under the above formulation and assumptions, the utility function for a j-k passenger can be written as follows:

$$u_{jk} = \begin{cases} w + \sqrt{f_{jk}} - p_{jk}, & \text{if traveling by direct flights} \\ w + (1/2)[\sqrt{f_{jh}} + \sqrt{f_{hk}}] - p_{jk} - T, & \text{if traveling via hub city h.} \end{cases} \quad (1)$$

3. Outcomes of the Three Networks

3.1. network-SE

As the first step, the demand functions will be generated. On the AH route, both Airline 1 and Airline 2 provide identical nonstop services, except for the frequency. The passengers (say the AH passengers) use one of the airlines so as to gain a higher utility. To lead passengers to use its services, each airline must set a hedonic price (i.e., the price adjusted for the frequency benefit) such that $p^1_{AH} - \sqrt{f^1_{AH}} = p^2_{AH} - \sqrt{f^2_{AH}}$. Let ϕ denote this common equal value. Then, the passengers who have $w \geq \phi$ use the airline services. As a result, the total number of passengers in market AH can be written as

(2) $$Q_{AH} \equiv q^1_{AH} + q^2_{AH} = W - \phi$$

Substituting the defined ϕ into (2), yields the demand functions as follows:

(3) $$p^1_{AH} = W + \sqrt{f^1_{AH}} - (q^1_{AH} + q^2_{AH})$$

(4) $$p^2_{AH} = W + \sqrt{f^2_{AH}} - (q^1_{AH} + q^2_{AH}).$$

In markets BH and AB, Airline 1 is a monopolist. In market BH (AB), a passenger who gains a non-negative utility will use Airline 1's direct flight (connecting flights) service. Then, the demand functions for the two markets can be derived and written as follows:

(5) $$p^1_{BH} = W + \sqrt{f^1_{BH}} - q^1_{BH}$$

(6) $$p^1_{AB} = W + (1/2)\left[\sqrt{f^1_{AH}} + \sqrt{f^1_{BH}}\right] - q^1_{AB} - T$$

The profit function of Airline 1 and that of Airline 2 can be written as:

(7) $$\pi_1 = p^1_{AH}(\cdot)q^1_{AH} + p^1_{BH}(\cdot)q^1_{BH} + p^1_{AB}(\cdot)q^1_{AB} - \left(f^1_{AH} + f^1_{BH}\right) \cdot K$$

(8) $$\pi_2 = p^2_{AH}(\cdot)q^2_{AH} - f^2_{AH} \cdot K$$

To make the analysis tractable, fixed cost K is normalized to be unity. Applying the Cournot supposition and solving the profit-maximization problems yield the corresponding first-order conditions for choices of q and f. The second-order conditions are satisfied. Then, the following equations can be derived by re-arranging the first-order conditions.

(9) $$q^1_{AH} = \left(W + 2\sqrt{f^1_{AH}} - \sqrt{f^2_{AH}}\right)/3$$

(10) $$q^1_{BH} = \left(W + \sqrt{f^1_{BH}}\right)/2$$

(11) $$q_{AB}^{1} = \left[W + \left(\sqrt{f_{AH}^{1}} + \sqrt{f_{BH}^{1}}\right)/2 - T\right]/2$$

(12) $$q_{AH}^{2} = \left(W - \sqrt{f_{AH}^{1}} + 2\sqrt{f_{AH}^{2}}\right)/3$$

(13) $$\sqrt{f_{AH}^{1}} = (q_{AB}^{1} + 2q_{AH}^{1})/4$$

(14) $$\sqrt{f_{BH}^{1}} = (q_{AB}^{1} + 2q_{BH}^{1})/4$$

(15) $$\sqrt{f_{AH}^{2}} = q_{AH}^{2}/2$$

Substituting (9), (11) into (13) yields the following (16). Substituting (10) into (11) yields (17), substituting (12) into (15) yields (18).

(16) $$\sqrt{f_{AH}^{1}} = \left(14W + 3\sqrt{f_{BH}^{1}} - 8\sqrt{f_{AH}^{2}} - 6T\right)/29$$

(17) $$\sqrt{f_{BH}^{1}} = \left(6W + \sqrt{f_{AH}^{1}} - 2T\right)/11$$

(18) $$\sqrt{f_{AH}^{2}} = \left(W - \sqrt{f_{AH}^{1}}\right)/4$$

Eq. (16)-(18) actually describe the strategic relationships between the carriers, which are similar to the Cournot quantity-setting model. Now, the corresponding outcomes listed in Table 1 can be obtained by solving the equations system of (9)-(15). The superscript "s" stands for the equilibrium values.

Table 1: Outcomes of network-SE (Spoke-entry)

Frequencies	$f_{AH}^{1s} = (25W - 12T)^2/2401$ $f_{BH}^{1s} = (29W - 10T)^2/2401$ $f_{AH}^{2s} = 9(2W + T)^2/2401$
Demands Fares	$q_{AH}^{1s} = p_{AH}^{1s} = (31W - 9T)/49$ $q_{BH}^{1s} = p_{BH}^{1s} = (39W - 5T)/49$ $q_{AB}^{1s} = p_{AB}^{1s} = (38W - 30T)/49$ $q_{AH}^{2s} = p_{AH}^{2s} = 6(2W + T)/49$ Sufficient non-negative condition: $q_{AB}^{1s} \geq 0 \leftrightarrow T \leq T_{q1AB}^{s} \equiv (19/15)W$
Profits	$\pi_1^s = 2(1230W^2 - 1024WT + 381T^2)/2401$. $\pi_2^s = 27(2W + T)^2/2401$.

3.2. network-FC

Airline 1 competes with Airline 2 with nonstop services on market AH. Because nonstop services are provided in each city-pair, there are no connecting passengers in this network. Correspondingly, the demand functions of markets AH and BH remain the same as network-SE, while that of market AB becomes

(19) $$p_{AB}^1 = W + \sqrt{f_{AB}^1} - q_{AB}^1$$

The profit function of Airline 2 does not change and that of Airline 1 changes as:

(20) $$\pi_1 = p_{AH}^1(\cdot)q_{AH}^1 + p_{BH}^1(\cdot)q_{BH}^1 + p_{AB}^1(\cdot)q_{AB}^1 - \left(f_{AH}^1 + f_{BH}^1 + f_{AB}^1\right) \cdot K - F,$$

where F is the fixed entry cost. Similarly, the following equations can be derived by re-arranging the first-order conditions for the two carriers.

(21) $$q_{AH}^1 = \left(W + 2\sqrt{f_{AH}^1} - \sqrt{f_{AH}^2}\right)/3$$

(22) $$q_{BH}^1 = \left(W + \sqrt{f_{BH}^1}\right)/2$$

(23) $$q_{AB}^1 = \left(W + \sqrt{f_{AB}^1}\right)/2$$

(24) $$q_{AH}^2 = \left(W - \sqrt{f_{AH}^1} + 2\sqrt{f_{AH}^2}\right)/3$$

(25) $$\sqrt{f_{AH}^1} = q_{AH}^1/2$$

(26) $$\sqrt{f_{BH}^1} = q_{BH}^1/2$$

(27) $$\sqrt{f_{AB}^1} = q_{AB}^1/2$$

(28) $$\sqrt{f_{AH}^2} = q_{AH}^2/2$$

(29) $$\sqrt{f_{AH}^1} = \left(W - \sqrt{f_{AH}^2}\right)/4$$

Using these corresponding equations yields the following equations.

(30) $$\sqrt{f_{BH}^1} = W/3$$

(31) $$\sqrt{f_{AB}^1} = W/3$$

(32) $$\sqrt{f_{AH}^2} = \left(W - \sqrt{f_{AH}^1}\right)/4$$

The strategic substitutive relationship between the two carriers appears in (32), that is, exists on market AH only. Solving the equations system of (21)-(32), yields the equilibrium values (noted by the superscript "c") listed in Table 2.

Table 2: Outcomes of network-FC (Fully-connected)

Frequencies	$f^{1c}_{AH} = W^2/25$, $f^{1c}_{BH} = W^2/9$, $f^{1c}_{AB} = W^2/9$, $f^{2c}_{AH} = W^2/25$
Demands Fares	$q^{1c}_{AH} = p^{1c}_{AH} = 2W/5$, $q^{1c}_{BH} = p^{1c}_{BH} = 2W/3$, $q^{1c}_{AB} = z\,p^{1c}_{AB} = 2\,W/3$, $q^{2c}_{AH} = p^{2c}_{AH} = 2W/5$
Profits	$\pi^c_1 = (59W^2/75) - F$, $\pi^c_2 = 3W^2/25$.

3.3. network-NH

Airline 1 competes with Airline 2 in market AH because the AH passengers have two different routings to choose from: Airline 1's one-stop services connected by direct flights HB and AB; and Airline 2's nonstop services. In other words, two vertically differentiated products exist in market AH. It is helpful for understanding our analysis by noting that the AB route becomes one of the two spoke routes, while the entered AH route becomes the rim route for Airline 1. Taking this into account, the demand functions for market AH can be derived and written as follows.

(33) $$p^1_{AH} = W + (1/2)\left[\sqrt{f^1_{BH}} + \sqrt{f^1_{AB}}\right] - (q^1_{AH} + q^2_{AH}) - T$$

(34) $$p^2_{AH} = W + \sqrt{f^2_{AH}} - (q^1_{AH} + q^2_{AH})$$

Note that markets BH and AB remain as a monopoly with Airline 1's nonstop services, and the demand functions are the same as (5) and (19), respectively. The profit function of Airline 1 changes as:

(35) $$\pi_1 = p^1_{AH}(\cdot)q^1_{AH} + p^1_{BH}(\cdot)q^1_{BH} + p^1_{AB}(\cdot)q^1_{AB} - \left(f^1_{BH} + f^1_{AB}\right)\cdot K - 2F,$$

where 2F are the exit and entry cost. Similarly, the useful equations derived by the first-order conditions are:

(36) $$q^1_{BH} = \left(W + \sqrt{f^1_{BH}}\right)/2$$

(37) $$q^1_{AB} = \left(W + \sqrt{f^1_{AB}}\right)/2$$

(38) $$q^1_{AH} = \left(W + \sqrt{f^1_{AB}} + \sqrt{f^1_{BH}} - \sqrt{f^2_{AH}} - 2T\right)/3$$

(39) $$q^2_{AH} = \left(2W - \sqrt{f^1_{AB}} - \sqrt{f^1_{BH}} + 4\sqrt{f^2_{AH}} + 2T\right)/6$$

(40) $$\sqrt{f^1_{BH}} = (q^1_{AH} + 2q^1_{BH})/4$$

(41) $$\sqrt{f^1_{AB}} = (2q^1_{AB} + q^1_{AH})/4$$

(42) $$\sqrt{f^2_{AH}} = q^2_{AH}/2$$

(43) $$\sqrt{f^1_{BH}} = \left(4W + \sqrt{f^1_{AB}} - \sqrt{f^2_{AH}} - 2T\right)/8$$

(44) $$\sqrt{f^{1}_{AB}} = \left(4W + \sqrt{f^{1}_{BH}} - \sqrt{f^{2}_{AH}} - 2T\right)/8$$

(45) $$\sqrt{f^{2}_{AH}} = \left(2W - \sqrt{f^{1}_{AB}} - \sqrt{f^{1}_{BH}} + 2T\right)/8$$

The strategic substitutive relationships across the three markets appear in (43)-(45). Solving the equations system of (36)-(42), yields the equilibrium values (noted by the superscript "n") listed in Table 3.

Table 3: Outcomes of network-NH (secondary New-hub)

Frequencies	$f^{1n}_{BH} = (5W - 3T)^2/81$ $f^{1n}_{AB} = (5W - 3T)^2/81$ $f^{2n}_{AH} = (W + 3T)^2/81$
Demands Fares	$q^{1n}_{BH} = p^{1n}_{BH} = 7W/9 - T/6$ $q^{1n}_{AB} = p^{1n}_{AB} = 7W/9 - T/6$ $q^{1n}_{AH} = p^{1n}_{AH} = 2W/3 - T$ $q^{2n}_{AH} = p^{2n}_{AH} = 2(W + 3T)/9$ Sufficient non-negative condition: $q^{1n}_{AH} \geq 0 \leftrightarrow T \leq T^{n}_{q1AH} = (2/3)\,W$
Profits	$\pi^{n}_{1} = [(56W^2 - 60WT + 45T^2)/54] - 2F$. $\pi^{n}_{2} = (W + 3T)^2/27$.

4. Comparison among the Three Networks

One of the objectives of this paper is to argue which network is optimal for Airline 1, given the spoke-entry. This goal can be achieved by comparing the profits derived under the three networks. Before comparing the profits in section 5, the comparisons of the flight frequency and the demand (and fares) in this section are also helpful for understanding the intuitions.

4.1. Comparing the two hub-spoke networks with network-FC

Comparing network-SE with FC is the same as examining the effects of shifting "a hub-spoke" type network to a fully-connected network for Airline 1. Comparing network-FC with NH also examines the effects of shifting the fully-connected network back to "another hub-spoke" type network. The results of the first (second) comparison are summarized by Lemma 1 (Lemma 2).

Lemma 1. Shifting network-SE to FC has the following effects on frequencies, quantity (fares) of Airline 1.

(a) $f^{1c}_{AH} < f^{1s}_{AH}$, $f^{1c}_{BH} < f^{1s}_{BH}$, $f^{1c}_{AB} > f^{1s}_{AB} (= 0)$;
$q^{1c}_{AH} = p^{1c}_{AH} < q^{1s}_{AH} = p^{1s}_{AH}$, $q^{1c}_{BH} = p^{1c}_{BH} < q^{1s}_{BH} = p^{1s}_{BH}$.

(b) $q^{1c}_{AB} = p^{1c}_{AB} \gtreqless q^{1s}_{AB} = p^{1s}_{AB} \leftrightarrow T \gtreqless \frac{8}{15} W$.

Proof. Immediately by comparing the corresponding values in Table 1 and Table 2.

Lemma 1-(a) describes that the shift decreases Airline 1's frequencies, quantity and fares of markets AH and BH. The intuition behind this is that the new AB direct flight shifts Airline 1's AB passengers from one-stop to nonstop services. This shift decreases the passengers using the spoke routes. In other words, the f-effect from the hub-spoke network vanishes and the decreases like in Lemma 1-(a) emerge.

Lemma 1-(b) states that the shift increases (decreases) the quantity and fare of market AB when T is large (small). This is because a larger (smaller) T gives Airline 1 a strong incentive to operate the AB direct flights (to continue to operate its hub-spoke network).

Lemma 2. Shifting network-FC to NH has the following effects on frequencies, quantity (fares) of Airline 1.

(a) $f_{AH}^{1n}(=0) < f_{AH}^{1c}$, $f_{BH}^{1n} > f_{BH}^{1c}$, $f_{AB}^{1n} > f_{AB}^{1c}$

(b) $q_{AH}^{1n} = p_{AH}^{1n} \gtreqless q_{AH}^{1c} = p_{AH}^{1c} \leftrightarrow T \lesseqgtr \frac{4}{15}W$;
$q_{BH}^{1n} = p_{BH}^{1n} > q_{BH}^{1c} = p_{BH}^{1c}$, $q_{AB}^{1n} = p_{AB}^{1n} > q_{AB}^{1c} = p_{AB}^{1c}$

Proof. Immediately by comparing the corresponding values in Table 2 and Table 3.

Because the comparison for Lemma 2 was done from the opposite direction to that of Lemma 1, the results are correspondingly reversed. The quantitative difference between Lemma 1 and Lemma 2 results from that the competitor exists in Airline 1's spoke (rim) route in network-SE (NH). This difference will be argued in a more detailed way in the next subsection. Then, ignoring the difference for the moment, the interpretations of Lemma 1 can be applied into Lemma 2.

4.2. Comparing network-SE and NH

Let us begin from the following lemma.

Lemma 3. Shifting network-SE to NH has the following effects on the two carriers' frequencies and quantity (fares):

(a) $\mathrm{sign}[f_{BH}^{1n} - f_{BH}^{1s}] = \mathrm{sign}[q_{BH}^{1n} - q_{BH}^{1s}]$, $q_{BH}^{1n} = p_{BH}^{1n} < q_{BH}^{1s} = p_{BH}^{1s}$.

(b) $q_{AH}^{1n} = p_{AH}^{1n} \gtreqless q_{AH}^{1s} = p_{AH}^{1s} \leftrightarrow T \lesseqgtr \frac{1}{24}W$; $v_{AH}^{2n} \gtreqless v_{AH}^{2s} \leftrightarrow T \gtreqless \frac{1}{24}W$, $v = f, q, \pi$.

(c) $q_{AB}^{1n} = p_{AB}^{1n} > q_{AB}^{1s} = p_{AB}^{1s}$.

Proof. Immediately by comparing the corresponding values in Table 1 and Table 3.

These various differences essentially result from whether Airline 2 operates on Airline 1's spoke route or on its rim route. The economic intuitions behind them are sensible, and can be provided as follows.

In network-SE and NH, an increase of f_{BH}^{1} has the same effect on Airline 1's revenue-increase from market BH. Thus, the difference comes from the other markets. An increase of f_{BH}^{1} in network-SE also increases Airline 1's revenue from market AB which is a monopoly (see (14) and (11)). An increase of f_{BH}^{1} in network-NH also increases its revenue from market AH which is a duopoly (see (40) and (38)). Thus, it is apparent that $f_{BH}^{1n} < f_{BH}^{1s}$ because the revenue-increase from the monopolistic AB market in network-SE is larger than that from the duopolistic AH market in network-NH.

Lemma 3-(b) shows the effect on Airline 1's quantity in market AH, which is opposite to the effect on Airline 2's outcomes. Consider the entry of Airline 2 and T=0. In network-SE, the aggressive strategy by Airline 2 (i.e., an increase of f^2_{AH}) incurs a relatively larger decrease of Airline 1's f^1_{AH} because of the direct competition on market AH. If this occurs in network-NH, the hub-spoke network under T=0 allows Airline 1 to operate relatively larger f^1_{BH} and f^1_{AB}. Consequently, $\left(\sqrt{f^{1n}_{BH}}+\sqrt{f^{1n}_{AB}}\right)/2 > \sqrt{f^{1s}_{AH}}$, and $q^{1n}_{AH} > q^{1s}_{AH}$. However, this relationship holds only if T is sufficiently small because q^1_{AH} is provided by one-stop service in network-NH. If T is large, the f-effect from the hub-spoke network weakens and this leads $\left(\sqrt{f^{1n}_{BH}}+\sqrt{f^{1n}_{AB}}\right)/2 < \sqrt{f^{1s}_{AH}}$ and $q^{1n}_{AH} < q^{1s}_{AH}$. On the other hand, the existence of T gives Airline 2 a competitive advantage. Then, the strategic substitutive relationship with Airline 1 results in $f^{2n}_{AH} > f^{2s}_{AH}$ when T is large.

Finally, Lemma 3-(c) shows the effect on Airline 1's quantity in market AB. Consider T=0. In network-SE, the aggressive strategy of Airline 2 forces Airline 1 to reduce its f^1_{AH} and this also induces a decrease of f^1_{BH}. As a result, even if T=0, q^1_{AB} decreases because the AB passengers use both AH and BH routes. In network-NH, Airline 2's strategy also forces Airline 1 to reduce both f^1_{BH} and f^1_{AB}. However, the decrease of q^1_{AB} is relatively small because the AB passengers use the AB route only. As a consequence, $\sqrt{f^{1n}_{AB}} > \left(\sqrt{f^{1s}_{AH}}+\sqrt{f^{1s}_{BH}}\right)/2$ and $q^{1n}_{AB} > q^{1s}_{AB}$. These results hold when T>0, simply because q^1_{AB} in network-SE is provided by Airline 1's one-stop services. The larger T is, the smaller q^{1s}_{AB} is.

5. Optimal Network Structure for the Network Carrier

This section investigates the optimal network for Airline 1. According to Table 1 to 3, the following results of comparisons between each network pair can be obtained by setting W=1, without losing any generality.

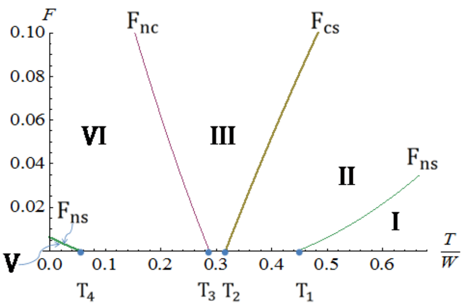
(46) $$\pi^c_1 \gtreqless \pi^s_1 \leftrightarrow F \lesseqgtr \left[\frac{-42841+153600T-57150T^2}{180075}\right] \equiv F_{cs}.$$

(47) $$\pi^n_1 \gtreqless \pi^c_1 \leftrightarrow F \lesseqgtr \left[\frac{169}{675}-\frac{10T}{9}+\frac{5T^2}{6}\right] \equiv F_{nc}.$$

(48) $$\pi^n_1 \gtreqless \pi^s_1 \leftrightarrow F \lesseqgtr \left[\frac{1616-33468T+66897T^2}{259308}\right] \equiv F_{ns}.$$

The defined critical values $F_j\ (j = cs, nc, ns)$ is a quadratic function of T. Let T_1 and T_4 denote the two solutions of $F_{ns} = 0$, and T_2 (T_3) denotes the smaller solution of $F_{cs} = 0$ ($F_{ns} = 0$). Figure 2 can be depicted to show the results easily.

Figure 2: Optimal network for Airline 1



The relationships in each region are: $\pi_1^c > \pi_1^n > \pi_1^s$ in Region I; $\pi_1^c > \pi_1^s > \pi_1^n$ in Region II; $\pi_1^s > \pi_1^c > \pi_1^n$ in Region III; $\pi_1^s > \pi_1^n > \pi_1^c$ in Region IV; $\pi_1^n > \pi_1^s > \pi_1^c$ in Region V. Then, the following proposition can be provided.

Proposition 1. Given the entry on its spoke route, the optimal network for Airline 1 is
(a) network-FC when T and F is in Region I and II of Figure 2.
(b) network-SE when T and F is in Region III and IV
(c) network-NH when T and F is in Region V

Proposition 1 can be explained as follows. The effects of entry/exit costs are apparent simply because network-FC (NH) incurs an entry cost (both entry and exit costs), the corresponding profitability of the network decreases as the entry and/or exit costs becomes larger. However, the intuitions focusing on the various degree of T might be interesting.

First, consider the comparison between network-SE and FC shown as (46). In line with the effects shown as Lemma 1-(a) and 1-(b), the result is intuitively sensible. Shifting network-SE to FC can increase Airline 1's profits only if the profit gain obtained by the operation on the AB route can compensate the profit-loss from the two spoke markets. This only occurs when T is larger than T_2. Oppositely, in the comparison between network-FC and NH, shifting network-FC to NH can be profitable only when T is smaller than T_3, see (47).

Turn to the comparison between network-SE and NH shown as (48). In network-SE, market AH is a duopoly while market AB is a monopoly (with outcomes influenced by T). In network-NH, market AH is a duopoly (with outcomes influenced by T) while market AB is a monopoly. Note that market BH is a monopoly in both networks.

When T is larger than T_1, $\pi_1^n > \pi_1^s$. This results from the fact that in network-SE, Airline 1 competes with Airline 2 on market AH, while it also incurs the negative influence of T on its monopolistic market AB. In network-NH, it competes with Airline 2 and incurs the influence of T on the same market AH, but its monopolistic AB market is independent of T. Thus, it is preferable to fully exploit its monopoly power on market AB in network-NH, in particular when T is large.

If T is in the middle degree ($T_1 > T > T_4$), then it becomes $\pi_1^n < \pi_1^s$. This is because the negative-influence of T on the monopolistic AB market in network-SE is smaller than that on market AH in network-NH, where Airline 2 has a competition advantage from T. If T is smaller than T_4, then in both networks, the larger number of connecting passengers allow Airline 1 to enjoy profit-gains from the larger f-effect. Coinciding with Lemma 3-(b), Airline 1's profit-loss due to competition is relatively smaller when Airline 2 operates on its rim route (as compared with operating on its spoke route). This is the case when Airline 1 operates network-NH. Thus, $\pi_1^n > \pi_1^s$ in this case.

Given these interpretations, Proposition 1 is intuitively sensible. Obviously, when T is large, the spoke-entry encourages Airline 1 to shift its network to network-FC. When T is sufficiently small ($T < T_4$) , Airline 1 has a strong incentive to retain its hub-spoke network (so as to enjoy large f-effects), but it has to face tough competition on its AH spoke (nonstop versus nonstop services). However, if Airline 1 shifts its network to the NH one, the large f-effects remain while the tough competition softens (nonstop versus one-stop services). This leads network-NH to be the optimal one. However, when T is intermediate, network-NH cannot be the optimal one because its competitor has a competitive advantage due to the certain middle degree of T. This is why network-SE is optimal in this case.

6. Welfare Analysis

6.1. Socially superior network

In order to provide meaningful policy implications, this section compares the social welfare achieved under the three networks. The social welfare is defined as the summation of all passengers' utility and the airlines' profits. According to Table 1 to 3, the social welfare under each network can be derived and written as:

$$SW^s = \frac{4975W^2 - 3404WT + 1256T^2}{2401} \quad (49)$$

$$SW^c = \frac{376W^2}{225} - F \quad (50)$$

$$SW^n = \frac{56W^2}{27} - \frac{13WT}{9} + \frac{5T^2}{4} - 2F \quad (51)$$

Without losing any generality, let W=1. Then the results of the comparisons are

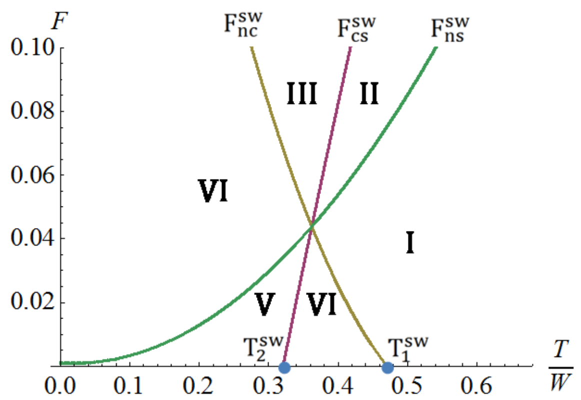
$$SW^c \gtreqless SW^s \leftrightarrow F \lesseqgtr \left[\frac{-216599 + 765900T - 282600T^2}{540225}\right] \equiv F_{cs}^{sw} \quad (52)$$

$$SW^n \gtreqless SW^c \leftrightarrow F \lesseqgtr \left[\frac{272}{675} - \frac{13T}{9} + \frac{5T^2}{4}\right] \equiv F_{nc}^{sw} \quad (53)$$

$$SW^n \gtreqless SW^s \leftrightarrow F \lesseqgtr \left[\frac{524 - 6924T + 188487T^2}{518616}\right] \equiv F_{ns}^{sw} \quad (54)$$

The defined critical values F_j^{sw} $(j = cs, nc, ns)$ is a quadratic function of T. Note that there are no real number solutions of $F_{ns}^{sw} = 0$. Let T_1^{sw} (T_2^{sw}) denotes the smaller solution of $F_{nc}^{sw} = 0$ ($F_{cs}^{sw} = 0$). Figure 3 shows the results easily.

Figure 3: Socially superior network



The relationships in each region are: $SW^c > SW^n > SW^s$ in Region I; $SW^c > SW^s > SW^n$ in Region II; $SW^s > SW^c > SW^n$ in Region III; $SW^s > SW^n > SW^c$ in Region IV; $SW^n > SW^s > SW^c$ in Region V; $SW^n > SW^c > SW^s$ in Region VI. Then, the following proposition can be provided.

Proposition 2. The socially superior network is
(a) network-FC when T and F is in Region I and II of Figure 3
(b) network-SE when T and F is in Region III and IV
(c) network-NH when T and F is in Region V and VI

The effects of entry/exit costs on social welfare are apparent because network-FC (NH) incurs an entry cost (both entry and exit costs). However, the intuition highlights on the effect of T might be interesting. When T is sufficiently large ($T > T_1^{sw}$), network-FC is socially superior simply because the saving of T is dominant. If T is not quite large, the two hub-spoke type networks could be socially preferable to network-FC due to the larger benefits from the f-effect.

Network-NH is socially preferable to network-SE in Region V and VI. First, consider the simple case where F is closed to zero and $T = 0$. Shifting network-SE to NH generates social gains through f-effects on the monopolistic AB market (Lemma 3-c), whereas it incurs social losses on the monopolistic BH market (Lemma 3-a). On market AH, the shift benefits the AH passengers who now use Airline 1's connecting flights, whereas it hurts the AH passengers who still use Airline 2's direct flights (details later). The former dominates the latter, and thus the shift also generates social gains on market AH. In addition, the social gains on market AH and AB is large enough to compensate the social losses on market BH. This leads network-NH to be preferable.

Put these intuitions in more detail. In network-SE, Airline 1 is a monopolist on market BH but it competes with Airline 2 on market AH. Therefore, it can offer a larger f_{BH}^1 but a smaller f_{AH}^1. In network-NH, Airline 1 is the monopolist on both spoke BH and AB. In addition, as $T = 0$, Airline 1 has a larger number of connecting AH passengers and its rival has no competitive advantage by T. These allow Airline 1 to offer larger f_{BH}^1 and f_{AB}^1, implies it rival Airline 2 can only offer a smaller f_{AH}^2 as compared with network-SE.

As a consequence, this shift benefits the AB passengers because Airline 1's connecting AB passengers need to use the smaller f_{AH}^1 in network-SE whereas its AB passengers use the larger f_{AB}^1 only in network-NH. These interpretations coincide with Lemma 3-(c). The shift decreases f_{BH}^1 (Lemma 3-(a)) and worsens the BH passengers. On market AH, the large f-effect (larger f_{BH}^1 and f_{AB}^1) in network-NH benefits Airline 1's connecting passengers whereas the smaller f_{AH}^2 in network-NH hurts Airline 2's direct flights passengers. The former dominates the latter, and thus social gains on market AH emerge.

Then, consider the case of $0 < T < T_1^{sw}$. The existence of T strengthens the superiority of network-NH. When T is quite small, the above intuitions focused on f-effects still hold. However, as T is noticeable, the shift creates larger social gains because Airline 2's direct flight AH is substitute of Airline 1's connecting flight BH-AB. This shift hurts Airline 1's connecting AH passengers, but it benefits Airline 2's direct flight passengers significantly. In addition, the direct flight of Airline 2 in network-NH saves the time cost T, but there is no direct flight AB in network-SE. These are the reasons why the NH is socially preferable.

6.2. Airline 1's optimal network and socially superior network

Combing the results of Proposition 1 and Proposition 2 yields Proposition 3 with Figure 4-a that shows the regions where the divergence emerges. Figure4-b is helpful for understanding the intuitions behind.

Figure 4-a: Airline 1's optimal network and socially superior network

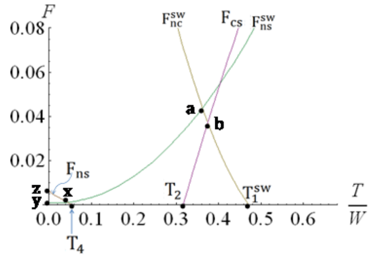
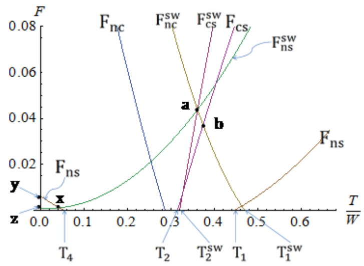


Figure 4-b: Airline 1's optimal network and socially superior network (for interpretations)



Proposition 3.

a) In region shown as {b-T_1^{sw}-T_2}, network-NH is socially superior but Airline 1 chooses network-FC.

b) In region {a-b-T_2-T_4-x}, network-NH is socially superior but Airline 1 chooses network-SE.

c) In region {x-y-z}, network-SE is socially superior but Airline 1 chooses network-NH.

To explain Proposition 3, first consider the divergence occurs as Airline 1 shifts its network from SE to FC. This divergence appears in the two regions between the critical curves F_{cs} and F_{cs}^{sw}. In the quite small region where F is limited and $T_2 < T < T_2^{sw}$, Airline 1 has an incentive to shift, but the shift is welfare-decreasing. For Airline 1, T is large enough to ensure the profitability of the shift. However, this shift loses some f-effects on Airline 1's AH and BH routes and hence it worsens Airline 1's AH and BH passengers (a welfare loss). Although the shift also benefits Airline 2 and Airline 2's AH passengers and Airline 1's AB passengers (each is a welfare gain), it is welfare-decreasing because the welfare loss is dominant. Airline 1 has no concerns on this welfare loss effect and thus the divergence occurs.

In the opposite region where F and T become larger, the shift turns to be welfare-improving but Airline 1 has no incentive to do so. Airline 1 does not shift because T is not large enough to recover the entry cost F. Suppose if Airline 1 shifts, it will bring the mentioned welfare gain and welfare loss. Interestingly, in this region the shift is welfare-improving overall because the welfare gain now dominates the welfare loss. This is because before the shift, a sufficiently large T implies the f-effects on the AH and BH routes is not significant, and hence the welfare loss by the shift is limited. Airline 1 has no these welfare concerns and the divergence emerges.

Then, consider the shift from network-FC to NH. The divergence appears in the region between the critical curves F_{nc} and F_{nc}^{sw}. Airline 1 has no incentive to shift because the created f-effect on BH and AB routes will be limited because T is large. However, if Airline 1 shifts, it will benefit Airline 2 and Airline 2's AH passengers because the competition on market AH softens and Airline 2 can offer a larger f_{AH}^2. Airline 1 has no concerns on this welfare-improving effect, and the divergence emerges.

Now, focus on the shift from network-SE to NH. Look at the large region between the critical curves F_{ns} and F_{ns}^{sw} and first consider the simple case where $F = 0$ and $T_4 < T < T_1$. Airline 1 prefers network-SE by

Proposition 1-(b). However, if Airline 1 forms network-NH, the social welfare could be improved greatly because network-NH involves Airline 2's direct flights. The f-effect from Airline 1's two spokes does not lose (but quantitatively changed from AH-BH to BH-AB spokes), and the formation saves some time cost T by Airline 2's direct flights. Airline 1 has no concerns on the latter effect, and therefore the divergence emerges. Then, this interpretation applies to the case of $F > 0$ and a larger T. The entry/exist cost decreases the superiority of network-NH, but this welfare loss by F can be recovered by Airline 2' direct flights because it can save a larger time cost T.

Now, consider the region (the same region V in figure 2) where F and T are quite small. For Airline 1, network-NH is preferable by Proposition 1-(c). A much smaller T increases the attraction of network-NH, and hence Airline 1 chooses network-NH even the entry/exit cost is larger. However, from the viewpoint of social welfare, the critical curve F_{ns}^{sw} is almost independent of T whereas it crucially depends on F. The quite small T implies that the welfare gain from the existence of Airline 2 is ignorable, but the entry and exit costs turn to be a significant welfare loss in region {x-y-z}. This is why Airline 1 has an incentive to form network-NH, but this reformation is welfare-decreasing.

7. Concluding Remarks

This paper has investigated the airline strategy of network reformation. The analytical network models have been motivated based on the observation that major carriers are likely to reform their hub-spoke networks, given some entrants entered their primary routes. The schedule competition model has been inspired by Brueckner (2004), Brueckner and Flores-Fillol (2007) and Kawasaki (2008; 2009). The simplified network model allowed us to capture the main features of airline quality (frequencies) competition.

The results of this paper can provide sharp and useful implications for a major carrier. In short, even its hub-spoke network effect weakens by the spoke entry, continuing to operate its initial network is a reasonable strategy, as long as the hub-through additional time cost for passengers is not sufficiently large. It is also noticeable that even the market size of its rim route is symmetrically large and the entry and exit costs are quite limited, offering nonstop service on its rim route while exiting from the entered spoke route cannot be a smart strategy, except the additional time cost by flying through its secondary new hub is quite small. In other words, if the candidate airport has some potential opportunity that can shorten the connecting time significantly, then creating a secondary hub to compete with the entrant may be considerable.

The social welfare analysis found that, given the spoke entry, creating a secondary hub on a major carrier's partial network is welfare-improving as long as the mentioned time cost is not sufficiently large. However, the network carrier has no incentive to do so. This finding suggests the necessity for a transport policy to encourage the network reformation which could be welfare-improving.

As to our knowledge, this is first attempt to address entry and exit on different type of routes in a hub-spoke network. There remain some limitations of the model which are desirable to be extended. First, the network size is limited to one hub linking two cities. Including other spokes cities to investigate the network reformation along with creation of multiple hubs of a major carrier is a subject for future work. Second, this paper focuses on the spoke-entry. It might be interesting to argue the network issue by taking entries to rim routes (in particular the entry by low-cost carriers) into account.

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Logistics Aspects of Avian Influenza Pandemic in Hong Kong

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Abstract

This paper investigates the logistics of handling possible avian influenza outbreaks. The research investigates various aspects of avian influenza relevant to the Hong Kong circumstances, such as literature review and the financial impacts of avian influenza pandemic. Then the paper will focus on various ways to minimize the risks of pandemic, such as the use of vaccination, non-pharmaceutical intervention (NPI) and poultry-slaughtering centre plan. This paper concentrates on discussing various logistics responses that can help the medical personnels to do their jobs more effectively in a possible avian influenza outbreak. This research concludes that vaccination and the non-pharmaceutical intervention (NPI) are important measures in countering the avian flu pandemic in the early stage of its widespread.

This paper also supports any measures that can trace the infected poultry as a way to prevent an avian influenza outbreak in the very first place. In this aspect, the research investigates about the Singapore experience in operating poultry-slaughtering centres. In view of the current trends, this paper concludes that the establishment of a central poultry-slaughtering centre becomes a less favorable policy options.

Keywords: Avian flu pandemic, H5N1, Hong Kong, non-pharmaceutical intervention (NPI), logistics

1. Introduction

This paper investigates the logistics of handling possible avian influenza outbreaks. The primary goal of logistics during an outbreak is to transfer the needed medical supplies, devices and equipment to the medical personnels for doing their missions. Since the goal is related to the lives and health of their patients, medical logistics is unique in that its main focus is to optimize effectiveness, and efficiency be only seen as a constraint to be managed. The concept of logistics in this paper has two major components:

1. Moving the medical personnels in connection with the counter avian influenza outbreak mission.
2. Supplying the force. This component includes the processes used to enable the deployed force to continuously maintain its readiness to accomplish its missions. This component relates to sustainment of medical personnels and support equipment. The medical forces in the field perform the best when they are healthy, well fed, properly clothed, and equipped to function in the targeted environmental conditions.

Logistics is traditionally an underappreciated activitiy (Pagonis, 1992). When the German Chief of Staff asked Marshall Rommel how he planned to supply and feed the two additional panzer corps that he demanded from Berlin, Rommel replied coolly: "That is quite immaterial to me. That is your pigeon."(Irving, 1977) In modern days, however, logistics becomes the key factor in determining the success of any important mission. Contrast Rommel‟s attitude, General H. Norman Schwarzkopf attributed the success of the Gulf War to its logistical operation. Without the logistical capacity to move unprecedented numbers of people and quantities of material to the battlefield in Middle East, US could not have won the Gulf War.[1] He saw it was only the superior logistical capacity that made the celebrated "end run" possible.[2]

[1] Just for eating and transportation, the US needed to move and serve more than 122 million meals to the war zone. This can be compared to feeding all the residents of Wyoming and Vermont three meals a day for forty

This paper will discuss the principles of logistics in relation to the circumstances of avian influenza outbreaks. There are three types of influenza virus: A, B and C. Type C causes mild symptoms, but types A and B can cause severe illness. Avian influenza (bird flu) is caused by a type A virus that is spread from bird to bird through respiratory secretions and contact with contaminated droppings (Gstraunthaler, 2008). The H5N1 strain of bird flu is prevalent in domestic and wild birds in Asia and Europe.

Influenza is a highly contagious viral illness, and the virus can also be spread through contact with a contaminated person or surface. Avian influenza A viruses do not usually infect humans, but more than 300 people, of whom two-thirds have died, have caught the H5N1 strain as a result of close and direct contact with infected birds (Bishop, 2007). Avian influenza virus could cause an epidemic in the country of origin and spreading globally in lights of modern transportation features, such as air travel and container trade.

This paper will investigate various aspects of avian influenza relevant to Hong Kong, such as literature review and the financial impacts of avian influenza pandemic. Then the paper will focus on various ways to minimize the risks of pandemic, such as the use of vaccination, non-pharmaceutical interventions (NPIs) and poultry-slaughtering centre plan.

2. H5N1 in Hong Kong

Hong Kong was one of the first places attacked by H5N1 infection. Outbreaks of highly pathogenic H5N1 avian influenza occurred in Hong Kong in 2001, twice in 2002 and 2003.[3] The transmission of avian H5N1 influenza viruses to 18 humans in Hong Kong in 1997 with six deaths established that avian influenza viruses can transmit to and cause lethal infection in humans.[4]

Shortridge et al. said that each of the H5N1 viruses from Hong Kong poultry markets that were tested were lethal in chickens, possessed polybasic amino acids at the carboxy-terminus of HA1, and by definition were highly pathogenic in poultry.[5] The authors noted that the poultry markets were of critical importance in the transmission of influenza viruses to other avian species and to mammals, including humans.

With the 1997 H5N1 experience, measures against avian influenza adopted in 2001 showed great improvements. In 2001, the flu struck three different markets in early May, when the death of 800 chickens occurred within three days, the government promptly implemented the decision on May 16 to slaughter 6,000 chickens from all poultry stalls in these three markets, even the source of the flu has not yet been established. The gene tests indicated the H5N1 strain was different from the one which killed six people in 1997, and even this strain was unlikely to affect humans, the government decided to close the poultry stalls in the three markets for two weeks and have them thoroughly sterilized.

For the chicken retailing market, the 2001 event showed that wholesale prices of chickens immediately dropped 20 percent within the week after the news came public. The sales were reduced about 40 percent over the few days after the event. The consumption of frozen chicken increased as consumers substituted it for the fresh product.

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days. During the war, almost 500 new traffic signs were erected along the Saudi Arabian road network, helping US soldiers find their destinations in a relatively featureless landscape (Langenus, 1991).

[2] Excerpt from General Schwarzkopf‟s February 27, 1991, Central Command Briefing, reprinted in *Military Review* (September 1991), p.97.

[3] Ellis TM, Bousfield RB, Bissett LA, Dyrting KC, Luk GS, Tsim ST, Sturm-Ramirez K, Webster RG, Guan Y, Malik Peiris JS. Investigation of outbreaks of highly pathogenic H5N1 avian influenza in waterfowl and wild birds in Hong Kong in late 2002. *Avian Pathol*, 2004 Oct; 33(5): 492 – 505.

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With the subsequent H5N1 events, the Hong Kong government tried to find a better way to minimize the chance of an influenza pandemic. This is a sensible direction as the cost of an influenza pandemic should not be measured in economic terms alone; it could present strong pressures on the logistics capacity of social essential resources. For example, in February 2007, when bird flu was found in poultry at a turkey farm in Suffolk, the community imposed policies such as closure of schools together with businesses and travel constraints, these measures put a hard test on the logistic ability of a community to deliver essential services to its people; such as food, health, and social care services.

Researches in Hong Kong H5N1 events showed that the principle mode of transmission of avian influenza from poultry to human is through direct contacts; and the avian influenza viruses, just like other veterinary viruses, cannot be eradicated. In other words, the risks that the avian influenza viruses may affect the poultry population cannot be completely eliminated. Therefore, there are two policy options available:

(1) To reduce the possible contacts between the public and live poultry at the retail end of the poultry industry. This policy option assumes that avian influenza infected poultry are already present in the retail market, the key focus is to separate the infected poultry from the customers.

(2) To minimize the possibility of the placing avian influenza infected poultry in the retail market by adopting preventive measures to prevent infected poultry flowing from local farms to the retail markets.

Future outbreaks of avian influenza are foreseeable. Stopping the infected poultry for reaching the retail market should be the key focus. The means to achieve such goal include the implementation of an effective isolation policy to contain and localize the infected poultry, so as to keep the avian influenza viruses away from the general public.

3. Literature Review

For understanding the general concept of risk management, one may find the *Harvard Business Review* article '*Preparing for evil*' by Mitroff and Alpaslan (2003) a helpful reference. The two authors observed that crisis-prepared players would not manage disasters through cost-benefit analyses. Smart players would focus their efforts on preventing crises rather than containing them after the fact. Efforts on preventing crises include but not limited to the design of strategic tools to improve preparedness towards disruption events.

In 2004, Dr. Jonathan Rushton, an animal health economist, published his research findings on evaluating the impact of avian influenza outbreaks in the poultry sectors in Cambodia, Indonesia, Lao PDR, Thailand, Vietnam. The study (Rushton et al. 2004) concluded that the potential danger of a human influenza pandemic should be the greatest concern with regard to avian influenza control and eradication. In order to develop plans of control, it needs to understand the winners and losers in an outbreak situation. And based on such understanding, the government could implement effective actions to motivate all actors to become actively involved in a control campaign. Rushton's research findings indicated that the epidemiological role of the different sectors identified appears to be poorly understood at present. He suggested two approaches may be helpful in bringing insights for gathering data in formulating the plans of control: (1) the researchers can carry out a value chain analysis to identify the key control points and important actors in the movement of eggs, day old chicks, live birds and products; (2) the policy makers can identify the risk factors and prioritize scarce resources through an analysis of the socio-economic circumstances of those who have died and their relationship with poultry systems.

Dr. Richard Coker from London School of Hygiene and Tropical Medicine assessed the planning documents issued by Pacific countries for outbreaks of influenza in people related. The study (Coker and Mounier-Jack 2003) found that the regional approaches were polarized. Thailand, China, and Vietnam had set out a strategic vision to strengthen future capacity in detecting and responding to disease in the future. By contrast, Hong Kong, Australia, and New Zealand took a strategic approach aimed mainly at harnessing available resources for stockpiling antiviral agents and vaccines. He observed that affluent countries have the capacity to stockpile antiviral drugs and, in the event of a pandemic, could rely on their capacity to procure vaccine rapidly through agreements. By contrast, lower-income countries in the Asia–Pacific region would find it difficult to access sufficient quantities of these globally scarce resources. Dr. Coker opined that the plans of Hong Kong, Australia, and New Zealand compared favorably with the best European plans. He noted that the weaknesses of preparedness plans in the Asia–Pacific region were much the same as those described for Europe. Most plans did not adequately address the operational responsibility at the local level, especially relate to the logistical aspects of vaccination and antiviral stockpiling, distribution, and delivery. In conclusion, Dr. Coker gave the warning that a pandemic might not wait until capacity is developed. It would also need to extend to allocation of scarce resources in a globally equitable fashion. The next pandemic will test notions of global solidarity.

4. Financial Impacts of Avian Influenza Pandemic

The outbreak of a contagious pandemic, even with a relatively small health impact, could exert strong adverse economic implications, as proved by 2003 SARS outbreak. According to an estimate by the Asian Development Bank, the economic impact of SARS was around US$18 billion in East Asia, which comes to around 0.6 percent of the total GDP in the region (ADB, 2003).

In addition to the direct impact of avian flu on agricultural output, the indirect effects could severely disrupt domestic economies. Trade and transport restrictions arise, incomes from tourism will fall, consumer spending will drop, and business confidence and investment deteriorate. The balance of payment pressures would arise, especially in tourism-dependent economies.

All global economic players should be mindful because disruptions in one jurisdiction could have spill-over effect in other jurisdictions. When the H5N1 virus first reported in East Asia, particularly in Vietnam, Thailand, Indonesia and China; just within 6 to 9 months, the virus has gone global, spreading to over 40 more countries (Brahambhatt, 2006). The cumulative number of confirmed human cases of death on account of H5N1 stood at 132 in 10 countries as reported in WHO Fact Sheet as of July 2006. Financial costs of a human pandemic are impossible to predict. The World Bank estimates that a severe avian flu pandemic among humans could cost the global economy about 3.1 percent of world gross domestic product, around US$ 1.25 trillion on a world GDP of US$ 40 trillion (World Bank, 2006).

Possible financial Impacts of an avian influenza pandemic may include a significant but temporary reduction in net capital flows to emerging markets, which may cause a breakdown in the trading infrastructure. The likely challenges to the central banks may be: (1) financing the borrowing needs of the governments from the affected regions, (2) inflation, (3) liquidity management, (5) payment and settlement systems, etc.

Avian flu pandemic would definitely affect the insurance sector. A flood of claims would likely to strain the capacity of the global insurance and reinsurance sectors. Underwriters are exposed multiple risks relate to the avian influenza pandemic, such as claims connect with business interruption, health, disability, medical malpractice, workers' compensation, and life insurance. Estimates of the impact of a global flu pandemic on the insurance industry vary widely. Standard and Poor's recently suggested a mild pandemic might produce $15-20 billion in worldwide losses, while losses from a more severe event might total up to $200 billion (Standard and Poor's, 2005).

5. Vaccines

Vaccination relates to the supplying component of logistics in countering the avian flu pandemic. There are two philosophies in treating this logistics component. First, to build up an inventory of vaccines "just-in-case." Second, to substitute the inventory by information. The attractive advantage of the second philosophy is to motivate the commercial sector to do the supplying logistics, so that the government will save tax monies on hiring people, building facilities to protect the inventory of vaccines.

Regardless of who should take up the costs of keeping the vaccines inventory, histories in countries with endemic infection show that vaccination can bring down the level of infection before its elimination.

When carried out in combination with other disease control measures, including enhanced biosecurity, culling of infected flocks with compensation, poultry movement control and management of markets, vaccination has a powerful impact in reducing disease incidence and virus load in the environment as has been demonstrated in Hong Kong, PR China and Vietnam.

Vaccination is also extremely valuable in high-risk places in which disease has recurred. For example, Hong Kong's poultry farms have remained infection-free for over four years following vaccination (which was introduced after repeated outbreaks), despite the presence of infection in wild birds in Hong Kong and in poultry in neighbouring provinces in mainland China (FOA 2008).

Vaccination must be supported by appropriate post-vaccination monitoring to ensure that adequate flock protection is being achieved, to determine whether virus circulation is occurring in inadequately vaccinated flocks and especially whether antigenic variants have emerged.

A vaccination programme should be planned as part of an integrated control strategy, subject to periodic review, which anticipates ultimate cessation of vaccination once the factors leading to virus persistence have been identified and addressed, and vaccination has reduced the number of cases to a level that will allow classical measures to succeed.

The cost and logistic challenges of widespread vaccination, especially in backyard poultry, are major constraints to effective use of vaccines and to sustain the programmes over a prolonged period. The cost of vaccination campaigns must be chaired with the commercial poultry sector and be subsidized in village backyard sector as a public good activity (prevention of regional and international crisis and of human pandemic emergence).

Unregulated and uncontrolled use of vaccines from unknown sources and of dubious quality and efficacy, or without associated disease control measures, may confound efforts to introduce a systematic approach to disease control.

Improperly vaccinated poultry flocks may perpetuate virus circulation through partially protected birds and remain a source of infection for other birds and humans. Active targeted monitoring programmes need to be in place in countries practising vaccination to ensure that any circulating H5N1 viruses are fully characterized and compared with existing vaccine strains for protective capacity.

Well-developed vaccination strategies, with advance arrangements for rapid access to vaccines, may offer a significant advantage in controlling and eradicating the disease in a newly-infected country.

Vaccination can reduce the level of H5N1 infection, which reduces the need to cull poultry. It brings favorable economic benefits by reducing the compensation. To sustain government-sponsored large scale vaccination campaigns, cost sharing with the commercial producer would be a sensible way, so that vaccination can target to areas where high-risks exist.

It is also necessary to set up post-vaccination review points for assessing the need for ongoing vaccination programs.

6. Non-pharmaceutical Intervention (NPI)

Non-pharmaceutical intervention (NPI) includes using the measures, such as closure of schools and bans on public gatherings to limit the spread. Statistics showed that cities that implemented the NPI sooner would suffer a much smaller overall death toll caused by the pandemic. NPI relates to the supplying component of logistics in countering the avian flu pandemic. The reason: during the beginning stage of a widespread breakout, the available supplies of effective vaccines were very limited.

For example, the 1918 influenza pandemic resulted in an unprecedented mortality rate, with an estimated 675,000 deaths in the United States, and more than 50 million deaths worldwide (Barry, 2004). The 1918 pandemic showed the value of adopting NPI in the early stage of the breakout.

Two cities in particular, Philadelphia and St. Louis, could illustrate the dramatic differences. Philadelphia caught news of the pandemic but downplayed its significance and allowed large public gatherings to continue taking place, most notably a city-wide parade on September 28, 1918. Bans on public gatherings, school closures and other NPI's did not begin until October 3. By then, the disease had already spread and begun to overwhelm local medical and public health services (Grinberg 2007).

In St. Louis, on the other hand, the first cases of disease among civilians were reported on October 5, and the city moved quickly to promote the "social distancing" policy within two days (Grinberg 2007). St. Louis mayor Henry Kiel followed the measures proposed by Dr. Max C. Starkloff, made an order to close schools, churches, theaters and other places where crowds could spread the flu. When flu deaths in St. Louis rose above 600, Dr. Starkloff suggested to close taverns, tobacco shops, department stores and many other businesses. In facing angry businessmen, Henry Kiel held his ground by pointing out that "It is a case of get the dollars and lose the lives or save the lives and lose the dollars." Said Dr. Starkloff, "The people are out of doors, getting lungs full of fresh air, which is better for them than if they were at work..."

The difference in response times between the two cities was approximately 14 days, but costs of the delay are evident when comparing the mortality rates and final death tolls across the two cities.

Philadelphia experienced a peak weekly death rate of 257 per 100,000 people and an overall death count of 719 per 100,000. St. Louis showed much lower totals, with a weekly mortality peak of just 31 per 100,000 and a final mortality count of 347 per 100,000 (Grinberg 2007). In short, Dr. Starkloff's strategy of "social distancing" saved lives. St. Louis' death toll of 1,703 equaled 2.8 for each 1,000 residents, lowest among major American cities (Barry, 2004).

The study finds that the time between the report of an outbreak and the implementation of NPIs is perhaps the most crucial element in lowering the spread of a deadly virus outbreak. Government needs to have a solid procedural plan to maintain school closings, to ban on public outings, and to make employees staying homes. These simple measures are among the many NPIs that can help to reduce exposure to the public spread of the virus.

7. Poultry-slaughtering centre plan

Some disasters are foreseeable, although it may be difficult to predict the exact timing of their occurrences. Therefore, the government should not solely focus on the preparedness of a possible outbreak of an avian flu pandemic, but also on minimizing the economic hardship of the affected social sectors. The establishment of a poultry-slaughtering centre may serve both purposes. First, a poultry-slaughtering centre facilitates the tracing of the infected inputs of poultry, which serves as a preventive measure. Second, a central run poultry-slaughtering centre may gradually shifted the working persons and resources from the poultry retail outlets, this lower the relief costs when the outbreak of an avian flu pandemic actually happens.

A slaughterhouse is a facility where farm animals are killed and processed into meat products. Since 2006 the Hong Kong government has devoted about three years to investigate whether to set up a central a poultry slaughtering plant to replace all sales of live poultry at retail outlets. The establishment of a licensing regime for poultry slaughtering plant is regarded as a precautionary measure against avian influenza.

Singapore Experience

The investigation starts with the learning from the Singapore experience. Starting from 1991, the Singapore Government banned the poultry slaughtering in wet markets.[6] It required all poultry to be processed at AVA

[6] In Singapore, the Wholesome Meat and Fish Act (the Act) provides that no person shall slaughter any animal in any premises which is intended for human consumption, unless those premises have been licensed by AVA as a slaughter-house and the person concerned has been granted by AVA a permit allowing him to slaughter the animal on those premises. Licensee who breaches any condition of licensing

(Agri-Food and Veterinary Authority)[7] approved poultry slaughtering plant. There are about 14 poultry slaughtering plants in Singapore, all are privately-run. Ten of them slaughter live chickens while four slaughter live ducks. The farms which supply the live chickens to the Singapore poultry slaughtering plants required to be AVA accredited. There are about 99 AVA-accredited farms, and they are located mainly in the Johor State in Malaysia. These comprise about 98% of the source of live chickens in Singapore. The high concentration of poultry inputs from one area simplifies the tagging process as the Singapore regulation requires all freshly slaughtered poultry carcasses be individually tagged.[8] The Singapore poultry slaughtering plants adopt the following measures:

1. The slaughter houses are designed as one-directional flow, so as to prevent cross contamination between live poultry and dressed carcasses. The partition materials could meet specific conditions to prevent bacterial growth and transmission.
2. The slaughter-houses have adequate sanitary facilities and are required to implement the Hazard Analysis and Critical Control Point (HACCP) or similar food safety system. A proper programme must be in place to recall products that are not processed in accordance with the law.
3. Slaughter-houses workers must receive adequate and appropriate training and are given protective clothing. Only authorized personnel are allowed into areas where the poultry is slaughtered, processed or handled.
4. The number of poultry to be slaughtered is subject to the approval of AVA. Live poultry are not allowed to be taken out of the slaughter-house or sold without the prior permission of AVA. Live poultry must be slaughtered within 24 hours of arrival at the slaughter-house.
5. The chilling process of the dressed poultry must be completed within 90 minutes after evisceration. Ice used for processing and chilling of the dressed poultry must be manufactured from uncontaminated potable water.
6. The dressed poultry must be stored in freezers at specified temperature. The temperature records of freezers should make available for inspection by AVA up to a period of three months.
7. All dressed poultry must be transported by vehicles with refrigerating facilities. The poultry slaughter house must furnish a daily report to AVA, stating the number and type of poultry for slaughter. The licensee must also provide all customs clearance permits for AVA inspectors.
8. No portion of the slaughter-house is allowed to be used as living quarters, and all activities taking place in the slaughter-house must be approved by AVA.

In terms of logistics, AVA only allows live poultry to be imported from Malaysia to Singapore through the route which passes through fewer residential areas. All live poultry undergo ante-mortem inspection by AVA officers at the Tuas Checkpoint to identify problem birds. About 65 to 75 trucks pass through the Tuas Checkpoint daily. They operate from 5:00 am to 1:00 pm from Monday to Thursday, and from 5:00 am to 3:00 pm on Friday and Saturday.

The Decision

The Hong Kong government made the final decision of holding up the central poultry slaughtering plant development because the latest assessment shows that the risk of avian influenza in Hong Kong is very low. Dr York Chow, Secretary for Food & Health, opined that the risk of human infection by avian flu has been reduced to a minimal level. The decision matched with the findings by the University of Hong Kong about the rate of H9N2 viruses after the implementation of the following two measures:

(1) Ban on the keeping of live poultry overnight in retail markets.
(2) Introduction of the buyout scheme for the live poultry trade in 2008. Following the licence-buyout scheme, the number of poultry retail outlets fell from more than 800 to the existing 133, while that of poultry farms dropped from 192 to 30. The rearing capacity fell from 3.9 million to 1.3 million.

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shall be guilty of an offence under the Act and is liable on conviction to a maximum fine of Singapore $10,000 (about HK$50,000) and/or 12-month imprisonment.

[7] AVA stands for Agri-Food and Veterinary Authority. AVA is the national authority on food safety for both primary and processed food.

[8] The information includes the source of poultry input, name of the slaughter-house, and the date of slaughter.

(3) On-going surveillance conducted in retail outlets by the University of Hong Kong found that the isolation rate of H9N2 viruses in 21 months has significantly dropped from 5.11% before banning the keeping of live poultry overnight in retail markets in July 2008 to 0.09% after the commencement of the ban (see table 1.).

Table 1. Surveillance of H9N2 in retail markets conducted by the University of Hong Kong

	Before the ban on overnight keeping of live poultry in retail markets	After the ban on overnight keeping of live poultry in retail markets
No. of samples collected	4 186	3 300
No. of positive H9N2	214	3
Isolation rate	5.11%	0.09%

Source: LC Paper No. CB(2)1698/09-10(03)

Besides, a change in preference also justifies the holding up of the central poultry slaughtering establishment. Hong Kong consumers have showed a preference towards frozen and chilled chickens, with their market shares at 64% and 30%, while that of live chickens at 6% of the total chicken supply. Such trend will reduce the need to develop a poultry-slaughtering centre.

8. Conclusion

This paper focuses on discussing the logistics responses on supplying the medical personnels in a possible avian influenza outbreak, so that they can do their jobs more effectively. The paper starts with the lessons learned from the histories of H5N1 incidents in Hong Kong and the economic implications of an outbreak. This paper concludes that vaccination and the non-pharmaceutical intervention (NPI) are important measures in countering the avian flu pandemic in the early stage of its widespread. This paper also support any measures that can trace the infected poultry as a preventive way to an avian influenza outbreak, the authors investigate about the Singapore experience in operating poultry-slaughtering centres and briefly discuss about the value of establishing such centres in Hong Kong. This paper concludes that three factors render the establishment of such centre a less favorable policy options, the three factors are: (1) the government policy on banning live poultry keeping overnight in retail markets; (2) the buyout scheme for the live poultry trade, and (3) a preference towards frozen and chilled chickens.

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Logistics Institutions and Logistics Firms' Competitive Advantage in Taiwan

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Abstract

This study identifies logistics institutions and empirically examines their impacts on competitive advantage using survey data collected from international logistics firms including logistics companies, freight forwarders, shipping companies, agencies, and airlines. Based on a multiple regression analysis, results indicated that logistics institutions such as the *regulation institution* are found to have significantly positive effects on competitive advantage in terms of *competitiveness, efficiency,* and *reasonable cost*, whereas the *physical infrastructure* has a positive effect on competitive advantage in the aspects of *service quality* and *reasonable cost*. Theoretical and policy implications of the research findings on logistics policy evaluation for policymakers are discussed.

Keywords: *Logistics institution, Competitive advantage, International logistics firms, Taiwan*

1. Introduction

The increase in global production sharing, the shortening of product life cycles, and the intensification of global competition all highlight logistics as a strategic source of competitive advantage (Arvis et al., 2007). Logistics contributes to the development of international trade and national economies in two significant ways. First, logistics is one of the largest costs involved in international business, thereby affecting and being affected by other economic activities. Second, logistics supports the movement of many economic transactions; it is an important aspect of facilitating the sale of all goods and services (Banomyong et al., 2008; Grant et al., 2006). The international movement of goods has been primarily organized by logistics services firms (i.e., freight forwarders and carriers), typically large networks of companies with worldwide coverage, capable of handling and coordinating the diverse actions required to move goods across long distances and international borders. Freight forwarders and carriers play important roles in the present wave of globalization: they facilitate an ever more demanding system that connects firms, suppliers, and consumers.

Nevertheless, globalization has resulted in a strengthening of global competition and has had a tremendous impact on the way companies nowadays operate. The resource-based view (RBV) asserts that firms gain and sustain competitive advantages by deploying valuable resources and capabilities (Wernerfelt, 1984; Peteraf, 1993; Ray et al., 2004). The resource-based view has been examined in many empirical studies focusing on a specific industry (Barney, 1991; Ray et al., 2004; Lu, 2007). While numerous studies have sought to define resources, capabilities, and/or competencies (Wernerfelt, 1984; Barney, 1991; Marino, 1996; Hafeez, et al., 2002) in an extension of this area of research, several studies have examined the country-specific influence on the business activities and performance level of multinational corporations (McGahan and Porter, 1997; Makino et al., 2004; Chan et al., 2008). The performance level of industries, firms, and business units is influenced by the availability of the resource inputs of production and their capabilities. It is also affected by contextual factors such as host country institutions, because firms cannot be immune to the institutional context of the host country in which they are embedded (Peng, 2002; Chan et al., 2008). The capability of logistics firms to access global networks depends on the quality of their national infrastructure as well as the effectiveness of their policies and institutions (Arvis et al., 2007). In an extension of previous studies, this study aims to examine the influence of the level of logistics institutions on competitive advantage in the international logistics firm's context in Taiwan. This research defines the level of logistics institutions as the extent to which the physical infrastructure, human capital, regulation institution, and sustainable institution in a host country are developed and are favourable to logistics firms.

The study proceeds as follows. In the next section, we briefly review the literature that provides the theoretical and empirical foundations of work on the influence of physical infrastructure, human capital, regulation institution, and sustainable institution on the competitive advantage. Section 3 describes the methodological context, including the questionnaire survey, sampling technique, and methods of analysis. Section 4 presents the results and findings of the survey. Conclusions drawn from the analyses and the implications of the findings for policymakers are discussed in the final section.

2. Literature review and hypotheses

In the context of logistics, this study refers to infrastructure and policies as the logistics institutions of a country. Institutions are commonly known as the rules of the game (Peng et al., 2009). North (1990) defined institutions as the humanly devised constraints that structure human interaction, whereas Scott (1995) described them as regulative, normative, and cognitive structures and activities that provide stability and meaning to social behaviour. Institutions can contain a variety of dimensions, including government programs (Lu et al., 2010; Peng et al., 2009). In this study, logistics institutions primarily include physical infrastructure, human capital, regulation institution, and sustainable institution relevant to the logistics sector. Physical infrastructure is conventionally thought to include investments in the construction and maintenance of ports, communications, and transportation networks. Human capital reflects intangible investments in people, mainly in the form of education and training. To the extent that education and training are provided by government or influenced by public policy, human capital may be thought of as human infrastructure (Globerman and Shapiro, 2002; Vining and Weimer, 2001). Social capital refers to the networks and shared values that encourage social cooperation, trust, and social relationships (Knack and Keefer, 1997). Globerman and Shapiro (2002) identified governance infrastructure as similar to the notion of social capital. A social capital might therefore include: an effective, impartial, and transparent legal system that protects property and individual rights; public institutions that are stable, credible and honest; and government policies that favour free and open markets. Basically, social capital relies on sanctions and trust. The sanctions include legal, rules and regulations, while trust emerges from moral and social norms (North, 1990; Humphrey and Schmitz, 1998). Accordingly, it is difficult to generalize about the statistical impact of institutional attributes, in part because the attributes are measured in different ways in different studies. Moreover, although many previous studies adopt measures that are closely related to the notion of institutions, there has as yet been no systematic attempt to directly relate institutions measures to industrial competitiveness for a wide cross-section of countries. There are a relatively small number of studies having discussions regarding the specific institutional elements that are especially robust determinants of the industrial competitive advantage in the logistics context.

It is should be noted that logistics institutions are not the only physical infrastructure that can contribute to national economic development and create a favourable climate for industries. Investment in human capital, physical infrastructure and the environmental sustainability has become more important. According to the General Assembly of the United Nations (1987), sustainability was defined as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* Recently, many countries have actively developed strategies to reduce emissions of carbon dioxide and other greenhouse gases, and to contribute to better safety, security and health and longer life-expectancy by reducing the risk of death, injury or illness. However, sustainable regulation may increase the cost of doing business and thus deter the industrial competitive advantage. On the other hand, a clean environment may be associated with a higher quality of life, and thus increase the industry's reputation and identity. To date, there are only a limited number of studies linking environmental and sustainable policies to firm performance (Klassen and Whyback, 1999; Montabon et al., 2007), with no consistent evidence of a race to the bottom with respect to environmental policies (Globerman and Shapiro, 2002). That is, there is no consistent evidence of a negative relationship between the sustainable institution and industrial competitive advantage.

It is widely argued that competitive advantage is determined to a great extent by government policies, infrastructure, institutional and legal environment (Arvis et al., 2007; Banomyong et al., 2008). North (1990) indicated that institutions in a firm's environment shape its behaviour, competitive advantage, and its performance. Porter (1990) defined international success by a nation's industry as possessing the competitive advantage relative to the best worldwide competitors. He also suggested that infrastructure was one of the important determinants of competitive advantages. Kostova and Roth (2002) examined the institutional and relational effects on the adoption of an organizational practice by subsidiaries of multinational corporations. They found that these institutions varied by country. Chan et al. (2008) investigated the effect of the level of institutional development of host countries on the level of and variation in foreign affiliate performance. Institution development was defined as the extent to which the economic, political, and social institutions in a host country existed. Chacar et al (2010) examined the degree to which home-country institutions in the product, financial, and labour markets impact on firm performance persistence. Understanding the effects of institutional capital on industrial competitive advantage may help policymakers understand which institutional factors are crucial determinants of the industrial competitive advantage. According, this study hypothesizes the following:

H_1: Physical infrastructure has a positive effect on logistics firms' competitive advantage in the aspects of competitiveness, efficiency, service quality, and reasonable cost.
H_2: Human capital has a positive effect on logistics firms' competitive advantage in the aspects of competitiveness, efficiency, service quality, and reasonable cost.
H_3: The regulation institution has a positive effect on logistics firms' competitive advantage in the aspects of competitiveness, efficiency, service quality, and reasonable cost.
H_4: The sustainable institution has a positive effect on logistics firms' competitive advantage in the aspects of competitiveness, efficiency, service quality, and reasonable cost.

3. Methodology

3.1 Sample

This study used a questionnaire survey to collect information from logistics service firms in Taiwan. The questionnaire was sent to 850 logistics service firms who were members of the Association of Global Logistics in Taiwan. Questionnaires were mailed to the offices of the senior executives of these firms targeted because they were considered appropriate respondents to provide information on logistics institution and acknowledge the industrial competitive advantage. The questionnaire was sent to them on 15th January 2010. The total number of usable responses was 169 and the overall response rate for this study was approximately 20 %.

3.2 Measures

A variety of the logistics institution dimensions have been addressed in the literature (Globerman and Shapiro, 2002; Kauppinen and Lindqvist, 2006; Chacar et al., 2010; Lu et al., 2010). Among these dimensions, physical infrastructure, human capital, regulation institution, and sustainable institution are suggested as important determinants of logistics institution and are incorporated into the research model. The measurement items for evaluating logistics institution dimensions were mainly adapted from previous studies. In order to ensure the instrument's accuracy and the content validity of the questionnaire, a comprehensive review of the literature and interviews with logistics experts were used in this study, i.e. the questions were based on previous studies and discussions with a number of executives and experts in the logistics sector. The final measurement items employed for evaluating the logistics institution and competitive advantage are presented in Appendix 1.

In this study, the logistics institution dimensions (i.e., independent variables) include physical infrastructure, human capital, regulation institution, and sustainable institution, whereas four items were used to measure the industrial competitive advantage (i.e., dependent variables), namely, competitiveness, efficiency, service quality, and reasonable cost. Each logistics institution item was measured in terms of the satisfaction level compared over the past five years using a five-point Likert scale, where 1 corresponds to "very low" and 5 to "very high", while each variable for the industrial competitive advantage was also assessed using a five point Likert scale, ranging from "1= much worse" to "5= much better."

3.3 Research Methods

This study aims to evaluate the effects of the logistics institution on competitive advantage in the international logistics sector. An exploratory factor analysis was employed to identify the crucial logistics institution dimensions such as physical infrastructure, human capital, regulation institution, and sustainable institution. A multiple regression analysis was subsequently used to examine the effects of logistics institution dimensions on industrial competitive advantage including competitiveness, efficiency, service quality, and reasonable cost. The analysis was carried out using the *SPSS 12.0 (2003) for Windows* and *Amos 5.0 (2003)* statistical packages.

4. Results of analyses

4.1 Profile of respondents

The data of this study was based on the information gathered from a questionnaire survey. Results revealed that 84.4% of respondents were either vice president or above or manager/assistant manager. Only a few respondents were in the position of director (3%), clerk (6%), and sales representative (1.8%). In general, managers are actively involved in and anchor operations in the businesses. Thus, the high percentage of responses from managers or above endorsed the reliability of the survey findings. Almost 40% of the respondents have been in operation for more than 20 years, 33.6% have been operating between 11 and 20 years, and 24.2 % for less than 10 years. Regarding the type of business, 47% of respondents were shipping agencies, while 19%, 14%, 9%, 4%, and 7% were freight forwarders, shipping companies, logistics companies, firms in air transport/express delivery, and others. As for the size of the respondents' companies, 59.6% of them employed less than 50 employees, while 29% and 11.4% employed greater than 501 and between 51 and 500 employees, respectively.

4.2 Perceptions of logistics institution and competitive advantage

As shown in Table 1, according to their aggregated scores for satisfaction level with the 22 logistics institution attributes over the past five years, respondents' perceptions ranged from neutral to high satisfaction (their mean scores were all over 2.6). The top five logistics institution attributes in their organizations were: *telecommunications, information technology system, inland transport linkage (e.g. road and rail), ports and maritime transport*, and air transport (their mean scores were 3.1 or more). Respondents showed lowest satisfaction with the following: *embed sustainable transport logistics policy in national policies (finance, trade, environmental, social, energy maritime etc.), integrating coherent logistics practices between companies and authorities, policy to ensure efficient service operation and multiplicity of services, promote the development and implementation of alternative fuels*, and *avoidance of unnecessary regulation* (their mean scores were below 2.82).

Respondents were also asked to indicate the level of competitive advantage in their logistics operations over the past five years based on a 5-point Likert scale ranging from (1= much worse to 5= much better). The most agreement with aspects of competitive advantage was service quality (mean = 3.28), followed by efficiency, reasonable cost, and competitiveness (see Table 2). Overall, respondents perceived competitive advantages in the international logistics industry in Taiwan to be in a better condition (their mean scores were 2.90 or more).

Table 1: Respondents' Satisfaction with Logistics Institution

Items	*Mean*	*S.D.*	*Rank*
Telecommunications	3.45	0.74	1
Information technology system	3.35	0.73	2
Inland transport linkage (e.g. road and rail)	3.20	0.81	3
Ports and maritime transport	3.16	0.80	4
Air transport	3.14	0.63	5
Corporate governance	3.09	0.68	6
Simplify the customs clearance procedures	3.01	0.89	7
Encouragement of logistics professional qualification	3.00	0.83	8
Eradication of corruption	2.95	0.91	9
Participating in the international standardization work of information exchange in logistics	2.95	0.75	9
Funding for logistics research and development	2.93	0.88	11
Knowledge sharing through electronic platforms	2.91	0.76	12
Clear long term perspective of regulatory changes (e.g. CO2 emissions reduction) allowing industry to prepare for their future implementation	2.90	0.76	13
Fostering smooth and fast integration and interoperability of different modalities	2.89	0.77	14
Effective mechanisms for protecting the market from too high concentration and monopolization	2.86	0.70	15
Avoid waste and controlled re-use of old products and materials	2.85	0.76	16
Tighten environmental guidance, balanced against the efficiency objectives	2.82	0.76	17
Embed sustainable transport logistics policy in national policies (finance, trade, environmental, social, energy maritime etc.)	2.81	0.77	18
Integrating coherent logistics practices between companies and authorities	2.80	0.75	19
Policy to ensure efficient service operation and multiplicity of services	2.78	0.92	20
Promote the development and implementation of alternative fuels	2.73	0.88	21
Avoidance of unnecessary regulation	2.67	0.87	22

*Mean scores are based on five-point Likert scale (1= very low, 5= very high).

Table 2: Respondents' Perceptions with Competitive Advantages

Items	*Mean*	*S. D.*
The quality of service for transport users (Service Quality)	3.28	0.62
The development of an efficient freight sector (Efficiency)	3.26	0.71
High quality service at reasonable cost with greater reliability (Reasonable Cost)	3.00	0.71
The competitiveness of the logistics industry (Competitiveness)	2.90	0.73

*Mean scores are based on five-point Likert scale (1= much worse, 5= much better).

4.3 Factor analysis results

Exploratory factor analysis with VARIMAX rotation was employed to identify crucial logistics institution dimensions. An eigenvalue greater than one was used to determine the number of factors for each dimension of logistics institution (Churchill and Iacobucci, 2004). 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. (1998). In addition, items which loaded on two factors were removed from further analysis. These two items were: *clear* *long term perspective of regulatory changes (e.g. CO2 emissions reduction) allowing industry to prepare for their future implementation* and *avoidance of unnecessary regulation.* As shown in Table 3, the results of factor analysis revealed that three factors accounted for approximately 70.95% of the total variance and were thus considered to significantly represent the logistics institution attributes. Four factors were subsequently found to underlie the logistics institution dimensions according to the respondents' perceptions. These four dimensions are labelled and described below:

Table 3: Results of Factor Analysis

Items	*Factors*			
	1	**2**	**3**	**4**
Policy to ensure efficient service operation and multiplicity of services	**.554**	.396	.246	.258
Effective mechanisms for protecting the market from too high concentration and monopolization	**.503**	.070	.458	.186
Corporate governance	**.599**	.003	.496	.246
Simplify the customs clearance procedures	**.592**	.361	.240	-.037
Eradication of corruption	**.535**	.327	.430	.150
Participating in the international standardization work of information exchange in logistics	**.748**	.332	.252	.110
Knowledge sharing through electronic platforms	**.739**	.178	.321	.288
Integrating coherent logistics practices between companies and authorities	**.763**	.346	.135	.154
Fostering smooth and fast integration and interoperability of different modalities	**.700**	.098	.186	.175
Ports and maritime transport	.228	**.805**	.089	.064
Air transport	.253	**.780**	.090	.076
Inland transport linkage	.180	**.782**	.148	.310
Information technology system	.175	**.811**	.273	.118
Telecommunications	.162	**.746**	.293	.191
Tighten environmental guidance, balanced against the efficiency objectives	.324	.192	**.805**	.116
Avoid waste and controlled re-use of old products and materials	.257	.224	**.860**	.057
Promote the development and implementation of alternative fuels	.197	.155	**.787**	.119
Embed sustainable transport logistics policy in national policies	.274	.319	**.662**	.198
Funding for logistics research and development	.264	.273	.212	**.854**
Encouragement of logistics professional qualification	.266	.221	.161	**.868**
Mean	4.41	4.55	4.20	4.25
S. D.	0.56	0.60	0.66	0.79
Eigenvalues	11.47	2.09	1.25	1.02
Variance Explained	52.55	9.16	5.34	4.54
Cronbach's α	0.91	0.91	0.88	0.92

(1) Factor 1, a regulation institution factor, consisted of nine items. *Integrating coherent logistics practices between companies and authorities* had the highest factor loading on this factor. It accounted for 49.16% of the total variance. Most of these items were related to regulation, therefore, this factor was identified as regulation institution.

(2) Factor 2, a physical infrastructure, comprised five items. These items were physical infrastructure in logistics operations. *Ports and maritime transport* and *information technology system* had the highest loading factors in this factor. This factor accounted for 9.85% of the total variance.

(3) Factor 3, a sustainable institution dimension, consisted of four items. These items were sustainability related attributes, therefore, this factor was identified as the sustainable institution. *Avoid waste and*

controlled re-use of old products and materials had the highest loading factor in this factor. Factor 3 accounted for 6.46% of the total variance.

(4) Factor 4, a human capital dimension, comprised two items, namely: *funding for logistics research and development* and *encouragement of logistics professional qualification.* It accounted for 6.46% of the total variance. Encouragement of logistics professional qualification had the highest loading factor in this factor.

The Cronbach alpha values coefficients of each measure were well above the suggested threshold of 0.8 (see Table 3), which was considered adequate for confirming a satisfactory level of reliability in research (Churchill and Iacobucci, 2004).

4.4 The impact of logistics institution on logistics firms' competitive advantages

To examine the effects of the logistics institutions on logistics firms' competitive advantages, multiple regression analysis was employed in this study. The four logistics institutional dimensions were used as independent variables in a series of regression models with each dimension of the logistics firms' competitive advantages treated as a dependent variable: competitiveness of the logistics industry, efficiency of its operation, quality of its service and cost derived from providing high quality service.

Table 4: Results of Multiple Regression Analysis

	Logistics Firms' Competitive Advantages							
	Model 1		*Model 2*		*Model 3*		*Model 4*	
Dimensions	Competitiveness β	(*t* value)	Efficiency β	(*t* value)	Service Quality β	(*t* value)	Reasonable Cost β	(*t* value)
Physical Infrastructure	0.069	(0.708)	0.092	(0.926)	0.218	(2.223)*	0.260	(2.858)**
Human Capital	0.063	(0.660)	0.076	(0.786)	-0.029	(-0.305)	0.102	(1.144)
Regulation Institution	0.382	(3.238)**	0.418	(3.485)**	0.136	(1.145)	0.304	(2.754)**
Sustainable Institution	-0.019	(-0.164)	-0.151	(-1.283)	0.168	(1.446)	-0.040	(-0.368)
F-value	10.660		8.839		9.752		17.862	
P-value	P<0.001		P<0.001		P<0.001		P<0.001	
R^2	0.206		0.177		0.192		0.303	
Adjusted R^2	0.187		0.157		0.172		0.286	
D-W value	1.893		1.814		2.211		1.870	

Note: *Significance level of p<0.1; **Significance level of p<0.05. β value = Standardised coefficient value

Table 4 shows the results of the four regression models and indicates that all four models were statistically significant at the 1% of significance level with F statistics values ranging from 8.8 to 17.8. In the first model with *competitiveness* as a dependent variable, the results showed that only *regulation institution* has a positive influence on *competitiveness*, *efficiency*, and *reasonable cost*, whereas *physical infrastructure* has a positive impact on service quality and reasonable cost. Accordingly, the results only partially supported the hypotheses $H_1$and H_3, however, the hypotheses H_2 and H_4 were not supported in this study.

In addition, the R^2 values representing the fit of the regression models were not so satisfactory ranging from 0.17 to 0.3. This means the models explain such percentages (17% to 30%) of variances of the dependent variables in the four regression models. While this might imply these models are missing some important factors or require an inclusion of some control variables to improve the R^2 values, an investigation was further undertaken into the causal relationships between logistics institutions and logistics firms' competitive advantage.

5. Discussion and Conclusion

Logistics institution has become a crucial enabler to enhance firm's competitive advantage. This study has drawn attention to the importance of the relationship between logistics institution and industrial competitive advantage in the logistics context. Several research findings are drawn from this study. First, despite an awareness of the existence of the notion of institution for many years, it is only now gaining acceptance as a way of sustaining a competitive advantage in a particular industry. However, no empirical study of the logistics institution was discussed in previous shipping or logistics-related research. This research not only identifies crucial logistics institution dimensions but also proposes a model for empirical studies to link logistics institution dimensions and industrial competitive advantage. To the best of our knowledge, this study is one of the first to examine the logistics institution in the logistics industry. The model may be used as a stepping stone for empirical research on logistics institution. Second, based on a multiple regression analysis, the findings indicated that logistics institutions such as *regulation institution* are found to have significantly positive effects on the competitive advantage aspects of *competitiveness, efficiency*, and *reasonable cost,* whereas the *physical infrastructure* has a positive effect on competitive advantage aspects of *service quality* and *reasonable cost*. This implies that *regulation institution* and *physical infrastructure* are important enablers to enhance competitive advantage in the logistics industry. From a practical standpoint, our suggestion to policymakers is that government should establish an effective transparent legal system and free and open market policy to help logistics firms to create an operating environment that fosters the competitiveness of trade and industry. These include simplifying the customs clearance procedures, effective mechanisms for protecting the market from monopolization, corporate government, and eradication of corruption.

Results also indicated that the physical infrastructure factors, including port and maritime transport, airport, information technology and communication system, and inland transport linkage were all important dimensions for administrators to take into account when reinforcing the logistics industry. Accordingly, this study implies that regulation is a necessary part of the Taiwanese economy. It must be intelligent, requires further development, and encourages competition. The harmonization of policies and regulations and the investment in infrastructure are preconditions for abolishing the barriers of logistics market. This study also suggests that the regulation and investment of logistics infrastructure must consider the development of the global logistics operating environment and the requirements of the logistics industry.

However, this research was limited to studying the impact of logistics institutions in the aspects of physical infrastructure, human capital, regulation institution, and sustainable institution. Future research could consider impacts of other institutional factors essential to the industrial competitive advantage, such as culture, ethical standards, currency stability, entrepreneurial profile, and regional institutional impacts (Chacar et al., 2010). In addition, this research was limited to examining the logistics institution enablers within a particular national industry in Taiwan. The logistics industry is an international business and future research could embrace the same scope of investigation and examine the industrial competitive advantage of other nations. Finally, the analysis conducted in this study was static, i.e., the evaluation of logistics institutions was undertaken at one point in time. Longitudinal research is needed to indicate how perceptions of logistics institutions may change over time.

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A Study on the Operation of Busan New Port Distripark

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Abstract

Korea has been focusing on to become the world-class logistics hub center in the Northeast Asia. For this purpose, South Korean government enacted the "Act of Governing the Establishment and Management of Free Trade Zones" in 2004. Under this law, Busan New Port has built and opened 16 container berths and 1,204,000m^2 logistics facility zone - so called Busan New Port Distripark occupied by numbers of multinational logistics corporations- is in operation. To accommodate growing demand on Busan New Port Distripark, BPA (Busan Port Authority) set a plan to provide additional logistics facility zones. In spite of its significance on regional economies and possible benefits and potentials, related study and academic review is not much being done in South Korea at the moment. Therefore, this paper aims to analyze the operation of the Distripark in Busan New Port and deriving some implications to become the foundation of further studies.

Keywords: Busan New Port, Distripark, Value-added Logistics, Free Trade Zone

1. Introduction

As the corporate economic activities are being globalized, the scale of logistics function is also required to be globalised. Ports and airports are critical points for the global logistics chain, and their hinterland and logistics zones have been developed accordingly to attract business and gain economic benefit to the regional economies. The trend of major ports would be providing incentives such as introducing free trade zone policy, offering lower CIT (Company Income Tax), and lower hire rate for the land to stay competitive.

Activating the port hinterland activity is beneficial in the respect of cargo creation. In the hinterland, freight is not only imported, exported, and trans-shipped, but also distributed, processed, and exported again, thus port's cargo throughput can be increased. Furthermore, it contributes to the regional economy by creating job opportunities and economic spread effect etc.

Busan New Port also is focusing on developing hinterland to stay competitive and eventually to become the hub port in the North East Asia. The new hinterland for logistics activities is now ready to open fully with 22 multinational companies. Currently, 14 corporations are doing business in the logistics center.

In spite of the significance of the huge project, the Busan New Port Distripark, related study is not so active in South Korea. Furthermore, the development plan, current conditions, investment status, the progress of construction and operation are not being checked and examined properly.

Thus, this study aims at investigating the facilities and operational conditions of the Busan New Port Distripark nominated for Free Trade Zone, and studying its implications.

2. Review of Busan New Port Distripark

Nowadays, logistics activities are becoming increasingly important. Particularly, a prominent value-added service zones provided by many container ports in the world are the Free Trade Zones or might be called the Distriparks. Free Trade Zones promise to bring economic benefits and also used to attract investment into a port area in order to establish a critical mass that will be self sustaining and attract further business investment and shipping cargo (UNESCAP, 2005).

Distribution is a key attraction to port users. Distriparks are advanced logistics parks with comprehensive facilities for distribution operations at a single location close to the cargo terminals and multimodal transport facilities for transshipment (UNESCAP, 2002). The successful Distriparks of Port of Rotterdam and Port of Singapore are optimistic prospects.

Table 1: Comparison between FTZ and FEZ

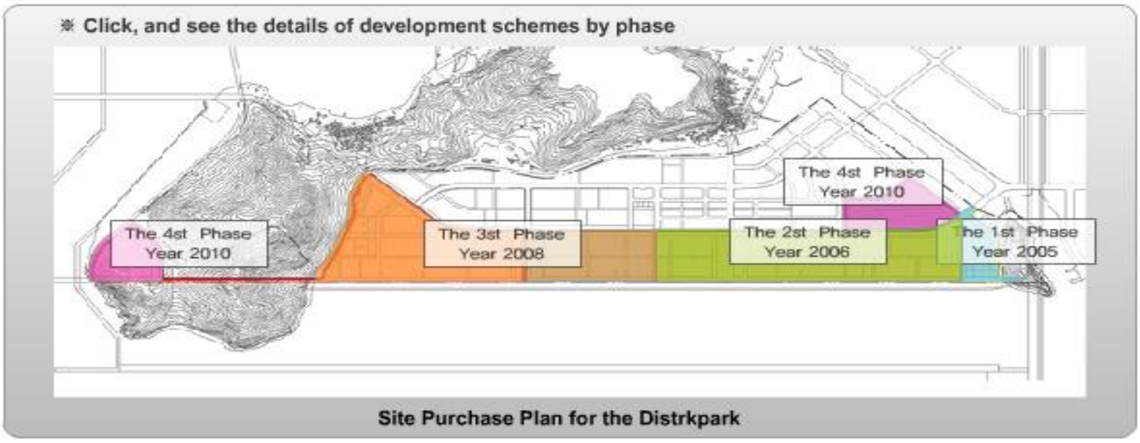
	FTZ	FEZ
Definition	-Enterprise Zone -Inducement of foreign investment, trade promotion and international logistics vitalization -Tax and rent relief, tariff and VAT exemption for encouraging logistics and manufacturing	-Special Administrative District: industrial function of logistics, manufacturing, service, and urban function of housing, education, and medical service -Supporting management activities of foreign - invested companies with tax and rental relief as well as other benefit to improve living conditions of foreigners for their convenience
Law	-Free Trade Zone Law Law of Designation and Operation of Free Trade Zone	-Free Economic Zone Law Law of Designation and Operation of Free Economic Zone
Purpose	-Encouraging foreign investment -Trade Promotion -International logistics vitalization	-Improvement of managing environment of Foreign - Invested Companies and living conditions for foreigners
Authority	-Industrial complex: Ministry of Knowledge -Port, Airport , and Hinterland: Ministry of Transport and Maritime Affairs	-Free Economic Zone Agencies of Cities and Provinces
Requirements	-International Container Service line which handles more than 10 million tons of cargoes p.a. -Container Port over a size of 20 kilotons - More than 500,000 m2 of land and hinterland	-International Container Service Line, which handles 10 million tons of cargoes p.a. -Container Port over a size of 20 kilotons
Conditions	-Logistics and Manufacturing	-Logistics, Manufacturing, International Schools, Foreign Hospital
Tax	-Tariff Exemption -VAT with zero rate	-Limited tariff exemption (3 years, capital goods) -VAT collection
National and State Land lease	-Basic rate: Low-price posted rate -Lease duration: maximum 50 years	-Exclusion of hiring duty on the aged and the disabled -Unpaid leave and monthly leave -Exclusion of paid day off -Improvement of living environment for foreigners e.g. foreign hospital

Source: BDIS web site http://www.busannewport.or.kr

Busan New Port seeks to become a port and logistics hub linking Korea with China, Japan and Russia. Opening a Distripark is one of important promotions. It is not only a Free Trade Zone (FTZ) but also a Free Economic Zone (FEZ), which is supported by the law of FEZ (FTZ and FEZ seem to be similar but a little bit different as shown in Table 1).

The purposes of Distripark are to induce international logistics companies and establish supporting facilities such as CFS(container freight station) as well as high-tech manufacturing and research and development facilities. Tenant companies in the distripark will be offered benefits such as tax-free, tax reduction and low lease rate. For instances, leases are provided for up to 50 years with annual rate of about 40 Korean Won (or around 3.6 US cents) per square meter to foreign-invested companies which operate in the logistics industry. This is one-fifteenth the rate for logistics ventures in Shanghai. Besides, higher value-added port throughput such as processing, and assembling are created. It is believed that by developing Free Trade Zones, Busan New Port will become the international logistics hub port and higher value-added cargo creating port from a transshipment-center port.

Figure 1: Site Development Plan for the North Terminal Distripark



Source : BDIS web site http://www.busannewport.or.kr

A proposed development plan for the North Terminal Distripark includes four phases is shown in the Figure 1. Actually, it has been developed and will be accomplished and fully operated at the end of the year 2010. A part of the Distripark has been operated in simultaneously with developing progress and contributed much on development of Busan New Port.

To go into details, the development plan of Busan New Port Distripark is presented in Table 2, which includes three Distriparks with their functions, area and percentage shown in sequent columns.

They are intended to offer great logistics services, provide space for warehousing and forwarding facilities and also a comprehensive range of value-added services, and support shippers and transport companies for Just-In-Time delivery at the lower costs.

Table 2: Development plan of Busan New Port Distripark

		Area(m^2)	rate(%)
North Terminal Distripark	Combined Logistics Facilities	1,043,838	26
South Terminal Distripark	Storage and Delivery Facilities	477,048	
	Assembly and Semi- manufacturing Facilities	88,515	
	Transshipment and Empty Container Storage Facility	282,183	

	Sub Total	847,746	21
Woongdong Distripark	Storage and Delivery Facilities	1,420,114	
	Assembly and Semi- manufacturing Facilities	589,950	
	Transshipment and Empty Container Storage Facility	147,682	
	Sub Total	2,157,746	53
Total		4,049,330	100

Source: web site of BPA

3. Operation of Busan New Port Distripark

Currently, 22 corporations are nominated as tenants in the Busan New Port Distripark by the end of September 2009. Among them, 14 companies run distribution centers, and the rest 8 have them under construction. Total area for the lease is 785,711m^2 and each company assigns between 16,528 m^2 and 103,682 m^2.

Table 3: Overview of the Tenant Companies in Busan New Port Distripark

Tenant Companies	Area Leased (m^2)	Capital (KRW100 mil.)	Foreign Capital (KRW100mil.)	Investment Countries
BIDC Inc.	103,682	70	13.9	Japan, Indonesia
Busan Newport CFS Inc.	20,916	20	0	n/a
Korea Express Co., Ltd. BND	37,017	77	11.6	Japan
SBNL Co., Ltd.	49,680	25	9.75	China
C.Steinweg Dongbu Distripark Busan Inc.	66,095	58	58	Singapore
C&S International Logistics Center Co. Ltd	66,373	75	7.5	Japan
First Class Logistics Co. Ltd	37,775	55	6	Japan, HongKong
Dongbang Logistics Center Inc.	37,018	27.5	3.5	China
DKLC	24,793	5	1	Japan, Hongkong
*Hyundai Cosco Logistics Co., Ltd.	30,978	50	14.5	China
*Busan Global Logistics Center	26,962	70	27.3	Japan
Busan Cross Dock	30,978	50	15	Canada, Singapore
*Pantos Busan Newport Logistics Center	26,962	55	26.9	China, Hongkong
*G&G Inc.	18,181	15	3	China
MS Distripark	33,057	25	2.5	Japan
*KN Logistics	33,057	40	18	Japan
*Newport International Logistics	34,714	26.7	1.7	Japan
*New World Logistics	33,057	14	1.4	Japan
*Bogo Logistics	30,230	10	2	China
Hanjin Kerry Logistics	16,528	35	12.5	Singapore
*Korea Express BND 2nd	27,658	80	8	Japan
Total	785,711	883.2	244.05	

Source: Derived from Busan Port Authority internal report (: Under construction)*

The total invested capital of tenant companies was KRW 883.2 hundred million of which foreign capital takes KRW 244.05 hundred million accounting for 27.6% of the total.

Table 4: Major Cargo Types and Value Adding Activities

Tenant Companies	Major Cargo	Major value adding activity
BIDC.Co.Ltd (incl. 2nd phase)	Marine equipments, Living goods, Car parts	Assembling, Processing

Busan New Port CFS.Co.Ltd	Living goods, Car parts(KD), Coil	Auto KD
Korea Express BND	Semiconductor materials, Machine facilities, Pulp, Coil, LME, Machine parts, Paper	Domestic/ Japan Export/ imports, Value added container logistics
Sebang Busan Newport Logistics	Coil, Construction materials, Copper sheet, AL INGOT, Coffee	Value added trans-shipment
C.Steinweg Dongbu Distripark, Busan	LME, Coil, Machine facilities	Global distribution of LME
C&S International Logistics Center	Car parts, Raw food stuff, Coffee, Coil	Auto KD, Packaging
First Class Logistics	Paper, Pulp, Marine equipments, Paint, Daily necessities, Clothing, General goods	Labeling, Assembling· Processing
Dongbang Logistics Center	Living goods	-
DKLC.Co,Ltd	Nuclear plant components, Strach, General goods, Coil, Car parts	Storage, CFS function

Source: Derived from Center for National Transportation DB (2009), and the website http://www.busannewport.or.kr

The foreign capital from Japan is the biggest followed by China, Singapore, Hongkong, Indonesia and Canada. Except Canada, all the foreign capital is from Asian region.

The tenant companies deal with a variety of freights such as living goods, medical equipment, general goods, car components, marine equipments, machinery parts, nuclear plant components, coil, LME and so on.

In addition to the traditional logistics activities such as handling and storage assembling, processing, labeling, packaging and auto knock-down (KD) are main activities which adds value on primary cargoes. Targeted market is mainly Japan, specially Russia is a main market for the KD as the gap between Russia's tax rate on finished cars and KD parts is big.

Table 5: Main Figures for the Tenant Companies in 2009

Tenant Company	Cargo Volume(TEU)			Value-added logistics ratio(%)	Sales (KRW100 mil.)
	Throughput (a)	Target Throughput (b)	(a)/(b)		
BIDC	41,767	66,297	0.63	n/a	121
Busan Newport CFS Co.Ltd	18,107	27,435	0.66	n/a	41
Korea Express BND	19,616	13,165	1.49	1.8	60
SBNL Co., Ltd.	18,960	21,545	0.88	7	49
C.Steinweg Dongbu Distripark Busan Inc.	8,454	38,427	0.22	0	23.6
C&S International Logistics Center Co., Ltd.	34,977	41,639	0.84	39	56.8
First Class Logistics	8,120	7,660	1.06	10~15	38
Dongbang Logistics Center Inc.	3,305	11,017	0.3	0	13
DKLC.Co.Ltd	65,305	-	-	18	n/a
Total	218,611	227,185	0.76		402.4

Source: Derived from BPA internal report

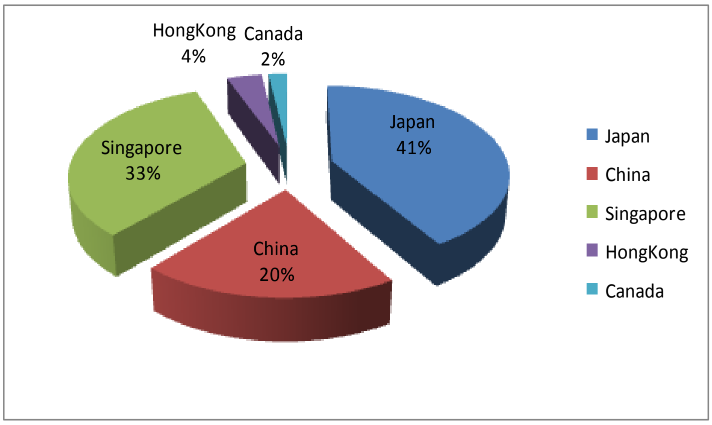
Total throughput of tenant companies in 2009 was 218,611TEU and the total target throughput except DKLC.Co.Ltd was 227,185TEU. The average ratio of throughput to the target throughput is 76%. Value-added logistics activities ratio is not being counted exactly but it is estimated generally 0% to 39% range. The amount of total sales is KRW 402.4 hundred million and it reaches 98.7% of total capital which is KRW 407.5 hundred million.

4. Implication

4.1 Limited Market Area

As described in the previous chapter, Asia's share of the foreign investment to the Busan New Port Distripark reaches up to 98% and it is mainly from China and Japan as show in Figure 2.

Fig. 2. The Share of Foreign Investment by Country

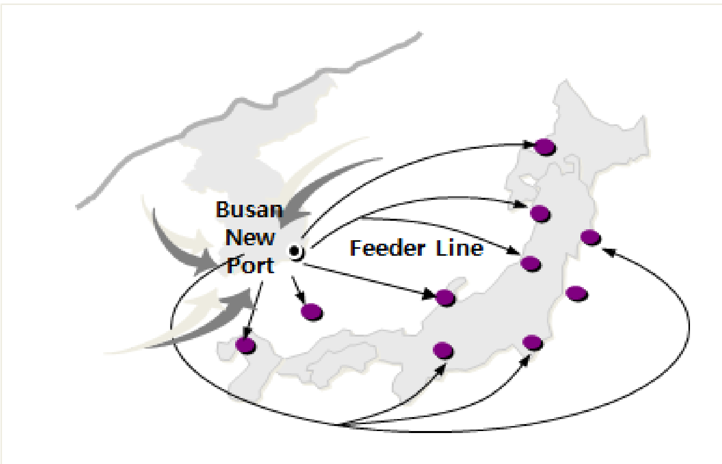


Source: Derived from Busan Port Authority Internal report

Those neighboring countries' share takes 61% of the whole. The share of Singapore was also rather high as C.Steinweg invested KRW 58hundred million itself.

The major target market of the Distripark seems to be Japan. Figure 3 represents the typical business model of logistics which in-house companies suggest. It is mainly to export products to Japan after adding value by assembling, processing etc. with components, parts, finished goods imported from China, Asia and America.

Fig. 3. A Typical Business Model



Source: Derived from interview with personnel in the tenant companies

It is due to the Japanese consumer market which is the world second biggest and the existence of over 50 feeder line network between Busan port and Japanese ports. However, for the prosperity of the Busan New

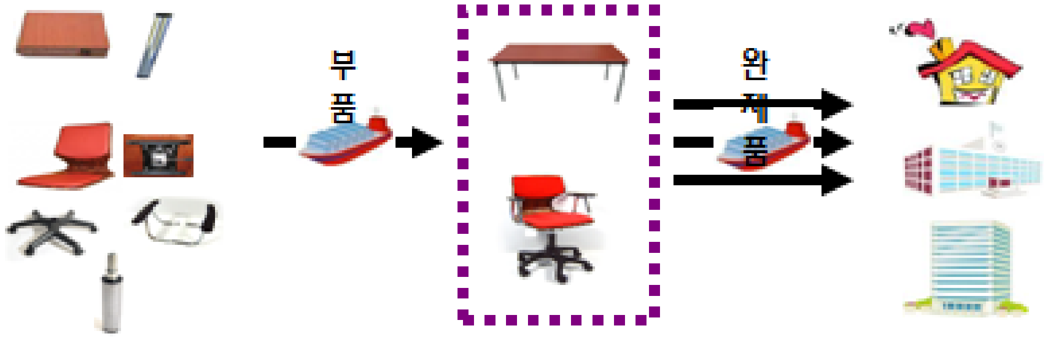
Port Distripark, attracting investments not only from Asia but also from other parts of the world is critical as well as with market expansion.

4.2 Low Ratio of Value-added Logistics Activity

As described earlier, the proportion of value-added logistics serviced by the 9 companies in operation is in the range of 0 to 39% and the average is 11.2%. Moreover, two surveyed companies did not perform any value-added logistics activities at all. It doesn't correspond to the mission of the Distripark in the FTZ which is adding value on simple logistics activities.

Likewise, the business model of value adding logistics service is limited. Representing cases are the exporting chairs to Japan after assembling with imported parts and materials (Figure 4) and the exporting cars to Russia after dis-assembling as the duty rate gap between finished cars and car components are big.

Figure 4: A Typical Value-added Logistics Activity



Source: Derived from interview with personnel in the tenant companies

Consequently, it is needed to create more value adding business models. Postponement can be considered to be a good principle to apply. As presented in Table 6, the postponement is a customizing method which postpones forming product forms until customer's order is received so that all the activities such as labeling, packaging, assembling, processing etc. come after the point of receiving orders.

Table 6: Principle of Postponement

Postponement Type	*Potential Products*
Labelling	Products sold under several brand names
Packaging	Products sold under several package sizes
Assembly	Products cube is greatly reduced if shipped unassembled
Semi-manufacturing	Products with a high proportion of ubiquitous materials

Source: Ballou, R.H. (1999), p.45, Table 2-2 amended

4.3 Low Utilization

By the end of 2009, the total leased area of the 9 corporations was 433,349m^2 and the throughput was 218,611TEU(Table 5). Thus, cargo throughput per one m^2 is approximately 7.5ton and it is far behind 12.9 ton which was aimed by Ditripark plan.

The low utilization is directly related to the short duration of the operation (shorter than 2 years on average) and cargo decline due to the global financial crisis in 2009. However, a big deviation of throughput between corporations operating in the Distripark still exists, and some of them only achieve 20 to30% of target throughput.

5. Conclusion

The purpose of this paper is to investigate the facilities and operational conditions of the Busan New Port Distripark nominated for Free Trade Zone and derive some implications.

By September 2009, 22 corporations were nominated into the New Port Distripark, and among them, 14 are already in operation. The present condition of those companies in operation has investigated and some problem was found as follows.

First, the foreign investment is too much concentrated in Asia which takes 98% in terms of investment amount and the logistics market is highly dependent on Japan.

Second, the value-adding logistics activity is not so active. The average ratio of value added activities performed by the 9 companies in operation is estimated only 11.2%, including the case which the value adding activity is not feasible due to the character of cargo the company deals with.

Third, the operation is rather poor even though it has not reached to the stable stage as tenant companies have been operated only around for 2 years so far on average. However, it's still inadequate considering increasing trend of throughput in the new port.

Consequently, Busan New Port Distripark needs to attract investment not only from Asia but also from other parts of the world as well as to diversify the market area. In order to achieve this, postponement principal could be considered to develop a variety of value adding logistics business models.

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Corporate Social Responsibility in China: An Empirical Investigation of ChengDu Hi-tech Industrial Development Zone

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Abstract

This study investigated crucial corporate social responsibility (CSR) dimensions and firm performance in China. A survey of 729 manufacturing firms in Chengdu Hi-tech industrial Development Zone (CDHT) located in the Sichuan province of China was undertaken in order to examine main taxonomy in CSR, using factor analysis, cluster analysis, and ANOVA analysis approaches. On the basis of factor analysis, three CSR dimensions were identified: employee and consumer interests, community involvement, and disclosure dimensions. Using cluster analysis, the 256 firms of respondents were categorized into three groups based on factor analysis scores – group 1, a disclosure oriented group, group 2, an employee and consumer oriented group, and group 3, an intensive CSR oriented group. ANOVA analysis tested differences in the three groups" firm performance. Group 3 had high performance indices whereas groups 1 and 2 had low performance indices in general. The implications of the three identified groups are presented and areas for future research suggested.

Keywords: *Corporate Social Responsibility, Cluster Analysis,*

1. Introduction

In recent years, with the international popularization of environmental awareness, green concepts, and renewable consumption, corporate social responsibility (CSR) has become highly valued. Under this framework, companies not only pursue profits for stakeholders and investors; they also devote themselves to environmental protection, labor rights, charity work, and community participation.

Several internationally recognizable brands have adopted social responsibility as a useful tool for market segmentation from competitors. For instance, many companies have participated in the Carbon Disclosure Project (CDP). The American brand Timberland disclosed its carbon emissions on their shoes. The biggest retailer in the world, Wal-Mart, and personal computer producer, Dell, both require suppliers to provide energy consumption information in order to calculate total greenhouse gas emissions.

The internationalization of companies has also led to discussions on transnational corporate ethics and the importance of corporate social responsibility. For instance, transnational companies are responsible for ensuring that the product supply chain meets social responsibility requirement. In order to encourage Uzbekistan"s government to terminate child labor in cotton harvesting, Wal-Mart has requested its global suppliers to refuse Uzbek cotton and raw materials. Nike, the world"s leading manufacturer of sports articles, was once the source of much controversy over its foreign-based factories, which led to global boycotts and "anti-sweatshop" movements. Consumers and human rights groups refused products from the company. Starbucks developed "Fair trade Coffee" and "Shared Planet" so coffee growers can receive higher returns (Starbucks, 2010). After the Wenchuan Earthquake, the RT-Mart company contributed 50 million RMB and a large amount of goods, which improved its corporate reputation and resulted in a popular jingle about shopping there.

With the international popularization of environmental awareness, world-famous brands have more cautiously selected their suppliers, resulting in competition between supply chains. In April, 2005, Nike made public the names and addresses of its 700 global suppliers, the first large-scale costume and accessories manufacturer to actively reveal its global supply chain. Further, as a result of increasing emphasis on the social responsibility of business, supply chain management has gradually developed into "green supply management" or "ethical supply chain management".

In addition, due to economic internationalization, production standards around the world have increasingly conformed to meet social responsibility requirements and companies in China cannot therefore avoid the new developments. Both international clients and consumers expect high standards from companies in China as indicated by international exposure of the recent wave of suicides by Foxconn factory workers in Shenzhen, China, which led to acknowledgement of the importance of CSR in China (Hille and Kwong, 2010).

Terms like CSR, corporate citizenship (Carroll, 1979), corporate social performance (CSP) (Swanson, 1995), and stakeholder management (Jones, 1995) are closely related. Carroll (1979: 500) defines CSR as "the social responsibility of businesses to encompass the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time". McWilliams and Siegel (2001:117) describe CSR as "actions that appear to further some social good, beyond the interests of the firm, and which are required by law". Recently, Bhattacharya and Sen (2004: 9) have emphasized that "not only is doing good the right thing to do, but it also leads to doing better".

Although interest in CSR in emerging markets has increased in recent years, most researchers still focus on developed countries (Lindgreen et al., 2009; Okamoto, 2009). Most research efforts have focused on investigating the relationship between CSR and organizational performance (Waddock and Graves, 1997; Lu et al., 2009), while relatively few has focused on the issue of identifying CSR types. Research on type or taxonomy, the foundation of research on strategic management (Zhao et al., 2006; Handfield et al., 1997), is one of the most important and fundamental steps in scientific research (Autry et al., 2008).

This study aims to explore critical CSR dimensions, identify different CSR oriented groups, and examine firm performance differences between the groups in the Hi-tech industrial context, thereby filling gaps in the CSR literature.

Chengdu Hi-tech Zone (CDHT) was one of the earliest state-level hi-tech industrial development zones in China. With a planned area of 87 km², CDHT comprises a south park and west park. There are more than 16,000 companies registered in the CDHT including over 750 foreign invested enterprises, 40 of which are fortune 500 companies, including Intel, Microsoft, Motorola, Siemens, Nokia, Ericsson, Corning, Sony, Sumitomo, Toyota, NEC, Carrefour, UPS, Alcatel, Ubisoft, among others. CDHT's economic index has grown over 25% annually. Its comprehensive strength has led to its ranking of fourth among China"s 55 state-level hi-tech zones (CDHT, 2010).

There are four sections in this study. Following this introduction, the next section focuses on the study sample, development of the research instrument, and data analysis methods. Section 3 presents exploratory factor analysis, cluster analysis and ANOVA results. Conclusions drawn from the research findings and their implications are discussed in the final section.

2. Methodology

2.1 Sample

This research was based on manufacturing firms in Chengdu Hi-tech industrial Development Zone (CDHT) located in the Sichuan province of China. Questionnaires with accompanying cover letters and stamp-attached envelopes were initially mailed to 729 potential respondents. The cover letter explained the objectives of the research project and how the data would be used. Three weeks later, second wave of questionnaires, accompanied by cover letters and stamp-attached envelopes, was sent to all non-respondents. In total, 256 completed questionnaires were returned. The total response rate was therefore 28 percent (256/929). The analyses presented in Section 3 are based on data derived from the 256 returned questionnaires.

Respondents in the semiconductor industry returned 9 questionnaires (3.5 percent of the total received); 17 returned them in the optoelectronic industry (6.6 percent of the total received); 35 in the computers and peripheral equipment industry (13.7 percent of the total received); 26 in the communications and internet industry (10.2 percent of the total received); 12 in the electronic parts/components industry (4.7 percent of the total received); 40 in the pharmacy industry (15.6 percent of the total received); 8 in the medical and biotech industry (3.1 percent of the total received); and 109 in companies representing other industrial sectors (42.6 percent of the total received). As regards the duration of responding firms‟ operation, just over eight percent (8.2%) had been in operation for more than 15 years; 39.8 percent had been operating between 4 and 8 years; and 28.5% percent for less than three years.

Turning to the number of employees in respondents‟ employing companies, nearly half (47.7 percent) of respondents‟ firms employed had less than 50 employees; just over a quarter (25.8 percent) employed between 51and 100 full-time workers; and 7.0 percent employed over 500 employees. Firms‟ sales varied considerably. Just over a quarter (26.2 percent) of firms‟ sales were between *RMB$* 11 million and *RMB$* 50 million, 16.4 percent recorded sales of over *RMB$*200 million, and 44.1 percent recorded sales below *RMB$ 10* million.

As regards respondents‟ job title, 6.6 percent were vice-presidents or presidents, 18.8 percent were presidents‟ assistants, 23.4 percent were department managers, and 14.5 percent were senior managers, which reinforced the reliability of the survey‟s findings. Further, over 43 percent of respondents had worked in their present company between two and three years, 21.5 percent had worked in their present company for less than one year, and just over 4.7 percent had been with the same company for more than 20 years.

2.2 Research methods

The research aims were accomplished by conducting a questionnaire survey. The research steps, which included questionnaire design and utilization of several data analysis methods, are described below.

Step 1: questionnaire design and content validity test

The first step was to select CSR attributes by reviewing the on CSR research literature. This was followed by questionnaire design, personal interviews with CSR practitioners, and a content validity test. The questionnaire design followed the stages outlined by Churchill (1991). Information sought was first specified, and then the following issues were settled: questionnaire type and its method of administration, the content of individual questions, form of response to and wording of each question, sequence of questions, and physical characteristics of the questionnaire. Determining questionnaire items, it is crucial to ensure the validity of their content, since this is an important measure of a survey instrument‟s accuracy. Content validity refers to the extent to which a test measures what the researcher actually wishes to measure (Cooper and Emory, 1995). The assessment of content validity typically involves an organized review of the survey instrument‟s content to ensure it includes everything it should and does not include anything it should not. The content validity of the questionnaire used in this study was established through a literature review and interviews with practitioners, that is to say, questionnaire questions were based on previous studies (Abbott and Monsen, 1979; Holmes, 1978; Luet al., 2009) and judged relevant by managers in ten manufacturing companies located in Chengdu hi-tech industrial development zone. Interviews with practitioners resulted in minor modifications to the wording of some questions and examples provided in some measurement items. Questionnaire items deemed to possess content validity.

Five-point Likert-type scale anchors were used. Respondents were asked to indicate their level of agreement with their firm"s implementation of questionnaire items on a scale ranging from 1 representing "Strongly Disagree" to 5 represented "Strongly Agree". Firm performance has been frequently measured by logistics researchers (Lu and Yang, 2006; Shang et al., 2010). In this study, respondents were asked to rate their firm"s performance relative to its major competitors by indicating its level of implementation of questionnaire items on a seven point scale, where 1 represented "Much Worse" and 5 represented "Much Better".

Step 2: factor analysis

Factor analysis was conducted in order to summarize a large number of CSR attributes into a smaller, manageable set of underlying factors, called dimensions. A reliability test was conducted to assess whether these CSR dimensions were adequate.

Step 3: Cluster analysis

A hierarchical algorithm (Ward"s method) was first used to define the number of clusters and cluster centroids, which then served as the starting points for subsequent nonhierarchical cluster analysis. One-way analysis of variance (ANOVA) and a Scheffe test were subsequently performed between the clusters and performance outcomes in order to identify any difference between clusters. All analyses were carried out using the *SPSS 12.0 for Windows* package, and results are presented in the following section.

3. Results of Empirical Analyses

3.1 Perceptions of CSR attributes

According to aggregated scores for firms" implementation of the 15 CSR attributes, respondents" level of agreement ranged from neutral to strongly agree (mean scores were 3.32 and above). The top three most commonly implemented attributes in respondents" firms were: (C14) our company emphasizes consumer privacy and provides protection for personal data, (C16) our company complies with the tax laws and regulations in all the countries in which it operates and contributes to the public finances of host countries by making timely payment of its tax liabilities, and (C15) our company does not further business interests by cheating our customers (see Table 1). In contrast, respondents" firms showed lowest implementation level with regard to the following: (C22) our company sponsors cultural and artistic activities, (C18) our company frequently holds charity activities, (C3) Our company ensures that timely, regular, relevant information is disclosed regarding our activities, structure, financial situation and performance.

Table 1: Respondents' Agreement with CSR Attributes

	CSR Variables	*Mean*[a]	*SD*[b].
c14	Our company emphasizes consumer privacy and provides protection for personal data	4.38	0.84
c16	Our company complies with the tax laws and regulations in all the countries in which it operates and contributes to the public finances of host countries by making timely payment of its tax liabilities.	4.38	0.88
c15	Our company does not further business interests by cheating our customers.	4.34	0.94
c13	Our company does not make false representation, nor engage in any practices that are deceptive, misleading, fraudulent, or unfair.	4.30	0.92
c7	Our company emphasizes staff development, skill training and on-the job-training.	4.21	0.97

c6	Our company does not discriminate against employees with respect to employment or occupation on such grounds as race, colour, sex, religion, political opinion, national extraction or social region.	4.20	0.95
c11	Our company requests its business partners to enhance environmental protection awareness and comply with related environmental regulations.	3.91	0.97
c19	Our company contributes to urban and community environmental improvement.	3.88	0.99
c20	Our company participates in community development and promotion of citizens" welfare.	3.82	1.03
c1	Our company applies high quality standards for disclosure, accounting, auditing, environmental and CSR reporting.	3.77	1.07
c21	Our company supports education related activities such as scholarships and intern opportunities.	3.73	1.07
c2	Our company adopts high standards of environmental and CSR reporting.	3.71	1.11
c3	Our company ensures that timely, regular, relevant information is disclosed regarding its activities, structure, financial situation and performance.	3.58	1.08
c18	Our company frequently holds charity activities.	3.56	1.10
c22	Our company sponsors cultural and artistic activities	3.32	1.18

[a] Mean scores are based on a 5-point Likert scale (1= strongly disagree to 5= strongly agree);
[b] S.D. = standard deviation.

3.2 Factor analysis

Factor analysis was used to reduce the 15 CSR attributes to smaller sets of underlying factors (dimensions). This helped to detect the presence of meaningful patterns among the original variables and to extract the main factors. Principal components analysis with VARIMAX rotation was employed to identify key CSR dimensions (see Table 2). Eigenvalues greater than one were used to determine the number of factors in each data set (Churchill, 1991). The three key CSR dimensions identified accounted for approximately 72.28 percent of the total variance.

Table 2: Factor Analysis to Identify Key CSR Dimensions

	CSR Attributes	*Factor one*	*Factor two*	*Factor three*
c13	Our company does not make false representation, nor engage in any other practices that are deceptive, misleading, fraudulent, or unfair.	**.845**	.208	.106
c14	Our company emphasizes consumer privacy and provides protection for personal data	**.827**	.152	.156
c15	Our company does not further business interests by cheating our customers.	**.826**	.280	.093
c16	Our company complies with the tax laws and regulations in all the countries in which it operates and contributes to the public finances of host countries by making timely payment of its tax liabilities.	**.778**	.214	.140
c7	Our company emphasizes staff development, skill training and on-the job-training.	**.743**	.136	.394
c6	Our company does not discriminate against employees with respect to employment or occupation on such grounds as race, colour, sex, religion, political opinion, national extraction or social region.	**.709**	.017	.433
c11	Our company requests its business partners to enhance environmental protection awareness and comply with related environmental regulations.	**.585**	.378	.332
c22	Our company sponsors cultural and artistic activities	.001	**.837**	.151
c18	Our company frequently holds charity activities.	.132	**.819**	.248
c21	Our company supports education related activities such as scholarships and intern opportunities.	.315	**.770**	.166
c19	Our company contributes to urban and community environmental	.370	**.704**	.311

improvement.			
c20 Our company participates in community development and promotion of citizens‟ welfare.	.423	**.693**	.254
c2 Our company adopts high standards of environmental and CSR reporting.	.303	.202	**.790**
c3 Our company ensures that timely, regular, relevant information is disclosed regarding its activities, structure, financial situation and performance.	.128	.310	**.788**
c1 Our company applies high quality standards for disclosure, accounting, auditing, environmental and CSR reporting.	.268	.353	**.749**
Eigenvalues	7.771	1.949	1.124
Percentage variance	51.80	12.99	7.49

To aid interpretation, only variables with a factor loading greater than 0.50 were extracted, a conservative criterion based on Hair et al., (1998). The scores on each of the three CSR dimensions (factors) were calculated for each respondent and submitted for subsequent cluster analysis. Three critical CSR dimensions (factors) were found to underlie the various sets of CSR attributes in Chengdu Hi-tech Industrial Development Zone. These were labeled, and are described below:

(1) Factor one, an employee and consumer interests dimension, consisted of seven items. Most of these items were related to employee and consumer interests. This factor accounted for 51.80 percent of the total variance. „Our company does not make false representation, nor engage in any other practices, that are deceptive, misleading, fraudulent, or unfair‟ had the highest factor loading on this dimension.

(2) Factor two, a community involvement dimension, comprised five items. These items were related to community involvement. „Our company sponsors cultural and artistic activities‟ had the highest factor loading on this factor. Factor two accounted for 12.99 percent of the total variance.

(3) Factor three, a disclosure dimension, consisted of three items. „Our company adopts high standards of environmental and CSR reporting‟ had the highest factor loading on this factor. Factor three accounted for 7.49 percent of the total variance.

3.3 Item-total correlation and reliability test

Item-total correlation has been used extensively in the psychology, marketing, and manufacturing literature (Churchill, 1991). It refers to the correlation of an item or indicator with the composite score of all items forming the same set. Items from a given scale exhibiting item-total correlations of less than 0.50 are usually candidates for elimination. If the items in a measure are drawn from the domain of a single construct, responses to these items should be highly inter-correlated (Churchill, 1991). As seen in Table 3, the item-total correlation of all CSR dimensions ranged from 0.665 to 0.796.

A reliability test based on Cronbach‟s Alpha, was used to assess whether the dimensions were consistent and reliable. Cronbach Alpha values for each dimension are also shown in Table 3. The reliability value of each factor was 0.84 or above, suggesting consistency and reliability (Nunnally, 1978).

Table 3 also indicates respondents‟ level of agreement with their firms‟ implementation of the three CSR. Mean score results indicated that the employee and consumer interests dimension had been implemented the most (mean = 4.25), followed by the disclosure dimension (mean = 3.69), and then the community involvement dimensions (mean = 3.66).

Table 3: Mean, Standard Deviation, and Cronbach Alpha Values for each CSR Dimension

CSR dimension	*Number of items*	*Cronbach Alpha*	*Mean*	*S.D.*[a]	*Range of item-total correlation*
1.Employee and consumer interests	7	0.92	4.25	0.76	0.665-0.796
2.Community involvement	5	0.89	3.66	0.90	0.670-0.765

3.Disclosure	3	0.84	3.69	0.95	0.683-0.730

[a] S.D. = standard deviation.

3.4 Cluster analysis results

Using two-stage cluster analysis techniques (Hair et al., 1998), 256 firms of respondents were categorized into three groups based on factor analysis scores. Seventy-four were assigned to Group 1, 75 to Group 2, and 108 to Group 3. Canonical discriminant functions (Klecka, 1980) demonstrated the nature of segment differences, and explained 98 percent of the variance.

3.5 Interpretation of clusters

ANOVA and Scheffe tests were used to examine whether the CSR dimensions differed between the three groups. Table 4 shows ANOVA results in terms of factor score coefficients. The three CSR dimensions were found to differ significantly between the three groups at the $p < 0.05$ significance level.

As shown in Table 4, Group 3 had the highest positive centroid score on the community involvement and disclosure dimensions. Group 2 had the highest positive centroid score on the employee and consumer interests dimension. Group 1 had a positive centroid score on the disclosure dimension. Based on the aforementioned findings, Group 1 was identified as a disclosure oriented group (DIS), group 2 was identified as an employee and consumer oriented group (EC1), and group3 was identified as an intensive CSR oriented group (INT).

Table 4: One-way ANOVA Analysis of CSR Differences between the Groups

Dimension	Groups 1 (DIS) (74)	2 (ECI) (75)	3 (INT) (107)	F Value	F [b] Prob.	Scheffe Test
1.Employee and consumer interests	-1.16 [a]	0.60	0.38	161.90	**0.00	3>1; 2>1
2.Community involvement	-0.30	-0.64	0.66	62.10	**0.00	3>1>2
3.Disclosure	0.20	-0.86	0.46	58.34	**0.00	1>2; 3>2

[a].The description of groups is based on factor scores with a mean of zero and standard deviation of one. For instance, the negative value of the factor score coefficient, -1.16 (see first column, first row), indicates that respondents placed less emphasis on dimension one.

[b]. *Significance level $p < 0.05$; **Significance level $p < 0.01$

One-way ANOVA analysis was employed to test differences in performance between the three groups on the basis of Scheffe test results. Respondents were asked to provide information relating to their firm‟s performance in terms of CSR image improvement, profit (before tax), market share, sales, and customer satisfaction (see Table 5). Firm performance indices significantly differed between the three groups. Overall, the INT group had better firm performance than the other two groups in terms of mean scores for firm performance indices. The DIS group had higher firm performance indices for profit (before tax), market share, and sales than the ECI group, whereas the ECI group had higher firm performance indices for CSR image improvement and customer satisfaction than the DIS group.

Table 5: One-way ANOVA Analysis of Firm Performance Differences between the Three Groups

Firm Performance	Groups 1 DIS	2 ECI	3 INT	F Ratio	Comparison	Scheffe Test
CSR image improvement	3.74	3.84	4.17	**17.10	3>2>1	3>1; 3>2
Profit (before tax)	3.73	3.37	4.05	**14.20	3>1>2	3>1>2

Market share	3.74	3.53	4.13	**10.27	3>1>2	3>1; 3>2
Sales	3.74	3.40	4.06	**11.96	3>1>2	3>2
Customer satisfaction	3.95	4.05	4.51	**15.12	3>2>1	3>1; 3>2

[a]. *Significance level p < 0.05; **Significance level p < 0.01

4. Conclusion and Discussions

This study has presented a study which examined the CSR attributes of companies in Chengdu Hi-tech Industrial Development Zone in China. The study‟s main findings are summarized below. Factor analysis was conducted to reduce the 15 CSR attributes to three critical CSR dimensions: the *employee and consumer interests dimension, the community involvement dimension,* and the *disclosure dimension*. These dimensions have been reported in previous studies on CSR (Abbott et al., 1979; Ullmann, 1985; Lu et al., 2009).

Using two-stage cluster analysis techniques, the 256 firms of respondents were categorized into three groups based on factor analysis scores. ANOVA and Scheffe tests were employed to ascertain whether the CSR dimensions differed between the three groups. The CSR dimensions differed significantly between groups. Based on test findings, group 1 was identified as a disclosure oriented group (DIS), group 2 as an employee and consumer oriented group (ECI), and group 3 as an intensive CSR oriented group (INT). One-way ANOVA analysis was used to test difference in the three groups‟ performance in terms of CSR image improvement, profit (before tax), market share, sales and customers satisfaction. The INT group had highest firm performance in all indices. The DIS group had highest firm performance in profit (before tax) market share and sales indices than the ECI group, while the ECI group had higher performance indices than the DIS group for CSR image improvement and customer satisfaction.

The INT group had high performance indices, whereas DIS and ECT groups had low performance indices in general. The findings suggest that the DIS group needs to improve the employee and consumer interests dimension and community involvement dimensions, while the ECI group needs to improve community involvement an disclosure dimensions. The DIS group therefore needs to pay close attention to transparency, consumer privacy, greater compliance with tax laws and regulations in the countries, in which group member operate, to increase sponsorship of cultural an artistic activities, provide more support to education related activities, and participate in more community development and citizens‟ welfare. The ECI group needs to apply higher standards for disclosure, accounting, auditing, and environmental and CSR reporting, and give more support to education, community, and charity activities. Although the INT group had high performance indices, there was a slight weakness in performance in the employee and consumer interests dimensions. Accordingly, the INT group needs to focus more on transparency, consumer privacy and protection of personal data, and compliance with the tax laws and regulations in those countries in which group members operate.

This study has several limitations. First, this research focused on ChengDu Hi-tech industrial development zone in China. While this study examined differences in firm performance of different CRS oriented groups, it did not explore why they differed. A future study could explore how and why differences existed between different CSR oriented groups. Third, this study was conducted at a particular point in time, a longitudinal study could be conducted to identify the impact of CSR dimensions on firm performance. Finally, this study utilized an exploratory analysis to identify different CSR oriented groups, future research could utilize structural equation modelling (SEM) to examine the effects of CSR dimensions on firm performance.

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Rise and Fall of Freedom of Contract under Bills of Lading – with Special Reference to the Development of the International Legislation and to a Special Issue under the Chinese Law [1]

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As a document normally issued by the carrier to the shipper after his receiving of the goods for carriage on board of his provided ship, the bill of lading has for a long time accomplished the transition from the mere receipt of the goods to the full-blown documentary of title as well as the evidence of the contract of carriage. It is the last function, that is, as an evidence of the contract of carriage that has caught the intensive attention of the international legislation in the last century. Compared with the other two functions of bills of lading, that is, the receipt of the goods and documentary of titles, the function of a bill of lading as an evidence of contract has been the focus of the international legislation, mainly contained in the Hague Rules, Hague Visby Rules as well as the Hamburg rules, though the Rotterdam rules , the result of the UNCITRAL‟s recent efforts in unifying the international carriage of goods by sea law has deviated a bit from the tradition in this respect to devote more spaces to the other two functions especially that of the documentary of title in terms of the negotiability of the bills of lading and the bills of lading‟s function of transferring it‟s conferred rights. The reasons for this focus could be largely explained as the side effect of the development level of the technology of the shipping, in terms of ensuring the safety of the ships at sea, of the time.

About more than one century ago, navigation at sea was very much a risky adventure, so was the shipping business which was obviously more dangerious than that at the modern time. So at that time, to put investment into the shipping business would take a real courage. Because of the scarcity of the financial investment, the ships available for enforcing the transportation and delivery of the goods largely resulting from the international trade in goods are very few. As a result, the carrier was in a very strong bargaining position in relation to the cargo interests. As normally the provider of the standard form of contract of bills of lading, the carrier often took full advantage of such strong bargaining position by using to the full of the freedom available to him at the time to contract out as much of his liability towards the cargo interests as possible. So in many of the bills of lading at that time , one can often find the lengthy exception clauses which virtually exclude any liability of the carrier for the cargo damages or losses occurring during the voyage, a typical unfair contract term at modern times. This practice of the virtual abuse of the freedom of the contract would certainly cause many hardships to the cargo interests, thus adversely affecting the international trade. When it comes to the early years of the last century, the international business circle no longer wished to let this develop further but to take action to impose legislative control of such an abuse. The result of such efforts is the birth of the Hague Rules, the earliest one of this kind at international level in regulating the contract of carriage of goods by sea as evidenced by the bills of lading.

But how the Hague Rules manage to exercise such a control? The following is a brief account.

This first international convention regulating the contract evidenced by the bill of lading is mainly based on some well-used standard form of bills of lading, and succeeded in establishing a minimum liability basis of the carrier which can not be reduced or excluded contractually. These minimum obligation mainly consists of the following three obligations imposed on the carrier, that is , care of goods , exercise of due diligence in providing a seaworthy ship and not to deviate in the prosecution of the voyage. These three obligations should then be mainly qualified by the following three kinds of exception clauses: first, total exclusion of liability clause as embodied in Art 4, rule 2, second. limitation of liability clause as mainly embodied in art. 4 r.5, and third, the limitation of action clause as embodied in art. 3, r. 6. Besides, the provision related to the carriage of dangerous goods as provided for under art. 4, r. 6 could also be treated belonging to the first kind as above

[1] This is a revised version of a paper delivered at the International Forum on Shipping, Ports and Airports 2010 with the theme of "Integrated Transportation Logistics: From Low Cost to High Responsibility", 15-18 October 2010, at Chengdu, Sichuan, China.
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mentioned as a further qualification of the carrier„s above mentioned three kinds of express obligations. On the other hand, art. 3, r. 8 mainly serves as a main controlling provision in the sense that it by its own wording would strike down any bill of lading clause aiming at reducing or contracting out the above mentioned minimum liability as provided for under the Hague Rules. So in the light of Art. 3, r. 8 alone, one can say that the abuse of the freedom of contract has been controlled to some extent. However, if the parties so agree, they can increase, also by reason of the same art. 3, r, 8, the liability of the carrier from the basis of the minimum liability. So in the light of only this, one may say that freedom of contract can still be practised under the Hague Rules in some limited scope. That said, still the outcome of this first international convention- the Hague Rules- can be said to be tilted towards or in a bit favor of the shipowners. The reason for this is mainly because the three kinds of exception clauses as mentioned above has largely provided shelter for some infamous excepted perils such as the negligence of the employees of the carrier or that of the third party in the navigation and management of the ship. In the presence of these exception clauses under the Hague Rules, the carrier need not take the trouble to embody them into his pre-prepared standard form of the bill of lading as they would be implied into the contract governed by the Hague Rules as part of such a contract anyway. So in this sense, the carrier‟s right of enjoying the freedom of the contract is still largely preserved or in other words, one of the products of the use or abuse of the freedom of contract in the pre-Hague Rules period has in fact been acknowledged and retained under the Hague Rules. That is why there were further needs for the evolution, if not the revolution, to the interests of the international trade if not to the interests of the cargo only, of the Hague Rules which will be discussed in the following.

The Hague – Visby Rules, completed in 1968, can not be said to tilt the balance further towards the cargo interests even in terms of the increasing of the limitation amounts for cargo damages which is mainly caused by inflation compared with its predecessor . The reason for this is mainly because that the framework under the Hague Visby Rules is not much different from that under the Hague Rules.. In fact , by incorporating partly the Himalaya clause into the Hague Visby rules through art.IV, r.2 , bis , the cargo interests have been virtually prevented by such a provision from choosing to sue the employees of the carrier in tort. To make the idea under the Himalaya clause statutory partly at least is an open endoursement of the doctrine of freedom of contract in the sense that the Himalaya clause is a product of the freedom of contract though it is in fact not so legitimate in front of the well respected doctrine of privity of contract in those days.. However, the fact that such a statutory Himilaya clause as embodied under art.IV, rule 2 bis excludes the independent third party from the list of beneficiaries who is otherwise a beneficiary under the conventional Himalaya clause and can enjoy the benefits of the exception clauses available to the carrier is obviously another obstacle to the freedom of contract in this area. In the similar vein, art.IV, r. 2 bis also makes it unnecessary for the cargo interest to make a choice of cause of action between contract and tort or something else such as bailment in order to evade the exception clauses embodied in Art. 4, rule 2. That is because it makes the exception clauses embodied under the Hague Visby Rules available to the carrier no matter on whatever cause of action the cargo plaintiff would choose to base his claim. Such a provision to exclude the self- same liability at different levels of cause of action could be regarded as a blessing to the contractual intention which is the foundation of the freedom of contract doctrine. With the mixed blessings added by the Hague Visby Rules, the fortune of the freedom of contract remains almost the same under the Hague Visby rules as under the Hague Rules.

When the Hamburg Rules was completed in 1978, the pendulum has been drastically swung further towards the cargo interests, that is, the framework of setting out the mandatory minimum liability of the carrier to be limited by the exception clauses has been changed dramatically into that of blending the basic liability and exception clauses into one single provision. Under such a provision, the exception for the carriers‟‟ liability for the negligence of his employees and some of his engaged third parties in the navigation and management of the ship which could be found under art 4, r.2 of the Hague or Hague Visby Rules has disappeared. So under the Hamburg Rules the carriers‟s minimum compulsory liabilities increased drastically, which is certainly an increased restriction on the freedom of contract on the part of the carrier. Consistent with this is the prolongation of the compulsory duration of the voyages from the tackle-to-tackle to the warehouse- to-warehouse under the convention, plus the added regulation of the document called the letter of indemnity which is made only valid between the carrier and the shipper under the Hamburg Rules. Besides, the peril of delay in the prosecution of the voyage has been regulated expressly for the first time under this kind of international convention as under the Hamburg Rules. All these new provisions introduced by the Hamburg Rules are further restrictions on the freedom of contract. That said, to have brought the deck cargo as well as life animals within the coverage of the Hamburg Rules under certain circumstances also has shrunken the scope of the operation of the freedom of contract. However, to add the third party engaged by the carrier as another beneficiary of the statutory Himalaya clause under the Hamburg rules could be regarded as adding credit to the product of the freedom of the contract -- the conventional contractual Himalaya clause. The increase of the compulsory time limit for action from one year under the Hague and Hague Visby Rules to two years under the Hamburg Rules could be said to restrict the freedom further on the part of the carrier who would very much hope to reduce such time limit to as short as possible a length. Nontheless, The same controlling provision to the effect of prohibiting the reducing and contracting out of the minimum liability of the carrier can also be found under Art 23 of the Hamburg Rules, which is an obvious restriction on the freedom of the contract, though like under the Hague or Hague Visby Rules, the increasing of the carriers" liability from such statutory minimum liability by agreement is allowed. Like that under the Hague Visby Rules, the fact that the Hamburg Rules also took the chance to increase the limitation amount to compensate for the loss of value for the remedy caused by the inflation over the years can not be said to allow more scope for the operation of freedom of contract as its effect has been mainly set off by the inflation. In all, it could be said that the enlargement of the scope of the regulation and the deletion of some important excepted perils in favour of the carrier evidence a drastic fall of the freedom of contract under the Hamburg Rules. That notwithstanding, though the members to the Hamburg Rules has increased steadily, many maritime powerful states refuse to endorse the rules thus reducing largely their practical effect.

The fact of the co-existing of the three conventions, that is, the co-existence of the Hauge, Hague Visby and Hamburg Ruels, obviously affect adversely the mission of international uniformity in this area. Additionally, there are many unsatisfactory areas in the conventions which need to be reformed and updated. Thus a new convention intended to replace the above three had been under drafting for some years and such a drafting had finally come to a conclusion on the 11th of December of 2008 when the General Assembly of the United Nations voted through the convention now called The Rotterdam Rules. Though how long would it take for it to take effect is still unknown, as upto recently this writer only found from the website of the UNCITRAL that little more than twenty states had signed the convention, but none of them had ratified and etc. the convention yet as it is so required by Art.94, rule 1 of the Rotterdam Rules for the Rules to take effect . Nevertheless, it is still worth giving it a brief account in the context of my paper here.

Although how generally the Rotterdam Rules would affect the shipping practice is still to be seen during its exposure to the reality after its eventual coming into force, the following obvious changes affecting the contractual freedom can be observed. First, The warehouse –to – warehouse duration of the voyage has been prolonged further to the door-to-door one, thus reducing the space for the operation of freedom of contract. That is in despite of the fact that under art.12.3, contractual parties are allowed the freedom to agree on the time and location of the receipt and delivery of the goods for determining the carriers" period of responsibility though such freedom is provided for under the same provision to be subject to two specific limits. Second, much more scope is given to the regulation of the shippers" liability and in fact the Rotterdam Rules has for the first time in this area set out the compulsory minimum liability for the shippers, which obviously restrict the freedom of contract in this area further. The reason for such a new area of regulation may be due to the fact that at modern times many shippers are in fact big companies and are no longer in a weak position as in the old days when the Hague Rules was drafted. Third, electronic documents also receive intensive regulation under this Rotterdam Rules so that freedom of contract has been denied of the chance of or limited to a smaller scope of playing an important role on this relatively new front. Fourth, the volume contract, service contract by another name, was introduced for the first time into this kind of convention. But unlike the general contract of carriage as evidenced by the bills of lading, paper or electronic, the volume contract is exempted from the mandatory application of the minimum liability as provided for under art 80 of the Rotterdam Rules. In other words, although the minimum liability as found under this new convention could be applied to the volume contract by default, they nevertheless can be contracted out or contractually modified. Besides, that some new terminology or concept such " controlling parties" and " contract performing parties " have been introduced in this new convention also signals the widening of the scope of the regulation of this new convention. This is obviously a result from the increased awareness of the growing complication of the shipping business. On the other hand, some old mechanisms as exiting in the older convention or conventions are generally retained or slightly modified. So the negligence of the employees of the carrier in the navigation and management of the shippers are also absent in the liability regime under the Rotterdam Rules as in the

Hamburg Rules; and the seaworthiness obligation on the part of the carrier has been extended beyond the beginning of the voyage which is actually similar in effect to that under the Hamburg Rules though under the Hamburg Rules the seaworthiness obligation is taken care of by the general provision related to the carriers„ liability and the word seaworthiness has disappeared altogether. Besides, the provision making the minimum liability compulsory as could be found in art. 79 of the Rotterdam Rules , which can be found in the previous three key conventions, has been retained , though it now applies also to the newly founded minimum liability of the shippers but not to the volume contract compulsorily as mentioned above. Moreover, the minimum liability as safeguarded by art. 79 can not be applied to the life animals as carried on board, as such minimum liability can be reduced in relation to the carriage of such life animals as provided for in art. 81 unless such reduction is proved to be motivated by the willful misconduct of the carrier or any other parties for whose acts or omissions the carrier is liable as Art. 18 of the Rotterdam Rules so expressly provide for. This, though, seems to enlarge a bit the scope for the operation of freedom of contract compared with that for the same matter under the Hamburg Rules, it is certain that it provides less freedom of contract in the same area than that under either the Hague or Hague Visby Rules.

Before the conclusion, a few words are added here for discussing briefly how the freedom of contract doctrine fares under the law of Chinese Mainland with respect to one particular issue. Chapter 4 of the Maritime code of China is well-known as a mixture of the three existing international conventions concerned. However, there are still many differences between the Chinese law and those international conventions. Apart from many other differences, one of the major differences indicating the falling down further of the doctrine of freedom of contract under the Chinese law compared with the existing three international conventions is that the parties to the contract of carriage of goods by sea can not by agreement prolong the time limit for action as that provided for under art. 257 of the maritime code of China. It should be noted that art 44 and 45 of the maritime code of China virtually incorporate the spirit of art 3, rule 8 of the Hague Visby Rules in that any contractual provisions can not effectively delete or modify the minimum liability of the carrier as provided for under Chapter 4 of the Maritime code of China, yet the provision about the time limit for action under the contract of carriage of goods by sea as evidenced by the bill of lading is set out in art.257 under chapter 13 thus excluding it from the scope of the application of the above mentioned art. 44 and 45. Such a legislation, which should be intentional rather than by accident or negligence, is in fact an endorsement of the doctrine under the Chinese law that the time limit for action should be statutory and thus should not be subject to the modification of the contract. Such a doctrine has been reinforced by art. 2 of "the Regulation of some of the problems concerned with the time limit for action in relation to civil cases" issued by the supreme court of China on the 21st of August of 2008 (which came into operation from September the first of 2008) in relation to the time limit for action generally.

To conclude, the historical development of the international legislation in relation to the carriage of goods by sea witnesses an ever widening of the scope of regulation and particularly an enlargement of the mandatory minimum liability of the carrier, as well as a newly imposed minimum mandatory liability on the shippers under the Rotterdam Rules. In the light of the above, it could be said that the scope of the operation of the freedom of contract has been reduced further. Above all, it seems likely that the trend that the freedom of contract is falling will continue under the bills of lading and the pendulum will not swing back to the interests of the carrier in this sense for years to come. This in fact is in line with the trend in the current business world. That is, in the wake of recent world-wide financial crisis, the accusation of over- regulation in the financial sector would not have much market in the near future to say the least .

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Event Triggered Institutional Innovation –
Evidence from Logistics Organization in Chinese Companies

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Abstract

It is the paper's aim to provide an assessment of the current organization of Chinese companies in the field of logistics by determining the status of Chinese logistics organizations. To accomplish our goal we develop a model describing institutional innovation in logistics organization of Chinese companies. Our model combines existing approaches explaining logistics organization's development with New Institutionalism theory. We empirically test the model at a sample of 142 Chinese manufacturing companies responding to a large scale survey. We find that Chinese enterprises use the strategy of decoupling, i.e. the external perception of logistics is more sophisticated than the actual implementation in the companies suggests. Moreover we find that logistics in China is just at the turning point from a function oriented perspective to logistics as a process oriented integrated function. The change process is initiated by pressure from the institutional environment to increase the efficiency of logistics, which has been triggered by the financial crisis. This paper contributes to research in different ways: it helps understanding the impact of external events on company intern logistics organization; moreover the knowledge on the development model helps deciders to assess their own logistics organization and to deduce improvement possibilities.

Keywords: *Institutional Innovation, Logistics, China, New Institutionalism, Organizational Change*

1. Introduction

In the course of time, logistics has always been thrust into focus in the time of crisis, which required an increase in efficiency (Bowersox and Closs, 1996; Stock and Lambert, 2000). This becomes evident when considering the USA and Europe as the nucleon of logistics: On both continents, logistics as a function was introduced in companies as consequence of a severe crisis of the established system, namely the switch from seller to buyer markets (Morgenstern, 1955). This external event demanded tremendous increases in productivity and performance (A.T. Kearney, 1981). Because of these crises, logistics as a function was introduced in western companies. Studies of cross-sectional data on logistics organization (La Londe and Masters, 1993; La Londe and Ginter, 2001; Ginter and La Londe, 2006) show that logistics organization evolved over time towards a higher level of organizational sophistication (Bowersox et al., 1989). These developments have always been subject to external drivers – like the concept of shareholder value (Christopher and Ryals, 1999)- outside the individual company (Heskett, 1973).

China, however, is in a similar situation like the one Europe and the US had to go through in the 1950s and 1960s. With China being highly integrated in the system of global labor division, the country has been severely hit by the economic crisis (Wearden and Stanway, 2008). The problem gets even more obvious when considering the already sky-high logistics costs in China (Beron, 2008). These considerations show that there is need for action among Chinese companies in the field of logistics in order to remain competitive and to survive the crisis. Crucial is the need to control logistics costs in China. One way to stabilize overall costs is to implement a rigid organizational structure that focuses on efficiency increase (A.T. Kearney, 2004).

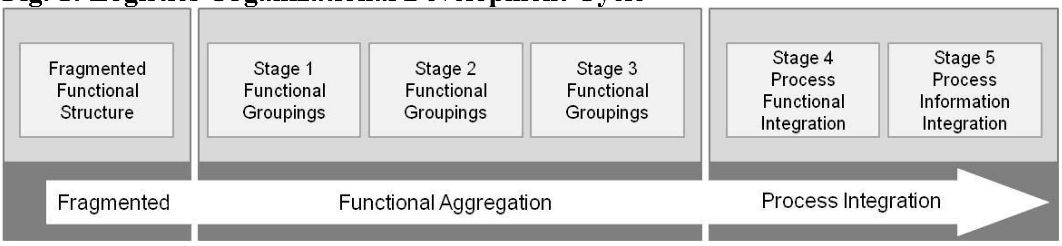
Various studies have been conducted describing logistics service providers and their business models in China (Jiang and Prater, 2002; Hong, Chin, and Liu, 2007; Lai et al., 2008). However, there is no research on the organizational logistics structures and competencies of Chinese enterprises. Thus, we aim to provide an assessment of the current organization of Chinese companies in the field of logistics by determining the status of Chinese logistics organization. To accomplish our goal we develop and empirically test a model of logistics development based on the New Institutionalism and existing organizational development models. This paper is organized as follows: In the beginning we develop a general, i.e. not country-specific, organizational development model using existing life cycle models and the theory of the New Institutionalism. Afterwards we formulate assumptions on Chinese logistics organization with regard to the specific situation in China based on the development model. We then follow by empirically testing our assumptions. Finally, we conclude with a discussion of our results and contributions to the literature.

2. Conceptual Background: Integrated Development Model

2.1. Existing Development Models

There are two different types of development models: (1) Logistics specific development models and (2) universal organizational development models. Bowersox and Closs (1996) introduce a systematic model showing the different organizational set-ups of logistics over time. The "logistical organization development cycle" by Bowersox and Closs (1996), is illustrated in figure 1.

Fig. 1: Logistics Organizational Development Cycle



Source: Bowersox and Closs, 1996

The organizational development follows the "prevailing paradigm" (Bowersox and Closs, 1996, p. 598) – fragmented, functional aggregation, and process integration. The development starts when there is no specific structure of logistics, the so-called fragmented functional structure. Then there has been a change in the company external perspective on logistics. Logistics was recognized as an efficient tool for cost reduction. Consequently, the function of logistics was singled out. In figure one there are three stages of functional groupings. That means that over time the responsibility of logistics grew. Because of external events like the ongoing globalization which resulted in the spread of globalized production and delivery networks, process integration became necessary. Consequently, logistics became responsible for the organization of all logistics related processes within a company (Bowersox and Closs, 1996). The shortcoming of this model is the fact that this is a rather descriptive model and thus it does not explain reasons for the change between the different stages.

Universal organizational development models like those of Greiner (1972) and Bleicher (1995), however, solve this problem as they explain the development of an organization including the reasons for a transition. They have in common, that the shift from phase to phase depends on solving of specific management problems. Differences are the parameters to distinguish the stages and the design of the phases.

The shortcomings of the existing development models – both general development models and specific models explaining logistics organizational development – is that they explain with a different degree of detail the internal organizational development and the transition between the stages because of internal organizational factors. As explained earlier, logistics is heavily influenced by factors, external to the company. Thus, there is the need to integrate the external perspective into the development models. For this sake we use the theory of the New Institutionalism, as it helps to integrate factors external to the company.

2.2. The New Institutionalism

Institutions describe social arrangements, norms, and regulations as framework which contains a code of conduct for specific situations. Institutions enable and constrain the behavior of actors and by doing so make social life predictable and meaningful (Zucker, 1977; Powell and DiMaggio, 1991). They are taken-for-granted and very durable, sometimes even if they are inefficient (Powell and DiMaggio, 1991). By adapting certain institutions organizations and actors of all kind seek legitimacy. Within this system of belief, legitimacy is an essential prerequisite to have access to special resources, e.g. employees or clients which are necessary to gain and retain competitive advantage (Powell and DiMaggio, 1991).

In this respect, institutional change can be defined as a difference in structure, state, or form over time. Institutional innovation then means leaving one state of taken-for-granted behaviors and entering into a new set of taken-for-granted behaviors (Rao and Giorgi, 2006). This change can come in two types: (1) The first is exogenous. The pursuit of legitimacy leads to uniformity in organizational fields, in which institutional change can only be initialized by a tremendous exogenous shock in the institutional environment, such as a change in society (Hira and Hira, 2000). (2) The second is endogenous and initiated by actors within organizational fields. These actors, or institutional entrepreneurs, are organizations which benefit from the creation of new structures and the deinstitutionalization of old and established institutions (Hwang and Powell, 2005). One essential factor to successfully introduce new structures and processes into an organizational field is legitimacy. Legitimacy allows for the access to important resources, either directly or indirectly through alliances and coalitions with resourceful actors, who ultimately serve as an important power base. Power that is necessary to fend off attempts by established actors that gain benefits from old and established institutions. It is only in the case when institutional entrepreneurs are more powerful than those actors who want to preserve the old status that endogenous change can take place (Maguire, Hardy, and Lawrence, 2004).

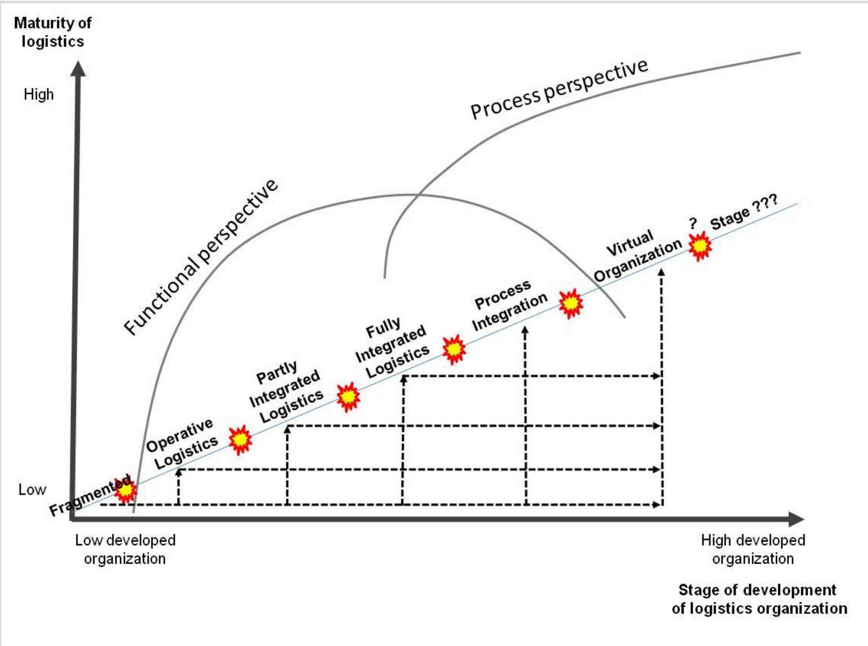
2.3. Integrated Development Model: Institutional Innovation in Logistics Organization

An integrated model of organizational innovation in logistics, which bases upon the development cycle of Bowersox and Closs (1996) and the theory of New Institutionalism, is shown in figure 2. On its x-axis the stage of development of logistics organization is depicted and on the y-axis the maturity of logistics is illustrated. This model integrates the internal company perspective – describing the stages of logistics organization – and the external perspective – outlining the common perspective of logistics. As this model is the development cycle of Bowersox and Closs (1996) – providing the internal perspective – enriched by the New Institutionalism, which helps to explain the external effects, there are two stages of the external perspective known from Bowersox and Closs (1996): (1) functional perspective and (2) process perspective. The internal company development has six stages: (1) fragmented structure – no perception of logistics as distinct function, (2) operative logistics – few logistics functions grouped together, (3) partly integrated logistics – logistics as an autonomous function, (4) fully integrated logistics – logistics department is responsible for all tasks of logistics work, (5) process integration – logistics becomes organized along the logistical value chain, (6) virtual organization – logistics is distributed among the members of a network of independent companies.

The model can be considered as one huge institutionalization process. There are two distinct paths of institutionalization: on the one hand, the external institutionalization process (functional and process perspective) and on the other hand, the internal institutionalization process (stage 1 to 6). The two levels influence each other; events on one level trigger changes on the other level. The internal perspective adopts ideas and structures from the external perspective. By doing so the internal perspective gains legitimacy. The external perspective gains even more legitimacy when its structures, which are applied in the internal company organization prove their efficiency. Both perspectives are subject to the same drivers in the same organizational field.

The process of the internal company development is embedded into the external perspective. The development of the internal setup starts with a short time delay with regard to the external perspective. Logistics is adopted into the company after it is institutionalized in the external perspective. Consequently, this time delay is based on the "organic" development of logistics. Besides the "organic" development there is the strategy of decoupling. It is used when institutional rules do not fit to the technical environment or are even contradictory to other rules. The strategy of decoupling implies that targets are formulated vaguely, structures are not checked regarding efficiency, and coordination is executed in an informal way. The advantage is that organizations seem to cope with institutionalized structures and thus retain their legitimacy. Moreover, because of the not-adoption of inconsistent elements conflicts are avoided. It is important to pretend the coping by using the exact vocabulary (Meyer and Rowan, 1977). This strategy can be applicable in the discussed context, when obstacles like business requirements or poorly trained employees impede the company from implementing institutional structures.

Figure 2: Integrated Model of Institutional Innovation in Logistics



The internal company institutionalization is an endogenous change process. It is triggered by the drivers from the technical environment, but influenced from the external perspective, representing the institutional environment. The specific situation of a company determines whether the technical or the institutional environment has bigger impact on the company. The transition between the stages is initialized by institutional entrepreneurs, who seek for higher efficiency.

An exogenous change takes place at the turning point from functional towards process oriented perspective. Radical organizational change processes which skip one or several stages can be explained by exogenous shocks, e.g. company crisis or the work of a consultancy agency. Because of these shocks, single stages can be jumped.

For the determination of the status of logistics organization of one or several companies according to that model one has to analyze the three following points: (1) the relationship between external and internal perspective, i.e. determining whether there is a simultaneous or a decoupled development in both perspectives, (2) the development of the external perspective, i.e. testing if the external perspective is predominantly functionally or process oriented or even in transitional state and (3) the development of the company internal perspective, i.e. examing the degree of functional integration and functional or process organization.

2. The Development of Logistics Organization in China

In the following chapter the three above mentioned points are hypothesized regarding the specific situation in China in order to determine the state of Chinese companies' logistics organization according to this model. Before developing the assumptions a brief overview on logistics in China is given.

3.1. Logistics in China

In the pre-reform era before the 1980s China's production and distribution was accomplished according to a state plan. The distribution network was rigidly organized and had three layers. At this time distributors provided services for transport and warehousing. The distribution system for this three level model was provided by the state (Jiang and Prater, 2002). Since China joined the WTO it has been allowed to foreign companies to provide their distribution services in China. In 2002, China's distribution system was in a transition stage between a rigid planned structure and a free market (Hong, Chin, and Liu, 2007). The nationwide system still exists but without the strict regulations. Thus, the three traditional levels compete against each other and against the new private companies and the newly entering foreign companies (Jiang and Prater, 2002). Logistics growth rate is above 10% and exceeds GDP growth rate since 2002 (Yang and Bode, 2007). In order to preserve this enormous growth, Chinese decision makers already realized that high skilled employees are necessary in logistics. As a consequence, China Federation of Logistics and Purchasing had 20,000 participants in their qualification courses until 2005. Although this figure is low compared to the overall population, it is a first step towards a better education in logistics (Xinqian, 2006). Logistics development in China is mainly influenced by its booming economy which is turning into buyer markets and the opening of the economy in 2001, which leads to competition from the Western hemisphere (Jiang and Prater, 2007)

3.2. Relationship between external and internal perspective: Strategy of Decoupling

Because of the tremendous change in China it is possible that some functions in Chinese enterprises could not keep pace with the external development and thus some institutionalized structures in the external perspective cannot be implemented due to a lack in skills. In China, however, there are certain factors which impeded an "organic development" in the past. For decades, there has been a controlled three-tier system which made institutional innovation and change obsolete. After the opening of the Chinese economy in 2001, Chinese enterprises with their logistics organization entered from one day to the other into global competition. In order to gain and retain legitimacy which makes them accepted as trade partner of European and US companies and to have access to these markets, Chinese companies adopted institutionalized structures from the western hemisphere. With logistics being a key element in global economy, a performing logistics organization is often a prerequisite to be selected as potential supplier. Besides these facts there are as well factors which impede a modern logistics organization: The implementation of a sophisticated perspective requires high skilled employees with experience in logistics. Because of the immense growth of the economy, highly qualified employees were required in all industries. Thus, there is a high probability that there were not enough employees specially trained for logistics. This discussion leads to the assumption that the external perspective is more sophisticated than the internal company logistics organization.

Assumption 1: There is a decoupling of the internal from the external company perspective on logistics, when
- *1.1: there is independency of the organizational implementation in the intercompany perspective and*
- *1.2: there is no difference in the degree of intercompany integration between companies which share the intercompany view and those which do not.*

3.3. Development in the external perspective

As a consequence of the state planned system, influences from the technical environment had not to be respected and institutional enforcements from the organization of logistics in international enterprises had no influence on logistics in China with the result that institutional innovation remained rare. These considerations show that sophisticated logistics has a short track record in China. When putting these findings into the context of the model for logistics organizational development, it can be stated that there has been hegemony of logistics from a functional perspective. After 2001, Chinese companies have been affected by the institutional environment, which is represented by European and US American enterprises. In order to increase and retain legitimacy, organizations adopt institutionalized structures from their environment. As Europe and the US are the most important trade partners, Chinese enterprises will adopt their process oriented perception on logistics in order to remain a highly recognized partner for trade. Moreover Western logistics service companies are entering the market since 2001 and thus Chinese companies use them as learning object. This discussion indicates that the change process from functional perspective has begun and no structural uniformity will be observable as the change process does not proceed simultaneously among the companies. When the full power of this concept is understood it will replace the functional perspective. The lack of broad theoretical understanding impedes a full understanding and a fast application of the process perspective.

Assumption 2: There is a diverse picture of logistics perspective among the companies, ranging from functional oriented companies to process oriented enterprises and thus logistics' perception is just in a transitional stage from functional to process oriented perspective.

3.4. Development of the company internal perspective

In case of conflicts between the external (institutional environment) and internal (technical environment) perspective the specific company copes with those needs which are perceived as most important. That is, the institutional forces are neglected when the technical environment requires a different structure than the institutional environment and the needs from the technical environment are crucial for the survival of the enterprises. Because of the state planned system, an institutional innovation process in logistics organization did not take place until after the entry into the WTO. Today, Chinese enterprises organize their logistics activities in a process oriented manner, as they want to have a legitimate structure to be able to interact with their European and American trade partners. With regards to the technical environment, China is affected by a change from seller to buyer markets (Pröll, 2005) and high logistics costs due to low efficiency (Beron, 2008). These facts require the development of logistics into a high performing function. Despite these facts which indicate a high developed logistics organization, one has to consider the hindering factor in the technical environment: low experience and poor education of logistics employees. Consequently, the implementation of process oriented logistics would overcharge employees. Yet, the problem of high logistics costs requires solutions. The need for an efficiency increase, i.e. cost reduction, leads to an aggregation of logistics activities in one department (BCG, 2005). This development is comparable to the USA and Europe when cost reductions were required (Bowersox and Closs, 1996).

Assumption 3: There is the trend to organize logistics as an integrated function, as Chinese companies have recognized the impact of logistics.

4. Research Methodology and Data Collection

Due to the fact, that until summer 2008 there was no data available which makes evaluation of logistics organization in Chinese companies possible, we conducted a large scale survey among Chinese owned production companies. This methodology was chosen to get a general impression about what logistics means to Chinese companies and to deduce the overall development stage an ongoing institutional change processes of logistics in China.

734 Chinese companies in China were contacted during July and August 2008 and 19.34% responded to our call, which resulted in 142 valid responses. General results prove that the sample is very suitable to study organizational phenomena in logistics operations, because: the respondents are exclusively from manufacturing industry where logistics plays a key role, the share of 92% medium and large companies ensures the prevalence of organizational problems and logistics importance is high among the sample as more than 70% have international customers, mainly from the US and Europe. We used the Kolmogorov-Smirnoff-Test and found that all our data is approximately normal distributed. This is a prerequisite for further tests. Besides, we conducted Chi-Square tests for determining the independency of two samples. The t-test served to prove whether differences in the mean value between two samples are significant or only accidental. The tests were conducted using XLSTAT an add-in for Microsoft Excel.

The questionnaire consisted of Likert style statements against which respondents answered on a 5-point scale (anchored as 1 = agree strongly, 5 = disagree strongly). Totally the questionnaire has ten pages and 36 questions. Tests were performed to check bias between early and late respondents. There were no significant differences between early and late respondents on any of the variables of interest.

5. Results

5.1. Coherence between perception of logistics and organization

The first point in the focus of the analysis is to detect whether there is coherence between the perception of logistics, which is dominant in a company, and the organizational structure of logistics.

Tab. 1: Chi-square Test on Logistics Perspective and Organizational Structure

Construct	*Valid Cells*	*Chi-Statistics*	*Degrees of Freedom*	*Critical Value at 5% α-level*	*Construct supported?*
Independency of intercompany view of logistics and customer integration	53	0.982	1	3.841	Yes
Independency of intercompany view of logistics and supplier integration	53	0.316	1	3.841	Yes
Independency of traditional view of logistics and customer integration	57	0.265	1	3.841	Yes
Independency of traditional view of logistics and supplier integration	57	0.827	1	3.841	Yes

To detect potential differences, two opposed logistics perspectives are considered: The “inter-company view” is the most mature perspective and implies that the intercompany value generation process is considered. “Traditional view” is this perception when logistics is a function in charge of storage, turnover and transport. The companies with these opposed views are analyzed regarding the degree of customer and supplier integration. A dependency of the organizational integration on the perspective of logistics is examined by a Chi-square test. As depicted in table 1 all the results are significant and the assumption of an independency of perspective and organizational structure cannot be discarded. This indicates that the construct is supported on the chosen significance level of 5%.

After proving the independency, one still has to check whether the level of integration is different between these companies which state an “intercompany view” and those which negate it. The level of integration is measured by the mean value which is calculated according to the submitted responses. In order to provide an answer to the question about the degree of integration, the following assumption is made: only those enterprises can be considered, for detecting a significant difference in the level of integration, where the “intercompany view” is the opposite of the “traditional view”.

Statistics from table 2 show a mean value between 3,667 and 3,873 for all parameters. This is a range between parameter values “sometimes” (3) and “often” (4). However, the integration of suppliers and customers is slightly higher in those enterprises which have an intercompany view on logistics compared to those which do not have this view. Moreover the standard deviation of integration is lower among those companies with an intercompany view. This smaller variance leads to the conclusion that there might be a higher tendency towards integration within the sample of companies with an intercompany view.

Tab. 2: Statistics about Degree of Supplier and Customer Integration

Construct	*Valid Cells*	*Mean Value*	*Standard Deviation*	*Max.*	*Min.*
Customer Integration AND Intercompany View on Logistics	49	3.796	0.866	5	2
Customer Integration AND NO Intercompany View on	15	3.667	1.113	5	1

Logistics					
Supplier Integration AND Intercompany View on Logistics	49	3.837	0.825	5	2
Supplier Integration AND NO Intercompany View on Logistics	15	3.667	1.113	5	1

In order to determine whether this difference is significant for all companies or only accidental in this sample a t-test is executed. According to test results (see table 3) the assumption "there is no significant difference in the mean value for neither supplier nor customer integration of companies with an intercompany view compared to those with no intercompany view" is supported by both tests.

Tab. 3: T-test Results on the Significance of Differences in Mean Values

Construct	*Valid Cells*	*T-Statistics*	*P-Value*	*Critical Value at 5% α-level*	*Construct supported?*
Independency of intercompany view of logistics and customer integration	64	0.472	0.638	1.999	Yes
Independency of traditional view of logistics and supplier integration	64	0.642	0.523	1.999	Yes

5.2. Logistics' perception – external perspective

Statistics showing the perspective of study's participants on logistics are depicted in table 4. The mean values of perspective 2, 3 and 5 are clearly above the value 3 (between "applicable" and "fully applicable"). They show only a maximum difference of 0,136 between perspective 3 and 5. The standard deviation for these three views is lower than for perception 1 and 4, which have a lower mean value as well. Perspectives 2, 3 and 5 show a strong concentration of the responses in the two upper categories.

One realizes that the first perspective, the traditional view, has the lowest mean value and the largest variance. Moreover it has the lowest median. This indicates that this point of view has the fewest supporters among the five perceptions. Most respondents share perspectives 2 and 3. A future development of the perception is indicated with 43% (out of 98 respondents) answering that they aim at the formulation of a companywide logistics concept within the next five years. Moreover 33% state that they aim at integrating their customers and suppliers into logistics.

Tab. 4: Statistics about Logistics Perception

Perspective on Logistics	*Valid Cells*	*Mean Value*	*Standard Deviation*	*Max.*	*Min.*
1. Logistics is Restricted to the Control and Realization of Goods' Transport and Storage	111	2.378	0.798	4	1
2. Logistics is Cross-Functional and Affects the Departments Sourcing, Production and Sales	116	3.483	0.551	4	2
3. Logistics Requires an Integral Management for Integrated Control of Goods, Information, Finance and Rights	111	3.523	0.553	4	2
4. Logistics is a Strategic Management Problem and Should be Rolled Out Company Wide	107	2.935	0.792	4	1
5. Logistics is not a fully company intern task, but comprises an interorganizational coordination	106	3.387	0.626	4	1

5.3. Organizational set-up – internal perspective

The organizational structure is analyzed in the following section. Findings show that there is full awareness among Chinese enterprises that logistics is an efficient tool for reducing costs. Results make the institutionalization process of logistics as a concept and function within a company visible: 74% use the term logistics. The use of the vocabulary is a prerequisite to implement logistics concept within a company. The next step after the use of the term is the installation of a dedicated logistics department. Already 68% of the respondents have one. The end of the described process is the establishment of a leading position for logistics. However, only half of the enterprises state to have a leading position for logistics.

Nowadays the prevailing structure is a central department with about half of the respondents stating this structure. Decentralized or hybrid structures show about the same diffusion rate. Logistics is predominantly hierarchically situated in middle management (87%). Logistics is represented by a top management member only in 6% of the interviewed enterprises. About the same proportion (7%) rank logistics on group leader level.

With regard to the required education level, it becomes evident that an average level of higher education is sufficient to start a career in logistics: 48% out of 95 respondents require a degree of a University of Applied Science and 39% state to employ Bachelor graduates. Only 6% state to prefer employing people with a Master degree and even nobody claims a Ph.D. In the same way as these higher degrees are no prerequisite for an employment in logistics only a minority of respondents require an apprenticeship (1%) or even no special education (5%).

Asked for the future strategy in the field of logistics respondents name a centralized logistics department as the dominating concept (23% aim at having one), while only 17% plan a hybrid or 8% a decentralized logistics department respectively. Moreover the share of enterprises with a logistics department is said to increase (22%). A head of logistics shall be employed by 15% of the respondents.

6. Discussion

Assumption 1 aims at the detection of coherence between perspective on logistics and the organizational structure: The assumption consists of two parts: (1.1) There is independency of the organizational implementation on the inter-company perspective and (1.2) there is no difference in the degree of intercompany integration between companies which share this view of intercompany perspective and those which do not share this view. The perspective and the integration of suppliers and customers are directly measured by questions from the survey. The Chi-square test shows that both, the integration of customers and suppliers, are not significantly different, neither among companies with an intercompany nor with the traditional perspective. Thus assumption 1.1 is supported. Assumption 1.2 is supported by the t-test. It shows that there is no significant difference in the degree of neither customer nor supplier integration among companies which share the intercompany view on logistics and those which do not. That means the intercompany integration is in the same stage in both company types. It indicates that the perspective on logistics has no influence on the organization as far as the intercompany integration is concerned. These findings support assumption 1 that there is decoupling among Chinese companies.

Assumption 2 aims at the determination of the position of the external development of logistics within the model and assumes that there is a diverse picture of logistics perspective among the companies at the turning point from functional to process perspective. This assumption indicates that it is a criterion to identify the turning point when there is no solely dominating perspective of logistics, but several. Considering the above discussed results, one can state that there is not one unique prevailing perspective. This finding is supporting the assumption that there is a change in perspective. The next point in the courses of testing assumption 2 is to determine which perspectives can be attributed to the functional and which to the process oriented point of view. These two perspectives form the borderline between function and process oriented thinking, and are the dominant perspectives. Moreover, another widely shared perspective of logistics as cross functional task is just the transition from pure functional thinking towards a process oriented approach. The understanding that logistics links procurement and production is just one step ahead before recognizing that the integrated management through the whole working process can increase performance even further. The “traditional view”, which means logistics is just storage and transport is the one which is shared by the least respondents.

These findings show that there is a clear trend towards a process oriented perception. It is not yet reached. But the perception of logistics as companywide activity is a prerequisite for process oriented thinking. The trend towards a process oriented perspective is emphasized by the fact that a huge percentage plans to establish a companywide concept and wants to integrate suppliers and customers. As a conclusion, one can state that the analysis supports assumption 2 that logistics perception among Chinese companies is currently in the transition between a functional perspective and a process oriented perspective. With regards to the results, we conclude that they already left the early stages of a functional silo approach and that the trend is already points into the direction of a process oriented approach.

Assumption 3 investigates whether there has been an external trigger, which leads to an organizational change. The testing of assumption three has the following two levels: First, one has to determine whether the impact of logistics on cost reduction is shared among the interviewed companies. Second, the indicators that help identifying the organization as an integrated function have to be evaluated. The result for the first requirement of the assumption shows, that 119 out of 120 respondents have fully understood the impact of logistics on potential cost reductions. Integrated logistics means that several tasks which are attributed to logistics are accomplished within one department and not independently. This development towards more competencies of an integrated department is outlined in the stages 1 to 3 in the theoretical model. In China, logistics department is in charge of the subsystems transportation, warehousing, and distribution. The low rate of logistics departments in charge of procurement (9,6%) is a clear indicator that logistics is concentrated on the outbound side. As China's industry is very export oriented, the outbound side with an effective distribution channel is crucial. In most companies the centralized logistics department is situated in the middle management. The dominating position of a central department will further increase as more enterprises aim at the implementation of a central department than at a hybrid or decentralized structure. The domination of the location in middle management in combination with the aggregation of traditional functions and the concentration on the outbound side in centralized logistics department, leads to the conclusion that the organization of logistics is a stage 2 organization. The future development towards a stage 3 organization is supported by the above discussed future strategy of logistics. The rising number of heads of logistics and the planned establishment of logistics on company management level support this thesis. These factors indicate that the competency of logistics will broaden as a stage 3 organization according to the model indicates. Consequently, the findings and analysis lead to the conclusion that assumption 3 is supported by the data.

7. Conclusion and Implications

This paper contributes in different ways to research in the field of organizational change and institutional innovation among logistics enterprises in China: First, an organizational development model is derived, which in contrast to existing models, explains the influence of events external to the company. Second, the data proves the development model and it verifies its applicability to China. Third, it is the first publication to study logistics organization in China. Consequently, based upon our findings about the set-up of logistics in Chinese companies the development and change processes of organizational innovation can be tracked over time.

The analysis proves the established model as applicable to China. The findings show that there is a decoupling of the external and internal development. The external perspective on logistics is at the turning point from the functional towards a process oriented view of logistics. Chinese logistics organizations are facing a tremendous change process towards implementation of process oriented management methods. This change process is initiated by pressure from the institutional environment and requirements from the technical environment to increase the efficiency of the logistics activities. The upcoming structural change as consequence of the institutional innovation will be accompanied by a change in position requirements of the employees as well. Consequently, training dedicated to the needs of a high performing logistics department will be necessary.

This study provides research implications in two different sectors. First, in the field of logistics in China and second, in the model itself: (1) the results provide information about the current status of organization in Chinese enterprises. But it does not give any evidence about the impact of logistics on productivity. These performance measurement figures can be evaluated together with a closer examination of specific organizational structures, e.g. supplier/customer integration by case studies, which enables a depth analysis of organizational structure. Based on this smaller case study panel a broad understanding of the organizational structure and the enablers of institutional innovation can be established. This knowledge can be the starting point for research about causal coherence between organizational structure of logistics and company performance within a broader study. (2) The model itself gives the following research implication: It is not yet determined which structure succeeds a stage 6 organization. Up to now there is no clear structure identifiable. A potential enhancement of the virtual organization might be the complete outsourcing of logistics to 4PL. This could be a next step after outsourcing of the production to a factory network.

This study's findings support managers in their daily work: The results of this first empiric study on logistics organization show those areas where improvement is needed. Moreover, managers can use these findings to assess their own organization regarding its performance and identify areas that need improvements.

However this study has some limitations. The analysis is rather descriptive and no correlation analysis is used. Thus it would be interesting to examine this dataset using correlation or regression analysis. Moreover this is a cross-sectional analysis, which does not make it possible to check whether the development stages of the model are followed. Consequently this study and the one of Yang et al. (2010) could be used as a starting point for a regular evaluation of the logistics organization in China, based on the longitudinal data one could determine whether certain stages are jumped in the Chinese development.

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The Operation Model of Mobile Payment: A Case of China

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Abstract

As a key component for Mobile Internet, mobile payment is a big shift for the traditional payment system, and the operation model is among one of the most important factors that influence the future of mobile payment. Because of its significant differences to other countries, China has to seek for the model fitting itself instead of simply following steps of others. This paper first presents the overall background for mobile payment development in China, as well as the influence of several recent released government policies, and finally discusses the possible mobile payment operation model in China.

Keywords: Mobile Internet, Mobile Payment, Operation Model, Third-Party Payment

1. Mobile Internet

After the mainframes, minicomputers, personal computers and desktop Internet era, our society is moving into the mobile Internet era. In early 2010, the number of mobile phone users in China has exceeded 7 million, and the number for the whole world is expected to break 5 billion in this year. As the representatives of mobile devices, mobile phones, PDAs (Personal Digital Assistant), MIDs (Mobile Internet Device), and E-books, are gradually replacing traditional personal computers as the main media to surf the Internet, because of its great mobility. We are moving to the new Mobile Internet era, which is different from today's Desktop Internet era we are familiar with. In the meantime, by leveraging the widely deployed 3G telecommunication technology, there are much more Mobile Internet users than that of the desktop Internet, and the development speed of Mobile Internet is also faster than desktop Internet. Along with the whole world, China is stepping into electronic payments era represented by mobile payments.

2. Mobile Payments

2.1 Background

Mobile payments, also known as mobile phone payments or m-payments, are payments for goods, services, and bills/invoices with a mobile device (such as a mobile phone, smart-phone, or Personal Digital Assistant) by taking advantage of wireless and other communication technologies (such as mobile telecommunications networks, or proximity technologies). Typical usage entails the user electing to make a mobile payment, being connected to a server via the mobile device to perform authentication and authorization, and subsequently being presented with confirmation of the completed transaction (Wikipedia; Dahlberg et.al 2008). There are two typical ways for mobile payment: (1) one is to connect mobile operators remotely via SMS or WAP, and deduct corresponding expense from the account, either bound to an bank account or just a virtual account of the mobile account; (2) the other one is to deduct expense directly from the embedded intelligent near-field communication card in the mobile, and the card can be bound to either mobile account or bank account.

According to statistics of China Union Pay, by the end of June, 2009, the number of mobile payment users in China achieves 19.2 million, in the first half year there are 62.685 million transactions totally, which amounts 17.04 billion yuan. According to the report from iResearch, the mobile payment market in China will reach 2.845 billion yuan, the total number of mobile payment users will exceed 150 million in 2010, and the market will maintain a 40% growth rate over the next three years. For the mobile payment industry, the huge subscriber scale and high market potential provide a large user base and market development space. Operation model is among one of the most important factors that influence the future of the market.

After several years' development, the mobile payment markets in Japan and South Korea are very mature, and they have entered the market segmentation, service development stage, therefore it is unlikely that their operation models would change quickly. While for Europe, USA and other countries, where the credit system is mature and complete, and the credit card payment system is very popular, therefore, they are not eager for new mobile payment solution, and that is why the mobile payment industry in these countries and regions lags a little behind the pace of Japan and South Korea. China is quite different from all of them. China is building up its national credit system, so the credit card market is still very small compared to cash transactions, which means fewer obstacles for the deployment of mobile payment. At the same time, the competition among mobile operators, banks (and bank union) and third-party payment platforms accelerates the development of mobile payment in China, though with different characteristics from Japan and South Korea. China is just entering the mobile payment era, and the market prospect is very promising. It is important to investigate the current situation for mobile payment development, and discuss its operation model.

2.2 Related Work

Lots of research has been conducted on mobile payment. Dahlberg et.al (2008) surveyed nearly all the important papers during 1999 and 2006, classified them according to different topics, and discussed major research problems. It provides a great overview of this area; however, there is no research about mobile payment in China in its referred papers, so we will focus the related work about China's mobile payment in the following. Hwang et.al (2007), Chen (2009) and Shi et.al (2009) introduces the new business models and usage cases derived from mobile payment, and these new schemes are getting more and more popular. Many researchers agree that China's mobile payment is in its early stage (Wu, 2008; Wang, 2008; Shi and Shuai, 2009), and they all agree that it is a very important stage (Zmijewska and Lawrence, 2006; Zhou, 2009; Men and Song, 2007; Huang, 2009). The industrial chain of mobile payment is sophisticated, including tons of upstream and downstream sectors, and they have complicated relations between each one, which means it is difficult to coordinate them (Lu et.al, 2007; Zhou, 2009; Yang and Yang, 207; Zhao, 2010; Au and Kauffman; 2008; Hu, 2009). Generally, all operation models can be classified into 4 categories (Zhai, 2007; Zhou, 2009; Huang, 2009; Bossuyt and Hove, 2007; Ondrus and Pigneur, 2006; Bourreau and Verdier, 2010), which will be introduced detail in the next section. However the research conclusions do not converge and it seems that neither model can win now (Chen, 2008; Deng, 2009; Zhang, 2009; Liu and Wang 2009; Huang, 2006). Moreover, all of them do not considering the differences between China and other countries (Wang, 2009; Liu et.al, 2008; Jiang, 2008). This paper is organized as following. Section 3 first introduces the classification of mobile payment operation models, and then describes the current status of mobile payment in China. Section 4 describes the differences between China and other countries which form the overall environment of mobile payment, and Section 5 analyzes the influences of recently released policies on mobile payment industrial chain's major sectors, and discusses the possible operation model of mobile payment in China. Section 6 concludes the paper.

3. Operation Models of Mobile Payment

3.1 Classification of Mobile Payment Operation Model

As an open market, there are many participants in mobile payment's value chain, including mobile operators, payment service providers (such as banks, China Union Pay, etc.), third-party payment service providers (such as Alipay, Paypal), applications providers (such as public transport, schools, public utilities), equipment providers (such as chip manufacturers, mobile manufacturers and terminal equipment providers), system integrators, merchants and mobile phone consumers. There are many mature mobile payment solutions, and the technology itself can be deployed without any difficulty. However, it is the operation model that determines the final solution, the deployment policy and market promotion policy. All of the three major participants, mobile operators, banks and third-party payment institutions, want to control the market, and their competition and cooperation relationships decide the mobile payment operation model and future directions. There are mainly four kinds of mobile payment operation models: mobile operators lead the market, banks lead the market, third party payment platforms lead the market, and mobile operators lead the market with the support from or cooperation with financial institutions.

3.1.1st Mobile Operators Lead the Market

The model is based on collection charges of mobile operators, which does not depend on banks' participation. When making mobile payments, the mobile account which is bound to the user's telephone expense is usually considered as the payment account, therefore, the transaction costs that consumers buy goods or services is deducted directly from the mobile account. In this way, banks gain nothing during the transaction.

3.1.2nd Banks Lead the Market

In this model, banks offer mobile payment services independently, while mobile phones are just the medium of payment. Mobile operators are only responsible for providing information access channel, but do not participate in operation and management, therefore, banks gain most of the profit.

3.1.3rd Third-Party Payment Platforms Lead the Market

The third-party payment is trading support platform that has financial contract with banks. They have dependable economic strength and reliable reputation in the industry, and they are independent of other financial institutions, especially independent of banks. Through third-party payment platform, the buyer purchase goods by the accounts provided by the platform, then the platform informs the seller for delivery. The platform will not transfer the money to the sell until the buyer has received and checked the goods and tells the platform that everything just goes fine. It connects mobile operators, banks and merchants. It not only can server the consumers with across banks services easily, which is difficult otherwise, but also can protect buyers from dishonest sellers.

3.1.4th Cooperation between Mobile Operators and Financial Institutions

It is the not surprising that mobile operators and banks work together can dominate the market, since the cooperation can take their advantages in mobile payment technology security and credit management fields, while eliminate each one's shortcomings.

3.2 Analysis of Current Mobile Payment in China

The mobile payment systems in Japan and South Korea are at the world's top level. Their operation model is mobile operators lead the market, and mobile operators are allowed to enter banking business fields under loose and comfortable finance environment. By providing various preferential measures, mobile operators attract equipment providers and merchants to join in the industry, and then create a complete industrial chain. In China, mobile operators, banks and third-party payment platforms are still seeking for the most fit operation model.

3.2.1st Mobile Operators

April 2009, China Unicom launched new mobile phones with built-in NFC card; June 2009, China Telecom and Shanghai Bank of Communications announced new mobile phones based on "E-surfing" electronic payment products. Users only need to buy a special SD card, then the phone can be used to pay utilities, buy movie tickets and make hospital specialist appointments and so on; in the same time, China Mobile released new SIM cards which support RFID. Users can use mobile payment service based on mobile contactless technology without having to change phones. March 11, 2010, China Mobile with 39.8 billion purchases 20% stake of Shanghai Pudong Development Bank, and becomes its second largest shareholder. This deal shows that China Mobile decides to control the mobile payment market, and it is apparent that China Mobile wants to follow the successful experience of Japan's NTT DoCoMo, which control the whole industrial chain by buying stocks of banks, credit card companies and other financial institutions.

3.2. 2nd Banks

March 2007, China Merchants Bank launched the "e-payment at will" mobile payment business; in June 2009, Bank of Communications launched a new generation of mobile banking "e Dong Jiao Hang"; in September 2009, China Union Pay launched "Hand Pay" product, which can be used for mobile payment via POS and 3G wireless networks instead of traditional bank cards. China Union Pay and China Mobile, as well as local telecom companies and local commercial banks have already tried "mobile wallet" service. Banks have to be active in market developing in order to avoid becoming subsidiaries of mobile operators, especially for those powerful banks.

3.1.3rd Third-Party Payment Platforms

There are lots of traditional third-party payment platforms in China, such as Alipay, CNCard, 99bill, Tenpay and so on, and nearly all of them have support for mobile payment, in the meantime, lots of new third-party payment platforms dedicated to mobile payment are emerging recently, such as SmartPay, Westone, Lefutong, and Eeepay and so on. According to the 2009 report from Analysis International, after 10 years of development, the third-party payment market's annual deal is close to 600 billion yuan in China. Based on the previous observations, we come to the conclusion that competition now dominates the relation among mobile operators, banks and third-party payment platform in China. Next we will discuss the current situation in China and its differences to other countries which forms the overall background of mobile payment.

4. The Environment for Mobile Payment in China

In order to investigate the operation model of mobile payment in China, we have to notice that there are many important differences between China and other countries, which forms the overall environment of mobile payments, and it is believed the environment can affect the future of the model dramatically.

Firstly, policies and regulations related to electronic payments are lagging behind. Mobile payment transactions lack of legal protection. If there were disputes, it would be difficult to resolve effectively, therefore, the potential risk for mobile payment is not acceptable for users, which would inhibit the user's willingness to consume through the new payment approach.

Secondly, in China, financial regulatory policies are strict, which create high barriers for mobile operators to enter the financial fields; at the same time, mobile operators own and fully control such rare resources as wireless network and mobile terminals (China Mobile has more than 500 million subscribers by the end of 2009, its market value reached $188.5 billion, and it is the world's largest mobile operator). Therefore, banks can hardly enter the mobile operator market.

Thirdly, China's nationalized banks are so big and powerful that it is impossible for them to give way to mobile operators when facing the promising mobile payment market. 2009 German "Frankfurter Allgemeine Zeitung" reported that, in the global bank market value list, the top 3 are all from China: Industrial and Commercial Bank of China, China Construction Bank, and Bank of China. In order to maintain the number of users, and guarantee the profit during the payment process, banks are unlikely to let mobile operators to get all the commission charges, and they will be very active in the industry chain.

Fourthly, the three mobile operators in China (China Mobile, China Telecom, China Unicom) have their respective advantages in terms of subscriber scale, mobile network infrastructure, quality of service and so on. As rivals, they have been competing for many years in different areas. Based on the current observation, all of the three operators have started to develop mobile payment market, and they are more active than banks.

Fifthly, due to the premature credit system in China, third-party payment platforms are becoming more and more popular because it can protect both buyers and sellers in the transaction in an incredible environment. In China, electronic payment market has a high share rate. According to Analysis International's report, in 2009 Q4, the turnover of third-party payment in China reached 184.91 billion yuan, among which, Internet payment contributes about 177.43 billion yuan, with a chain relative ratio growth of 19%. The total annual turnover of third-party payments is about 555.03 billion yuan, with an increase of 135.6%. Alipay, Tenpay and Chinapay stand in the top three positions, whose shares are 52.0%, 24.7% and 7.0% respectively. Their success means great pressures to banks online payment services. Third-party payment platforms are important roles in China, and it will play an important role in operation model gaming.

Finally, China’s mobile payment market scale is extremely huge. Both China's Internet users and mobile phone subscribers ranked first in the world (China Internet Network Information Center, CNNIC published “The 25th China Internet Development Statistics Report” at December 2009, and it shows that China's Internet users totaled 384 million; mobile Internet users increased 120 million in the last year, and has reached 233 million: mobiles have become a new economic growth point), therefore, the potential scale of mobile payment market is much more bigger than other countries. And now, China’s mobile Internet market is still in its early stage, in order to hold the positions in industry chain, different sectors will inevitably conduct fierce competition.

All these features constitute the overall environment of mobile payment in China, and we believe that without considering these factors, it is deemed to fail by following other countries’ operation models directly.

5. The Future of Mobile Payment Operation Model in China

June 21, 2010, People’s Bank of China officially announced the “The Procedures for Non-Financial Institution Payment Service”. According to the procedures, without the approval of People’s Bank of China, any non-financial institutions and individuals can not engage in or disguise payments business. The procedures have been put into force from September 1, 2010. Banks, mobile operators and third-party payments platforms are facing new opportunities and challenges, and they might change the actions accordingly.

5.1 Mobile Operators

First, direct stakes in commercial banks or third-party payment. By the end of March 2010, China Mobile successfully becomes the shareholder of Shanghai Pudong Development Bank. China Mobile's 39.8 billion yuan is enough to support the bank’s normal business development in the following 3 years; in the meantime, it can also support the bank to develop new personal financial services for mobile payment. By being its shareholder, China Mobile bypasses a lot of restrictions defined in the procedures for non-financial institutions. Second, develop close cooperation with financial institutions. In April, 2010, China Unicom and Bank of Communications established strategic business partner relationship. China Unicom will provide mobile payment services based-on the partnership. And recently, China Unicom also established close cooperation with Bank of China, and they will work together on mobile banking, mobile payment, e-commerce, information services by taking each one’s advantages. Nowadays, it is not realistic for mobile operators to hold a large number of shares of a bank or acquire a bank. On the one hand, mobile operators have to develop the mobile payment market; on the other hand, they have to obey the procedures. Therefore, one possible choice is to learn the experience of China Unicom, to carry out cross-industry cooperation with the banking industry. This might be a great shift for mobile operators.

5.2 Banks

China Central Bank has been developing new standardized online cross-bank financial services products, the second generation of payment system (known as the “super e-bank”) since 2009, and it has been put into use at the end of last August. Compared to existing e-banks, the biggest breakthrough of super-e-bank is that it supports instant cross-bank transfer and cross-bank inquiry. In other words, it connects all commercial banks existing e-banks into a single big e-bank. This means that it is possible to set up a super mobile payment service, which is built upon the super-e-bank and can provide only one interface to mobile operators, and it is much easier to establish cooperation between banks and operators than ever.

5.3 Third-Party Payment Platforms

On the one hand, the issue of the procedures means Alipay, TenPay and other third-party payment platform providers have to be approved by the central bank, obtain the business license in order to continue its payment service one year later. One the other hand, the procedures provides a formal approach for the third-party payment platforms to become authorized and qualified financial institutions, which is impossible otherwise.

The deployment of the “super-e-bank” is also a challenge for the third-party payment platforms. Many companies, such as Alipay, have begun to open up new areas. Alipay has set up a wireless group, dedicated to mobile payment services, to improve client development. Moreover, Alipay focuses on mobile remote payments areas, and it has been cooperated with handset manufacturers, operating system providers and even operators.

6. Conclusions

Based on the analysis of the present situation of China's mobile payment, it is apparent that mobile payment is an inevitable trend in the development of payment in China, and there is also a great space for its development. However, China's mobile payment industry is still in its infancy, the composition and structure of the industry chain is not yet clear, and no one knows what the operation model would be exactly. Therefore, different potential stakeholders have been trying their bests to lead the market, and the competition is especially fierce among mobile operators, banks and third-party payment institutions. This is inevitable in the early stage, however disordered competitions can lead to serious waste of resources, and low efficient market, from which users can benefit little. The development of mobile payment in China is at a crossroads, the primary challenge is to depict a clear picture of the operation model as soon as possible, otherwise the whole industry can result in over competing, and misses great development opportunities.

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Carrier's Liability in Multimodal Carriage Contracts in China and its Comparison with US and EU

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1. Introduction

The world of transport has changed considerably over the last few decades. International transportation of goods is increasingly carried out on a door-to-door basis, involving more than one mode of transportation. This has been possible due to the growth of containerized transportation.[1] The increasing use of containers,[2] together with technological developments improving the system for transferring cargo between different modes, has considerably facilitated the development of multimodal transport. Much of international trade is now carried out on a door-to-door basis involving different modes of transport under one contract.

Multimodal transport is the carriage of goods by at least two different modes of transport on the basis of a multimodal transport contract.[3] In addition to multimodal or combined transport, there are several other phrases such as intermodal, house-to-house, and door-to-door transport to describe such transport.[4] Comparing to the unimodal, through or other types of contract for the carriage of goods, the basic features of a multimodal transport are: (1) two or more modes of transport are used for the carriage of goods; (2) the entire carriage is under one single contract which does not exclude the existence of any subcontracts; (3) one party, usually called multimodal transport operator, is responsible for the entire carriage.

The attempts to establishing a uniform legal regime to ensure development of international multimodal transport at international level started by the International Institute for the Unification of Private Law (UNIDROIT) in the 1930s. This area of law was considered more and more important with the introduction and development of containerization of cargoes.[5] To correspond to this commercial reality, efforts to establish a legal regime for multimodal transport were further made by the Comité Maritime International (CMI) and a "Convention on Combined Transport – Tokyo Rules" was drafted in 1969. Although the rules in the previous drafted conventions were reflected in standard bills of lading such as the "Uniform Rules for the Combined Transport Document" of the International Chamber of Commerce (ICC) and despite other efforts on an international level, it was not until 1980 that the United Nations Convention on International Multimodal Transport of Goods was adopted (hereinafter referred to as the MT Convention). However, the MT Convention has not succeeded in attracting sufficient ratification to enter into force.[6] When it became obvious

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[1] UNCTAD, "Multimodal Transport: The Feasibility of an International Legal Instrument" *UNCTAD/SDTE/TLB/2003/1*, 13 January 2003, p.4.

[2] Ralph De Wit, Multimodal Transport (1995), p.4: "The so-called container revolution has altered the transport of goods enormously."

[3] The definition from the UN Convention on International Multimodal Transport of Goods, *UN Doc.TD/MT/CONF/16*, reprinted in 19 *ILM* 938 (1980), done at Geneva on 24 May 1980 (the Multimodal Convention), which offers the definition of "international multimodal transport".

[4] William Tetley, Marine Cargo Claims, 4th ed., Vol.2. 2008, p. 2257; John F. Wilson, *Carriage of Goods by Sea*, 6th ed., 2008, p.246; Thomas J. Schoenbaum, *Admiralty and Maritime Law*, Vol.1, 4th ed.,2007 p.589.

[5] United Nations Conference on Trade and Development, *The Economic and Commercial Implications of the Entry into Force of the Hamburg Rules and the Multimodal Transport Convention*, p.22.

[6] For a general introduction of historical review see the UN Document: *IMCTRAD/SDTE/TLB/2*, "Implementation of Multimodal Transport", report prepared by the UNCTAD secretariat, p.9. United Nations Conference on Trade and

that MT Convention was not likely to ever come into force, the United Nations Conference on Trade and Development (UNCTAD) secretariat established a joint working with the ICC to elaborate model provisions for multimodal transport documents. [7] The Joint Working Group completed the preparation of the UNCTAD/ICC Rules for Multimodal Transport Documents in 1991, and the Rules were entered into force in 1992.[8] The UNCTAD/ICC Rules have similar features that the MT Convention has such as basis of liability while distinguishing themselves by providing for a network system in terms of liability and, like in the Hague Rules, permitting nautical fault and fire exemptions for loss occurring in a sea-leg. The UNCTAD/ICC Rules have widely been accepted by the industry. Standard forms of contract such as the FIATA Bill of Lading 1992 and MULTIDOC- 95 incorporated them. However as the UNCTAD/ICC Rules are contractual in nature, their role is limited.[9]

In order to solve multimodal transport problems, two different models for liability are used: the uniform liability and the network liability system. Under the uniform system, a single liability regime applies regardless of the leg in which the loss or damage occurred.[10] Under the network system, on the other hand, different rules depending on the leg when the loss or damage occurred apply.[11] Each system has its own advantages and disadvantages. The advantage of the uniform system is that it is simple and transparent for all parties involved in the transport.[12] However, the disadvantage of this system for the contracting carrier is that his right of recourse to his subcontractor will vary depending on applicable unimodal regime.[13] On the other hand, the advantage of a network liability system for the multimodal transport operator is that his liability to the shipper will not exceed the liability of the performing carrier. However, this system is detrimental to the shipper since, in the container trade, loss is often concealed as the container is sealed upon receipt and is not open until delivery. Therefore, the damage may not be localized. Even if the damage is identified, it may occur gradually or span on two legs. As a result, any network system must be supplemented by default rules; otherwise, there may be a gap in terms of liability between the applications of the unimodal conventions.[14]

The past decades have witnessed the fast development of international trade and modern transport in China. Like in the most other trading countries in the world, the legal problems surrounding multimodal transport continuously emerge. Even if cargoes are transported in a much safer way nowadays, they are frequently damaged or lost during transport. When cargo is damaged or lost, the owner of the cargo must suffer a loss. This paper aims to explore carrier‟s liability in multimodal transport contract in China and compare the main issues with the counterparts in the US and EU.

2. Carrier's Liability and Cargo Claims under Multimodal Transport Contracts in China

A. An Overview of the Existing Multimodal Transport Legislations in China

It is very likely that a multimodal transportation contract involves foreign interests. According to article 145 of the Civil Law and article 126 of the Contract Law, the parties to a contract involving foreign interests may

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Development, The Economic and Commercial Implications of the Entry Into Force of the Hamburg Rules and The Multimodal Transport Convention, p.27: "… At the end of the 1980s it became obvious that the MT Convention would not enter into force in the immediate future. The main reason cited for this was that as long as the Hamburg Rules were not in force, there was no point in bringing the MT Convention into force since this would create too big a gap between the liability of the MT operator and that of the subcontracting ocean carrier who would still be liable only under "the Hague Rules or the Hague –Visby Rules."

[7] Mahin Faghfouri, "International Regulation of Liability for Multimodal Transport," 5 *WMU* 95, p.99.

[8] UNCTAD/ICC, *Rules for Multimodal Transport Documents*, Publication No:481, 1992.

[9] Christopher Hancock, "Multimodal Transport and The New UN Convention on The Carriage of Goods," 14 *JIML* 484, p 486.

[10] Hancock, p 488; Vibe Ulfbeck, "Multimodal Transports in the United States and Europe - Global or Regional Liability Rules?" 34 *Tul. Mar. L. J.* 37, p. 46.

[11] *Id.* ; *Id.*

[12] Hanckok ,p. 489.

[13] *Id.*; Ulfbeck, p. 47.

[14] *Id.*

select the applicable law for resolution of a contractual dispute, except as otherwise stipulated by law. The applicable law includes domestic laws and international conventions. At this juncture, it is worthy to mention there are a number of unimodal transportation conventions and China has ratified some of them which include "The Agreement on International Railroad through Transport of Goods, 1951", "The Warsaw Convention" and its amendment of the "Montreal Convention, 1999". If the parties in the case have not made any choice, the law of the country to which the contract with the closest connection shall apply. [15] If a multimodal transport contract does not involve foreign interests, or the parties select to apply Chinese law, then the relevant laws and regulations in China will apply. The following will be focused on the exploration of the carrier‟s liability under multimodal transport contracts and the related cargo claims, where there is no foreign element is involved or the contracting parties select to apply Chinese law. The legal framework for regulating multimodal transport contracts in China consists of laws and regulations.

3. Maritime Code 1993, Chapter IV, Section 8: Special Provisions Regarding Multimodal Transport Contract

Unlike the US and the most EU countries, China has its own Maritime Code which took almost 40 years and went though more than 20 drafts for its preparation. It came into force in 1993 and its many aspects, when drafting, were largely modeled on the Hague Rules, the Hague/Visby Rules, the Hamburg Rules, and other international conventions. The total of 278 articles is divided into 15 Chapters. Chapter IV, Section 8 is devoted to regulating multimodal transport contract.

Article 102 of Chapter IV provides a specific definition of multimodal transport contract. It is "a contract under which the multimodal transport operator undertakes to transport the goods, against the payment of freight for the entire transport, from the place where the goods were received in his charge to destination and to deliver them to the consignee by two or more different modes of transport, one of which being sea carriage." It, is, thus, clear that the provisions in this Chapter only apply to multimodal transport contract including a sea leg. This definition should be read in conjunction with the definition of the term "multimodal transport operator" provided in the same article which describes the multimodal transport operator as "…the person who has entered into a multimodal transport contract with the shipper either by himself or by another person acting on his behalf." Consequently, China takes the contractual approach like in Europe by regulating multimodal contracts.

Section 8 comprises of five articles. Besides the definitions given in Article 102, it lays down the provisions of "period of responsibility", "liability of the multimodal transport operator" and other important matters.

4. Contract Law 1999

In 1993, the Standing Committee of the National People‟s Congress ("NPC") started to draft the contract law. As a result, five drafts were submitted separately to the Legislative Affairs Commission of the Standing Committee of the NPC in the following years. Finally the Contract Law was promulgated in 1999.

The Contract Law consists of 23 Chapters and 428 Articles. It is divided into three parts: namely, General Provisions, Specific Provisions and Supplementary Provisions. Among them, the Specific Provisions deal with 15 types of contracts which include contracts for transportation. According to Article 288, a contract of transportation is "…a contract whereby the carrier carries passengers or goods from the starting place of carriage to the agreed destination, and the passenger or the shipper or the consignee pays for the ticket-fare or freight." Obviously, this definition includes contract of carriage of goods and contract of carriage of passengers. For contract of carriage of goods, there is a special section - Section 4 – dedicated to contracts for multimodal transportation. It, however, does not provide an express definition of multimodal transportation.

In general, the carrier carrying goods shall: (1) accept the normal and reasonable carriage request of a shipper; (2) carry the goods safely to the agreed destination within the agreed time period or within a reasonable time

[15] The Contract Law, Art.126.

period; (3) carry the goods to the agreed destination via the agreed or customary carriage route. Those obligations are equally applicable to a multimodal transportation business operator.

5. Regulations Governing International Multimodal Transport of Goods by Containers, 1997 (hereinafter referred to as the Regulations)

The Regulations, issued by Ministries of Communication and of Railways, came into effect on 1 October 1997. The Rules contained in the Regulations apply mandatorily to the international multimodal transport of goods by containers by waterway, highway and rail from a place in one country at which the international containers are taken in charge by the international multimodal transport operator to a designated place of delivery located in a different country. But they do not cover the international multimodal transport of goods by containers by air. [16]

The Regulations include 8 chapters and 43 articles. It regulates international multimodal transport of goods by containers from different aspects which include the administration of the multimodal transport, documents, the liabilities of multimodal transport operator, claims etc.

6. The Interactions between the Laws and Regulations

Most of multimodal transport involves a sea carriage stage, but it also happens that some multimodal transport contracts for carriage of goods do not include a sea leg. According to Article 123 of Chapter 8 of the Contract Law, if there are provisions as otherwise provided for a multimodal transport contracts in other laws, such provisions shall be obeyed.[17] Thus, the multimodal transport of goods involving a sea leg will be governed by the Maritime Code. Since there is no law specifically dealing with multimodal transportation which merely takes place among the modes of rail, road or civil aviation, the multimodal transport without a sea leg will be subject to the provisions of the Section 4, Chapter 17 of the Contract Law. The Regulations are merely rules and regulations implementing laws promulgated by legislative bodies with a view to strengthening and controlling the international multimodal transport of goods by containers, therefore they do not fall within the ambit of "other laws" referred to in article 123 of the Contract Law. As a consequence, any provisions therein contrary to those of the Maritime Code or the Contract Law will be considered null and void.

B. Cargo Claims

1. Whom to Sue?

Under a multimodal transport contract, the cargoes must be placed in the containers and carried by different means of transport such as ships, railway wagons or aircrafts from place of departure to place of final destination, without being unpacked for sorting or verification when being transferred from one mode of transportation to another. If any loss of, or damage to the goods happened, cargo interests would be better off if they can pursue one single operator who would be responsible for the entire transport, rather than against several carriers involved.

According to Article 103 of the Maritime Code, the period of liability of the multimodal transport operator covers "the period from the time he takes the goods in his charge to the time of their delivery." Clearly, the period of operator‟s responsibility covers the entire carriage. The Maritime Code also allows the multimodal transport operator to enter into separate contracts with unimodal carriers with regard to different sections of the transport under the multimodal transportation contract. However, in the later case, the responsibility for the multimodal transportation carrier with respect to the entire transport will remain unaffected. [18]

The Contract Law adopts the similar rule to regulate the liability of multimodal transportation business operator. It is possible for the multimodal transportation business operator to enter into agreements with the

[16] The Regulations, Arts.2 & 4.
[17] The Contract Law, Art.123.
[18] The Maritime Code, Art. 104.

unimodal carriers participating with multimodal transportation on their respective responsibilities for different sections under the multimodal transportation contract. [19] But it is clear from Article 317 that the responsibility of the multimodal transport business operator with respect to entire transport will remain unaffected.

It is very likely that the multimodal transport operator will make contracts with other parties in respect of various parts of the transport; while the cargo claimants are not party to those sub-contract. It is, however, clear that the multimodal transport operator undertakes to transport the goods for the entire carriage. Therefore, cargo interests may only claim against the multimodal transport operator when any loss, damage or delay is incurred to the goods.

The question may arise as to the possibility for the cargo interests to claim against the sub-contractor(s). If the multimodal transport operator himself may not be worth suing, can the cargo interest sue the sub-contractor(s)? It depends on the fact whether multimodal transport operator signs the contract with the sub-contractor for the cargo interests as an agent or principal. In the former case, a direct contractual relationship between cargo interests and sub-contractor may exist and cargo interests can sue the sub-contractor according to the terms in the carriage contract. The claimant may, however, have the alternative to claim against the sub-carrier in tort.

2. Law and Jurisdiction

Cargo interests must ensure the proper applicable law of the contract. Like in the US and the EU, the Maritime Code, the Contract Law and the Regulations also adopt a system of "network" liability. Under the "network" system, the liability of the multimodal transport operator, i.e. damage or loss known to have occurred during a particular section of transport, is determined by reference to the international convention or national law applicable to that particular section of transport.[20] It follows that, for example, if there is loss or damage occurring during the carriage by sea, the operator"s liability must thus be subject to the relevant international or domestic law on the sea carriage. [21] It is possible that more than two conventions or domestic laws may apply to different parts of a multimodal transport.[22] If, however, the loss or damage cannot be localized, the Maritime Code will apply to determine particular issues on liability or limitation of liability.

Section 4 of chapter 17 of the Contract Law will apply if the multimodal transportation carriage does not involve a sea leg. Like in the Maritime Code, it adopts a network system of liability.[23] Accordingly, if it can be established at which stage of transport the loss or damage took place, then the rules and regulations applicable to that specific mode of transport will be applied in determining the liability of the multimodal transportation business operator. In case of non-localized damage, i.e. where it is not known at which leg of carriage the loss or damage occurred, the provisions of Contract Law will govern the liability of the multimodal transportation business operator.

The Regulations apply mandatorily only if any provisions therein are not contrary to those of the Maritime Code or the Contract Law. The Regulations do not cover the international multimodal transport of goods by containers by air.

Cargo interests must also ensure the legal proceedings are commenced in the correct jurisdiction. An international convention, if applicable, may normally outline the relevant provisions on the subject. However, cargo interests may have to choose among different jurisdictions, or they may be faced with the possibility to sue against the defendant in a jurisdiction which is not favourable to them. In any case, it is important for the

[19] The Contract Law, Arts 317& 318.
[20] The Maritime Code, Art. 105.
[21] Mo, John Shijian, *Shipping Law in China* (1999), p.130.
[22] Ibid.
[23] The Contract Law, Art. 321: " Where the damage to, destruction or loss of goods occurs in a specific section of the multimodal transportation, the liability of the multimodal transportation business operator for damages and the limit thereof shall be governed by the relevant laws in the specific model of transportation used in the specific section. Where the section of transportation in which the damage or destruction or loss occurred cannot be identified, the liability for damages shall be governed by the provisions of this chapter."

cargo interests to bring the claim in the right jurisdiction which is most advantageous to them. If the claim is brought in China, the Civil Procedure Law[24] and Special Maritime Procedure Law[25] contains rules on jurisdiction over cases on multimodal transport contract.

3. Proving the Loss

To effectively bring his claim, the cargo interests must prove his loss. This essentially means that the claimant must establish that the multimodal transport operator has failed to deliver what he had contracted to transport. For any type of claim, it is important for the cargo interests to give notice of loss or damage within the stipulated time period. Where the multimodal transport includes a sea leg, according to article 81 of the Maritime Code, notice of loss or damage must, failing joint inspection when the cargo interest receives the goods and where the loss of or damage to the goods is not apparent, be given in writing to the carrier. The notice of loss or damage must be given in writing within seven consecutive days from the next day of the delivery of the goods, or, in the case of containerized goods, within 15 days from the next day of the delivery of the goods. If the cargo interest fails to give such a notice, "such delivery shall be deemed to be prima facie evidence of the delivery of the goods by the carrier as described in the transport documents and of the apparent good order and condition of such goods."[26] Where the Contract Law applies, the carrier is *prima facie* deemed to have delivered the goods in conformity with the statement indicated in the carriage contract and if the consignee fails to make any claim within the agreed time limit or within a reasonable time limit.[27] There is no further explanation as to the meaning of "claim" in the article, but it may be construed as "notice of loss or damage" in the appropriate context.

A multimodal transportation business operator issues multimodal transportation documents upon receiving the goods from the shipper. In the document, the operator states the quantity and apparent conditions of the goods received. In case of loss, the claimant is required to prove that the goods discharged were not the goods stated to have been received for transportation, comparing the difference between the discharge and the loading point.

4. Proving the Carrier"s Breach

In almost all cases, it is not sufficient if the claimant can only prove a *prima facie* case as stated in the above section. For the claimant to succeed in the end, he needs to prove that its loss was the direct result of a breach by the carrier of the obligations as agreed in the contract or by law.

Chapter IV of the Maritime Code applies to determine the basis and the extent of liability of the multimodal transport operator in case of non-localized damage when a sea leg is involved in a multimodal transport. The basis of the liability of the carrier for loss or damage to goods is in effect similar to that of The Hague and Hague/Visby Rules. The carrier is required before and at the beginning of the voyage, to exercise due diligence to make the ship seaworthy, properly man, equip and supply the ship. He is bound to "properly and carefully load, handle, stow, carry, keep, care for and discharge the goods carried."

According to the principle established in Article 321 of the Contract Law, the liability of the multimodal transportation business operator shall be dealt with under Chapter 17. Article 311 of the Contract Law provides that: "A carrier shall be liable for damages to or destruction of goods during the period of carriage unless the carrier proves that the damage to or destruction of goods is caused by force majeure, by inherent

[24] The Civil Procedure Law, Art. 28: "A lawsuit brought for a dispute over transportation contract via…combined transportation shall be under the jurisdiction of the people"s court located in the place of the departure or the destination, or where the defendant has its domicile."

[25] The Maritime Procedural Law, Art. 6(2): "A lawsuit brought on maritime transportation contract may be, in addition to the provisions of Art. 28 of the Civil Procedure Law of the People"s Republic of China, under jurisdiction of the maritime court of the place of its port of transshipment."

[26] The Maritime Code, Art. 81.

[27] The Contract Law, Art. 310.

natural character of the goods, by reasonable loss, or by the fault on the part of the shipper or consignee." For concealed damage, the Contract Law provides for the strict liability.

If the Regulations are applicable, Article 27(1) states the principle that the multimodal transport operator "shall be liable for loss of or damage to or delay in delivery of the goods that happened while the goods were in his charge." Article 32 of the Regulations ensures that contractual agreements do not override the provisions of the law concerning the liability of the multimodal transport operator. Here, the "law" mainly refers to the Maritime Law and the Contract Law in China.

Delay in delivery occurs not infrequently in multimodal transport. The operator is held liable for delay in delivery of the goods under the Maritime Code, Contract Law and the Regulations. [28] The operator is liable for economic loss arising from delay in delivery even without actual loss of, or damage to goods, unless such economic losses occurred from causes for which the carrier was not liable. Provisions are also made for conversion of delay into total loss, for instance, the person entitled to make a claim for the loss of goods may treat the goods as lost if they are not delivered within 60 days from the date agreed for delivery. [29]

5. Excluding and Limiting the Carrier's Liability

The carrier will seek to deny a breach of any duty owned towards the claimant, and the carrier could then try to extinguish the claim either by arguing that the claim has been time-barred or by pleading one of the exceptions to liability allowed by the applicable law. But since the multimodal transportation operator may enter into separate contracts with unimodal carriers with regard to different sections of the transport and a network system of liability is adopted to apply to multimodal transport contract in China, the provisions of the relevant laws and regulations govern the liability exceptions and limitation of the multimodal transportation operator.

Under the Maritime Law, for example, a multimodal transport operator will be entitled to rely on the exceptions which include nautical fault and fire provided in article 51, which is mainly based on the Hague Rules exceptions to relieve himself from liability for loss or damage to goods. With respect to the limitation of liability, if loss of or damage to the goods has occurred in a certain section of the transport, the provisions of the relevant laws and regulations governing the specific section of the multimodal transport shall be applicable.[30] For non-localized loss or damage, the rules contained in Maritime Code will apply. Accordingly, carrier is entitled to limit his liability for loss of, or damage to the goods to an amount equivalent to 666,67SDR per package or other shipping unit, or 2 SDR per kilogram of the gross weight of the goods lost or damaged, whichever is higher, unless the nature and value of the goods have been declared by the shipper and inserted in the bill of lading, or a higher limit has been agreed upon between the carrier and the shipper. [31] The carrier, however, will lose the right to limit his liability if it is proved that the loss, damage in delivery resulted from his act or omission done with intent to cause such loss, damage or delay, or recklessly and with knowledge that such loss or damage would probably result. [32]

Where the Contract Law applies, the amount of damages for the damage to or destruction of the goods is ascertained according to different rules. If there is such an agreement, the amount of damages shall be the amount as agreed on the contract by the parties. Where there is no agreement or the agreement is unclear, the market price at the place where the goods are delivered at the time of delivery or at the time when the goods should be delivered shall be applied. Concerning the amount of damages, the Contract Law also provides a possibility that "where, after the contract becomes effective, there is no agreement in the contract between the parties on the terms regarding quality, price or remuneration and place of performance, etc. or such agreement is unclear, the parties may agree upon supplementary terms through consultation. In case of a failure in doing so, the terms shall be determined from the context of relevant clauses of the contract or by transaction

[28] For example, the Maritime Code, Art. 50, the Regulations, Art. 27.
[29] The Maritime Code, Art. 50, the Regulations, Art. 27(2).
[30] The Maritime Code, Art. 105.
[31] The Maritime Code, Art. 59.
[32] The Maritime Code, Art. 59.

practices."[33] In addition, where the laws or administrative regulations stipulate otherwise on the method of calculation of damages and on the ceiling of the amount of damages, those provisions shall be followed.

The Regulations also provide applicable rules for limitation of liability. The multimodal transport operator is not entitled to the benefit of the limitation of liability if it is proved that the loss, damage or delay in delivery resulted from his act and omission done with the intent to cause such loss, damage or delay, or recklessly and with the knowledge that such loss, damage or delay would probably result. [34]

The carrier‟s liability for the economic loss resulting from delay in delivery of the goods is also limited. It is normally limited to an amount equivalent to the freight payable for the goods so delayed. [35] The carrier, however, is not entitled to limit his liability if it is proved that the delay in delivery resulted from his act or omission done with the intent to cause such loss, damage or delay, or recklessly and with knowledge that such loss, damage or delay would probably result. [36]

The shipper is heeded for liability under certain circumstances. For example, according to Article 320 of the Contract Law, the shipper is liable for any loss suffered by multimodal transportation business operator as a result of his fault, even if he has transferred the transportation document to other parties.

It is possible that the claim is time barred. For example, according to Article 34(1) of the Regulations, where the multimodal transport includes a sea leg, any action against the multimodal transport operator shall be time-barred if proceedings have not been instituted within a period of one year. This period is extended to two years where there is no sea carriage involved and an action is brought against the multimodal transport operator under the General Rules of Civil Law. The limitation period commences from the day following which the goods were delivered or should have been delivered by the multimodal transport operator. [37]

7. Carrier's Liability under Multimodal Transport Contracts in the United States

In the United States, different statutory regimes apply to different modes of transport. The Hague Rules were incorporated into domestic law with the enactment of the Carriage of Goods by Sea Act (COGSA) in 1936.[38] The COGSA governs ocean common carriage to and from the United States. COGSA applies tackle-to-tackle, i.e. from the time the cargo is being loaded to the time when it is discharged from the vessel. The intent of the drafters of the Hague Rules was that claims arising outside tackle-to-tackle period should be governed by national law or by contractual agreement between the parties.[39] Accordingly, COGSA allows the parties to extend the application of COGSA. If the parties do not extend the application by agreement, the Harter Act applies to the period before loading and after discharge. The Harter Act governs contracts of carriage between ports of the United States and inland water carriage.[40] Rail transport, on the other hand, is governed by the Carmack Amendment. In order to find who is liable under the multimodal contract, several issues must be resolved.

A. Issuance of Through Bill of Lading

Where a multimodal transport is at issue, ocean carrier may issue an international through bill of lading. Such a bill of lading may effectively serve as a receipt, evidence of the contract, and as a document of title. [41] A bill of lading may be subjected to the Hague-Visby Rules or COGSA for the entire period while

[33] The Contract Law, Art. 61.
[34] The Regulations, Art. 31.
[35] The Maritime Code, Art. 57.
[36] The Maritime Code, Art. 59.
[37] The Regulations, Art. 34(2).
[38] 46 U.S.C. App. § 1312.
[39] Michael E. Crowley, "Admiralty Law Institute Symposium: The Uniqueness of Admiralty and Maritime Law: The Limited Scope of the Cargo Liability Regime Covering Carriage by Sea: The Multimodal Problem," 79 *Tul. L. Rev.* 1461, p.1471.
[40] 46 U.S.C. App. § 190 etc.
[41] Schoenbaum, p. 595.

the goods are in the custody of the carrier, including inland transport, by inserting a clause paramount. In this case the intent of the parties must be properly and clearly expressed in the through bill of lading.[42]

B. Applicable Law

In principle, the facts of the case decide what law to apply. However, there are some other principles applicable to multimodal cases. As mentioned above, the COGSA compulsorily applies during the period from the time the goods are loaded on the ship and until the time when they are discharged from the ship; whereas the Harter Act compulsorily applies outside this period while the goods are in the custody of the carrier.[43] However, the application of Harter Act does not include inland transport stage.[44] Besides, the compulsory application of COGSA or Harter Act, COGSA and Hague Rules specifically allow parties of a carriage contract to extend COGSA, the Harter Act, or any other limitation of liability regime to shoreside contractors such as stevedores, terminal operators, warehousemen, and inland carriers.[45] In other words, this is done either by the Clause Paramount which extends application of COGSA beyond the time goods are on the vessel or by the Himalaya Clause which extends the benefits of the carrier‟s defenses and liability limits to shore side third parties.[46]

On the other hand, the Congress enacted the Carmack Amendment as part of the former Interstate Commerce Act in 1906.[47] Originally, the Carmack Amendment applied only to rail carriers and only to domestic inter-state carriage.[48] It was extended to trade with territories and adjacent countries in 1915, and to road carriage in 1935.[49] The Carmack Amendment applies to carrier that is subject to jurisdiction of the Surface Transport Board. Accordingly, 49 U.S.C § 10501 (a) provides that:

> **(1)** *Subject to this chapter, the Board has jurisdiction over transportation by rail carrier that is—*
>
> > ***(A)*** *only by railroad; or*
> >
> > ***(B)*** *by railroad and water, when the transportation is under common control, management, or arrangement for a continuous carriage or shipment.*
>
> ***2)*** *Jurisdiction under paragraph (1) applies only to transportation in the United States between a place in—*
>
> > ***(A)*** *a State and a place in the same or another State as part of the interstate rail network;*
> >
> > ***(B)*** *a State and a place in a territory or possession of the United States;*
> >
> > ***(C)*** *a territory or possession of the United States and a place in another such territory or possession;*
> >
> > ***(D)*** *a territory or possession of the United States and another place in the same territory or possession;*
> >
> > ***(E)*** *the United States and another place in the United States through a foreign country; or*
> >
> > ***(F)*** *the United States and a place in a foreign country.*

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42 Schoenbaum , p.596.

43 Schoenbaum, p.597, 649 ff. Before Congress enacted COGSA in 1936, Harter Act governed ocean carrier‟s liability for port-to-port carriage within the United States. 46 *U.S.C.* §30702 (2000).

44 Schoenbaum, p.597; David W. Robertson / Michael F. Sturley, "Recent Developments in Admiralty and Maritime Law at the National Level and in the Fifth and Eleventh Circuits," 32 *Tul. Mar. L. J.* 493, 526

45 COGSA § 1307 Agreement as to liability prior to loading or after discharge
Nothing contained in this chapter shall prevent a carrier or a shipper from entering into any agreement, stipulation, condition, reservation, or exemption as to the responsibility and liability of the carrier or the ship for the loss or damage to or in connection with the custody and care and handling of goods prior to the loading on and subsequent to the discharge from the ship on which the goods are carried by sea.
Hague Rules Art.7 ″ Nothing herein contained shall prevent a carrier or a shipper from entering into any agreement, stipulation, condition, reservation or exemption as to the responsibility and liability of the carrier or the ship for the loss or damage to, or in connexion with, the custody and care and handling of goods prior to the loading on, and subsequent to, the discharge from the ship on which the goods are carried by sea.″

46 Crowley, p. 1471.

47 *Id.* p. 1464.

48 Hepburn Act § 7, 34 Stat. 595 (1906); *Michael F. Sturley, " Maritime Cases About Train Wrecks: Applying Maritime Law to the Inland Damage of Ocean Cargo*, " 40 *J. Mar. L. & Com*. 1, 3 and fn. 12 there.

49 Sturley, "Maritime Cases About Train Wrecks," p, 3 and fns.13,14.

It is to be stressed that the Carmack Amendment applies to the inland *carrier* rather than *contract of carriage*:[50] Both 49 U.S.C. § 11706 and § 14706 read that *″...[T]hat rail carrier and any other carrier that delivers the property and is providing transportation or service subject to the jurisdiction of the Board under this part are liable to the person entitled to recover under the receipt or bill of lading….″ and ″That carrier and any other carrier that delivers the property and is providing transportation or service subject to jurisdiction under subchapter I or III of chapter 135 or chapter 105 are liable to the person entitled to recover under the receipt or bill of lading….″ respectively*. It is clear from this wording is that the Carmack Amendment‟s basis is the carrier.

Consequently, the court may apply either the provisions of bill of lading[51] or the Carmack Amendment if the parties do not elect to apply COGSA, Harter Act or any other liability regime to the leg that is outside the compulsory application of the COGSA or Harter Act.[52]

Moreover, a through bill of lading may provide that the liability of carriers is based on the network system. In this case, each carrier‟s liability will be determined in accordance with the leg that it performs.

Application of COGSA to the Inland Leg

In order to determine if maritime law is applicable to the inland leg of multimodal carriage, one must ascertain the nature of the contract first. Generally, the rail or road carriage is non-maritime whereas the ocean carriage is maritime in nature. If inland and ocean legs of the carriage were covered by separate contracts, maritime law will then be inapplicable. Because, as a general rule, admiralty jurisdiction in a contract case arises only when the subject-matter of the contract is *purely* or *wholly* maritime in nature.[53] Until recently, "mixed" contracts, which involve obligations for both sea and land carriage, such as a multimodal bill of lading, were considered to fall outside a federal court‟s admiralty jurisdiction. [54]

However, in 2004, the Supreme Court in *Norfolk Southern Railway Company v. James N. Kirby*[55] ruled that: "*Conceptually, so long as a bill of lading requires substantial carriage of goods by sea, its purpose is to effectuate maritime commerce--and thus it is a maritime contract. Its character as a maritime contract is not defeated simply because it also provides for some land carriage.*"[56] Very recently, Supreme Court reiterated this view in *Kawasaki Kisen Kaisha Ltd., et.al v. Regal-Beloit Corp*[57].

C. Application of the Carmack Amendment to the multimodal transport contracts

Whether the Carmack Amendment is applicable to the inland leg of multimodal transport is in dispute.[58] Eleventh Circuit establishes a rule that when a shipment of foreign goods is sent to the United States with the intention that it comes to final rest at a specific destination beyond its port of discharge, then the domestic leg of the journey (from the port of discharge to the intended destination) will be subject to the Carmack Amendment as long as the domestic leg is covered by separate bill or bills of lading.[59]

The other courts, however, have applied the Carmack Amendment to inland leg of multimodal transports by relying on the plain language of the statute. In other words, they applied the Carmack Amendment to a single

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[50] Vibe Ulfbeck, "Multimodal Transports in the United States and Europe - Global or Regional Liability Rules?" 34 *Tul. Mar. L. J.* 37, 44.
[51] *Commercial Union Ins. Co. v. M/V Bremen Express* 16 F.Supp. 2nd 403, 1999 *AMC* 2002 (S.D.N.Y 1998).
[52] Schoenbaum, p.598.
[53] *Hartford Fire Ins. Co. v. Orient Overseas Containers Lines (UK) Ltd*., 230 F.3d 549, 555-56, 2001 *AMC* 25 (2d Cir. 2000) at 12; Sturley, p. 6 and fn.27; See generally Schoenbaum, p.130 ff..
[54] *Id.* at 13; *Id.,* p. 6.
[55] 543 U.S. 14
[56] 543 U.S at 27.
[57] Syllabus No. 08–1553. [Not reported yet. Order list of states as 561 U.S.___ (2010)].
[58] Schoenbaum, p. 598; Crowley, p.1485.
[59] *Swift Textiles,Inc. V. Watkins Motor Lines*, Inc. 799 F.2d. 697, 701.

bill of lading to the extent that the shipment ran beyond the dominion of COGSA and the Harter Act. [60] In other words, if the parties to a bill of lading do not extend COGSA or the Harter Act to inland transport, liability under the multimodal transport will be determined according to COGSA, Harter Act and the Carmack Amendment respectively depending on the leg where damage occurred. [61]

D. Application of a State Law to Inland Carriage

If the court rejects admiralty jurisdiction, state law may apply. In *SS "Ming Prosperity"*[62], the cargo was shipped from Hong Kong to Los Angeles on ship and from Los Angeles to New York by rail. The cargo was destroyed in a train derailment and caught fire. The court held that there was no admiralty jurisdiction because the dispute involved a non-maritime obligation that could not be severed from the maritime obligation and the train derailment was not incidental to the maritime contract.[63] In the absence of maritime jurisdiction, the claim was governed by New York law, which was the place of delivery, the importer‟s residence, and location of the business injury.[64]

E. Application of Foreign Law or International Convention

Moreover, in case of loss or damage occurring in a foreign country, an international convention or foreign law may be applied.[65] In *Hartford Fire Insurance Co. V. Orient Overseas Containers Lines*[66], a through bill of lading for the shipment of a container of 301 packages of bicycles and bicycle framesets from Oconomowoc, Wisconsin to Spijkenisse, The Netherlands was issued.[67] The container was picked up in Oconomowoc and transported by truck to Chicago. From Chicago, the container was moved by rail to Montreal, Canada, where it was loaded onto defendants‟ vessel, the M/V OOCL Bravery.[68] Defendants transported the container by sea from Montreal to Antwerp, Belgium, and then discharged it to a participating carrier who was supposed to transport it by truck to the consignee‟s premises in Spijkenisse.[69] Defendants had selected DeBrock Gebr. Transport, N.V. ("DeBrock") as their trucker between Antwerp and inland destinations in Europe, but DeBrock subcontracted with N.V. Groeninghe ("Groeninghe") to transport said container from Antwerp to Spijkenisse.[70] A Groeninghe truck picked up the container from defendants‟ ship at Antwerp.[71] Later on the same evening, thieves stole the truck, together with the container of bicycles, after the truck had been left on a public road without any supervision or guard near the driver‟s domicile in Deurne, Belgium.[72] The police was able to track down approximately 30 of 301 stolen packages, but the remainder was never recovered. Plaintiff filed a claim for the value of the missing packages. [73]

The district court concluded that the Carriage of Goods by Sea Act (COGSA), 46 U.S.C.S. § 1300 et seq., governed the entire intermodal carriage from Wisconsin to The Netherlands and, therefore, that COGSA‟s provision on limitation of liability applied even though the cargo was lost while being transported by truck in

[60] *Neptune Orient Lines Ltd. v. Burlington Northern and Santa Fe Railway Company* 213 F.3d 1118; 2000 U.S. App. LEXIS 11452; 2000 *AMC* 1785; „*If the final intended destination at the time the shipment begins is another state, the Carmack Amendment, 49 U.S.C.S. § 14706, applies throughout the shipment, even as to a carrier that is only responsible for an intrastate leg of the shipment. Similarly, if the final intended destination at the time the shipment begins is a foreign nation, the Carmack Amendment applies throughout the entire portion of the shipment taking place within the United States, including intrastate legs of the shipment.‟ Project Hope v. M/V Ibn Sina* 250 F.3d 67; 2001 AMC 1910.

[61] Schoenbaum, p.598

[62] 920 F. Supp. 416

[63] *Id* at 420.

[64] *Id* at 421.

[65] Schoenbaum, p.599.

[66] 230 F.3d 549.

[67] *Id* at 552.

[68] *Id.*

[69] *Id.*

[70] *Id.*

[71] *Id.*

[72] *Id* at 553.

[73] *Id.*

Europe after having been discharge from the vessel. On appeal, the court first concluded that the bill of lading in this case involved land carriage that was more than "incidental" to sea carriage, thus placing this dispute outside of the court‟s admiralty jurisdiction.[74] Next, the court found that the appropriate law to apply under the bill of lading with respect to the loss of goods in Belgium was the Convention on the Contract for the International Carriage of Goods by Road, 1956, not COGSA.[75]

F. Network System in the United States

There is no statute in the United States implementing the network system. However, this does not mean that network system is not applied in the United States. As mentioned before many bill of ladings embody the network principle. The network system in the United States is understood in several different ways.

One way of explaining the system is that whereby the applicable law (i.e. COGSA or Carmack Amendment) travels with the cargo, each carriers‟ liability is limited to the transport segment that it performs. [76] Accordingly, it is said that each carrier is potentially liable only for the part of the journey for which it was responsible.[77] This understanding of network system seems different than the way it is understood in Europe. Because this wording implies that it also deals with the liability of subcontracting carrier.[78]

Another way the network liability system is understood is that the contracting carrier assumes the liability for entire transport, e.g. the contracting carrier extends its liability regime to cover all stages of the transport and subcontractors cover their own liability regimes. [79] It is obvious that this understanding of network system is disadvantageous for the contracting carrier as the recourse action against the subcontractor will be different from the one covering the entire transport.[80] That is to say while recourse action against to subcontractor will be determined in accordance with applicable law to the leg that subcontractor actually performs, contracting carrier‟s liability for the whole transport period will be probably subject to totally different rules.

The third way the network system is understood in the United States is similar to European system. Accordingly, the contracting carrier assumes the liability for entire transport and its liability is determined in accordance with applicable rules of the leg where damages occurred.

8. Cargo Claim under Multimodal Transport Contracts in Europe

A. In General

Within Europe, the ocean carriage is regulated by Hague-Visby Rules or adapted version of these Rules; whereas in the United States international ocean carriage is governed by COGSA which is based on the Hague Rules. However, one can say that in general ocean carriage laws both in the U.S. and Europe are similar. On the other hand, the road carriage in Europe is governed by the Convention on the Contract for the International Carriage of Goods by Road (hereinafter referred to as the CMR)[81]; while rail carriage is governed by Convention concerning International Carriage by Rail 1980 CIM/COTIF[82].

Both CMR and COTIF/CIM govern „contracts for carriage‟ rather than „carriers‟. This approach is considered to be a contractual approach and is explained being that these Conventions only regulate the relationship between carrier and shipper.[83]

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[74] *Id*. at 555-556.
[75] *Id*. at 558-559.
[76] Schoenbaum, p.599.
[77] *Id.*
[78] Ulfbeck, p.52.
[79] Draft COGSA 1999 includes this princle of network system. It is obvious that this system is adventageous.
[80] Ulfbeck, p.54.
[81] Signed in Geneva in 1956. 55 States are the party to the Convention currently.
[82] Signed in Bern 1980 and amended by the Vilnius Protocol of 3 June 1999 (1999 Protocol), which entered into force on 1 July 2006.
[83] Ulfbeck, p. 45.

There are two views explaining the multimodal contracts in Europe: „plurality of contracts" and „*sui generis*" contract.[84] According to *plurality of contracts*, multimodal transport contract contains several contracts for different modes of transport; thus subjecting the contracting carrier to different liability rules depending on the leg of the transport.[85] Following the *sui generis* contract view, on the other hand, multimodal transport contract is not regulated by the existing conventions; therefore some European states, such as Germany and the Netherlands, has enacted legislation on the multimodal transports.[86]

B. Extending maritime law to the inland transport

European maritime law regime, based on the Hague Rules, covers the liability of the carrier on "tackle-to-tackle" basis. It is questionable if the maritime law regime can be extended to inland part. European Maritime law regime has no rule preventing the parties of the contract to extend the maritime law to the inland leg. Do CMR and COTIF/CIM have any such rule preventing the parties to extend maritime law to road or rail transport fall under their scope? First, under the CMR and COTIF/CIM, the liability of the carrier is stricter. Secondly, under these conventions, the extent of the limitation of liability is rather restricted. Thirdly, the CMR and COTIF/CIM are applicable to a specific type of unimodal transport while including provisions dealing with multimodal transport. Thus, if the multimodal contract falls under these provisions the parties cannot extend maritime liability regime to the inland leg.[87]

The other question is how to qualify the multimodal contract between the carrier and shipper? The views on this issue are varying in Europe. In *Quantum Corp. Inc. v. Plane Trucking Ltd*.[88], an English case, goods were carried from Singapore to Paris by air and from Paris to Dublin by truck under a multimodal contract. The District court found that the CMR was not applicable to the liability of multimodal carrier; therefore, the multimodal carrier was not liable for the theft of the goods by the sub-carrier"s driver during the international road leg from Paris to Dublin. The Court of Appeal rejected the argument and held that in accordance with the general conditions of contract, Air France had the option to carry goods by road. When Air France chose to carry goods by road, the transport by road from Paris to Dublin was governed by the CMR. In conclusion, the scope of art.1 of CMR, which reads "…[T]his Convention shall apply to every contract for the carriage of goods by road", was found broad enough to govern the case. Although this case does not involve an ocean carriage, it is highly significant in the field of multimodal transport. This case also has been highly criticized. The argument against was that a contract for the carriage of goods does not become a contract for the carriage of goods by road just because it allows for performance by road.[89] By contrast, a French court, a Belgium court, and the Danish Supreme Court have reached opposite results in cases whose facts were similar to facts in *Quantum Corp. Inc. v. Plane Trucking Ltd*. case.[90]

It is to be noted that none of the cases discussed so far addresses the issue of what the qualifications for a multimodal contract are. As mentioned above, there are two views in Europe on this subject. Decision of the Court of Appeal in *Quantum Corp. Inc. v. Plane Trucking Ltd*. reflects "plurality of contracts" view, i.e. liability of the contracting carrier for inland leg of transport is governed by CMR.[91] Thus, under the English law, extension of the maritime law to the inland leg would not be possible as inland leg of multimodal contract fall under the CMR Accordingly, the answer to the question of whether maritime to be extended to inland leg will be different in Europe.

C. Application of the Inland Transport Conventions to Multimodal Transports

1. Multimodal Transport under CMR

[84] Ulfbeck, p.73.
[85] Ulfbeck, p.48.
[86] Ulfbeck, p.73-74.
[87] Ulfbeck, p.70.
[88] [2002] 2 Lloyd"s Rep. 25.
[89] Ulfbeck, p.73, fn. 163,164 and cases cited there.
[90] *Id.*
[91] *Id.*

A reflection of contractual approach of CMR Art.1 is based on the contract which is explained in Art.1.1:

> *″This Convention shall apply to every contract for the carriage of goods by road in vehicles for reward, when place of taking over of the goods and the place designated for delivery, as specified in the contract, are situated in two different countries,…″*

Furthermore in Art. 2, CMR sets out its multimodal aspect by providing that[92]:

> ″1. *Where the vehicle containing the goods is carried over part of the journey by sea, rail, inland waterways or air, and, except where the provisions of article 14 are applicable, the goods are not unloaded from the vehicle, this Convention shall nevertheless apply to the whole of the carriage. Provided that to the extent it is proved that any loss, damage or delay in delivery of the goods which occurs during the carriage by the other means of transport was not caused by act or omission of the carrier by road, but by some event which could only occurred in the course of and by reason of the carriage by that other means of transport, the liability of the carrier by road shall be determined not by this convention but in the manner in which the liability of the carrier by the other means of transport would have been determined if a contract for the carriage the goods alone had been made by the sender with the carrier by the other means of transport in accordance with the conditions prescribed by law for the carriage of goods by that means of transport. If, however, there are no such prescribed conditions, the liability of the carrier by road shall be determined by this convention. …″*

According to this article, goods should not be unloaded from the road vehicle used on the previous stage when a new stage of the overall carriage started. In other words, the CMR applies when the entire vehicle loaded with goods or the goods and trailer are sent on by the other mode.[93] However, there are cases of transport where goods are loaded from both vehicle and trailer and put on a ship, regardless of contract governed by a separate contract or not. [94] The Court of Appeal in *Quantum Corp. Inc. v. Plane Trucking Ltd.* applied CMR by means of Art. 1 of CMR.[95] This is also the dominant approach employed by the Dutch courts.[96] By contrast, in Germany multimodal contracts do not enter the scope of the Art.1 of CMR; rather CMR applies to multimodal contracts by virtue of Art.2 or the National German Law, i.e. German Transport Law Reform Act sec.452.

2. Multimodal Transport under CIM/COTIF

Like the CMR Convention, CIM/COTIF 1999 has some multimodal aspects, According to Art.1:

> *″§1 These Uniform Rules shall apply to every* **contract of goods** *by rail for reward when the place of taking over the goods and the place designated for delivery are situated in two different Member States , irrespective of the place of business and the nationality of the parties to the contract of carriage. …*
>
> *§3 When international carrier being the subject of a single contract includes carriage by road or inland waterway in international traffic of a Member State as a supplement to transfrontier carriage by rail, these Uniform Rules shall apply.*
>
> *§4 When international carrier being the subject of a single contract of carriage includes carriage by sea or transfrontier carriage by inland waterway as a supplement to carriage by rail, these Uniform Rules shall apply if the carriage by sea or inland waterway is performed on services included in the list of services provided for in Article 24§ 1 of the Convention…*"

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[92] This provision was introduced at the request of the United Kingdom for multimodal through traffic, particularly for traffic accross the English Channel and the North Sea. Malcolm Clarke/ David Yates, *Contracts of Carriage by Land and Air*, 2004, p.5.
[93] Clarke/ Yates, p.5-6.
[94] Clarke/ Yates, p.5-6.
[95] Marien Hoeks, Multimodal Transport Law, 2010, p. 120 ff.
[96] Karijin Haak*, Carriage Preceding or Subsequent to Sea Carriage under The Rotterdam Rules*, paper presented at the Conference „The Rotterdam Rules Appraised" on September 24-25, 2009 at the Erasmus University, Rotterdam, the Netherlands, p. 9-10. There is one exception to this rule.

Again paragraph 1 reflects the European contractual approach. Furthermore, by this provision a feeder service to railway station falls under the scope of the CIM as long as the service does not cross the border. Otherwise, there would be conflict with the compulsory scope of CMR. Likewise, application of CIM is extended to services such as ferries run by railways.[97]

D. Network System in Europe

The multimodal transport within Europe has been based on network system or limited network system.[98] Network system is also embodied in German[99] and Dutch[100] national legislation on multimodal transport. On the other hand, the network liability system is preferred system in contracts.[101] Therefore, it is the contractual carrier who is the focus under the network system.[102] As a result, liability of contractual carrier‟s is variable as it is dependent upon at which stage the loss or damage to the goods occurs.[103]

As mentioned in this article, often existing unimodal transport conventions in Europe focus on the type of the contract rather than the transport activity itself.[104] Contracting carrier‟s liability is determined in accordance to the leg where the damage occurs. Moreover, under these transport conventions, the contracting carrier is subject to network system.[105]

The direct liability of subcontracting carrier is not regulated under these conventions; rather, it is regulated by national law, mostly in tort settings.

If the subcontracting carrier is sued directly by the shipper based upon tort, the subcontractor may benefit from maritime law according to Himalaya clause in the carriage contract between the shipper and contracting carrier. On the other hand, if the subcontracting carrier is sued by the contracting carrier in recourse action, mandatory rules of either CMR or CIM/COTIF will apply according to mode of the transportation.

Furthermore, because the direct liability of the subcontractor does not fall under network liability system, the concept of "hypothetical contract" is developed. In accordance with this concept, reference is to be made to the rules that would have governed the liability of the subcontracting carrier, if the shipper had directly contracted with the subcontractor.[106] It is said that in spite of its shortcomings, the network liability model

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[97] „§ 1 The maritime and inland waterway services referred to in Art. 1 of the CIV Uniform Rules and of the CIM Uniform Rules, on which carriage is performed in addition to carriage by rail subject to a single contract of carriage, shall be included in two lists :

a) the CIV list of maritime and inland waterway services,

b) the CIM list of maritime and inland waterway services…‟

For the list of the services see http://www.otif.org/en/publications/lists-of-lines-or-services-cim/cim-list-of-maritime-and-inland-waterway-services.html (visited August 3, 2010).

[98] Ulfbeck, p. 48.

[99] By the entry in force of the Transport Law Reform Act in 1998, transport law has undergone substantial changes. The new Act which is based on the 1956 Convention on the Contract for the International Carriage of Goods by Road (CMR), applies in a uniform manner to carriage of goods "over land, on inland waterways or by aircraft" with the exception of maritime transport. Furthermore, the Act also applies to multimodal transport of goods including a sea leg. Sec. 452 of the Act provides network system where damage is localized in general. See Sec. 452 ff. "Implementation of Multimodal Rules," Report prepared by UNCTAD Secretariat, *UNCTAD/SDTE/TLB/2*, 25 June 2001, p. 44 ff.

[100] Multimodal transport is governed by the Dutch Civil Code. Arts. 40-43 include core provisions on multimodal transport. The Civil Code in art. 41 adopts the network principle for localized damages. If the damage is non-localized, then the liability of the combined transport operator will be determined by the rules and regulations governing the mode of transport, which impose the highest level of liability on the operator in accordance with art.43 of the Civil Code. "Implementation of Multimodal Rules," Report prepared by UNCTAD Secretariat, p.51 ff.

[101] Such as ACL, NEDLLOYD, HAPAG LLOYD. Ulfbeck p.49 fn.45 referring Rolf Herber, The European Legal Experience with Multimodalism, 64 *Tul. L. Rev.* 611, 618.

[102] For instance Dutch Civil Code art. 42-43, German Transport Law Reform Act sec.452.

[103] Ulfbeck, p. 50.

[104] Ulfbeck p.48. CMR Art.1.1.; CIM/COTIF Art. 1 §3 and §4;

[105] Uflbeck p.48.

[106] This is the language used in art. 2.1; German Transport Law Reform Act sec.452.

achieves an important task under European Law.[107] It harmonizes the liabilities in the contract chain. Accordingly, even if the subcontractors‟ liability towards shipper is not regulated by the international conventions, the liability of the subcontracting carrier towards the contracting carrier is often regulated.

9. Multimodal Aspect of Rotterdam Rules

On 11 December 2008 the UN General Assembly adopted the „United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea‟, and authorized a signing ceremony for the Convention to be held in Rotterdam, recommending the new Convention to be known as the "Rotterdam Rules". The new Convention was signed by the 16 States on the September 23, 2009; and other 4 States later on, making totally 20 signatory States currently.[108]

The Rotterdam Rules extends and modernizes the existing international rules relating to the contract of maritime carriage of goods. The Rotterdam Rules aim to replace the Hague Rules, the Hague-Visby Rules and the Hamburg Rules; accordingly, it will achieve uniformity of law in the field of maritime carriage and provide for modern industry needs in terms of door-to-door carriage.

As mentioned above, there are two systems applicable to door-to-door transport: uniform system and network system. After long discussions, consensus was reached on the „limited network‟ system for the Rotterdam Rules. Like the existing European transport Conventions, the Rotterdam Rules takes the contractual approach by providing in art. 1(a) that contract of carriage *is "…a contract in which a carrier, against payment of freight, undertakes to carry goods from one place to another. The contract shall provide for carriage by sea and may provide for carriage by other modes of transport in addition to the sea carriage."*

This concept is known as "maritime plus" and requires, by art. 6, that both the whole carriage of goods as well as the sea carriage must be international. It is explained that the Rotterdam Rules have not been envisaged generally as a multimodal convention rather prepared with the intention to regulate contracts of carriage by sea in which carrier extends its services to other modes of transport.[109]
According to „limited network system‟ used in the Rotterdam Rules, special provisions apply to inland parts of the carriage that are different than those applicable to the maritime transport. The related provision is art. 26 titled, *„Carriage preceding and subsequent to sea carriage‟*, which provides that:
" When loss of or damage to goods, or an event or circumstance causing a delay in their delivery, occurs during the carrier‟s period of responsibility but solely before their loading onto the ship or solely after their discharge from the ship, the provisions of this Convention do not prevail over those provisions of another international instrument that, at the time of such loss, damage or event or circumstance causing delay:
(a) Pursuant to the provisions of such international instrument would have applied to all or any of the carrier‟s activities if the shipper had made a separate and direct contract with the carrier in respect of the particular stage of carriage where the loss of, or damage to goods, or an event or circumstance causing delay in their delivery occurred;
(b) Specifically provide for the carrier‟s liability, limitation of liability, or time for suit; and
(c) Cannot be departed from by contract either at all or to the detriment of the shipper under that instrument."

Although this provision seems to be complicated, it can be summarized as follows: (1) where there is a relevant inland transport convention, liability rules of that convention[110] applies under the „hypothetical

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[107] Ulfbeck, p.50.
[108] For updated statutus of the Convention see, „Status 2008 - United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea - the "Rotterdam Rules"‟
http://www.uncitral.org/uncitral/en/uncitral_texts/transport_goods/rotterdam_status.html (August 3,2010).
[109] Francesco Berlingieri, *Multimodal Aspect of The Rotterdam Rules*, paper presented at the Colloquium of the Rotterdam Rules 2009 held on September 21,2009, p.2
Papers- colloquim, http://www.rotterdamrules2009.com/cms/index.php?page=text-speakers-rotterdam-rules-2009 (visited August, 32010).
http://www.rotterdamrules2009.com/cms/uploads/Def.%20tekst%20F.%20Berlingieri%2013%20OKT29.pdf (August 3, 2010); Gertjan van der Ziel, Multimodal Aspect of the Rotterdam Rules, *Uni. L. Rev.* 981, p.982.
[110]e.g. CMR, CIM/COTIF, CMNI, or 1999 Montreal Convention.

contract of carriage" if loss or damage occurs in this leg of transport;[111] And (2) if the provisions of Rotterdam Rules conflict with the provisions of the other conventions -that may be applicable to the contract according to their own provisions- other conventions listed in Art. 82 of the Rotterdam Rules will be given priority. [112] As above mentioned both CMR and COTIF/CIM 1999 conventions contain provisions that have multimodal effects. Therefore, there will be probably many cases of –particularly- sea and road and/or rail transport combinations of transport, where there will be conflicts of said conventions.

10. Concluding Remarks

For any type of cargo claim, the objectives of the parties are in essence simple: the cargo-claimant has suffered the loss and he seeks to cover damages against the carrier; the carrier, except in the situation where he is liable without question, on the other hand, seeks to deny, exclude or limit liability for that loss. [113] However, the claim itself and its handling may present more complexities than the objective of a claim in a practical context. Cargo claim in a multimodal transport contract can be even more complex as it involves different stages and modes of transportation throughout the world. For a multimodal transport, it is common that a network system of liability is applied in practice. Things would become intricate if more than two domestic laws or international conventions apply to the different parts of a multimodal transportation. The parties to multimodal carriage contract normally use the choice of law provisions or Himalaya Clause to a multimodal transport contract, however, it has turned out that there has been low predictability and high litigation costs. [114]

As explored in the analysis in the paper, the levels of regulations for multimodal transport contract in each of China, the US and the EU countries share similarities; but differences also remain. Each has its own unique regulatory characteristics and principles. The Chinese Maritime Law is an example where the international conventions on the carriage of goods by sea do not apply. [115] As far as the multimodal transport contracts are concerned, despite the recognition of the Rotterdam Rules in various jurisdictions, it will probably fail to achieve the aim of uniformity as intended; particularly it is merely a "maritime-plus" convention. With the continuous development of container trade, there is an imperative need to have a multimodal convention which is broad enough in scope to govern the rights and liabilities of all parties involved in multimodal carriage, including inland carriers and their contractors. [116]

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[111] van der Ziel, p.983. For more information on the subject van der Ziel, 981 ff; Berlingieri, *Multimodal Aspect of The Rotterdam Rules,* p.3 ; Christopher Hancock, *Multimodal Transport and The New UN Convention on the Carriage of Goods*, 14 JIML 484,490 .; Krijin Haak, *Carriage Preceding or Subsequent to Sea Carriage under The Rotterdam Rules*, p.3, paper presented at the Conference „The Rotterdam Rules Appraised" on September 24-25, 2009 at the Erasmus University, Rotterdam, the Netherlands (Not published yet).

[112] See Erik Rosaeg, *Conflicts of Conventions in the Rotterdam Rules,* paper presented at the Conference „The Rotterdam Rules Appraised" on September 24-25, 2009 at the Erasmus University ; Rotterdam, the Netherlands (Not published yet). Art. 82 or the Rotterdam Rules reads that "Nothing in this Convention affects the application of any of the following international conventions in force at the time this Convention enters into force,including any future amendment to such conventions, that regulate the liability of the carrier for loss of or damage to the goods:
(*a*) Any convention governing the carriage of goods by air to the extent that such convention according to its provisions applies to any part of the contract of carriage;
(*b*) Any convention governing the carriage of goods by road to the extent that such convention according to its provisions applies to the carriage of goods that remain loaded on a road cargo vehicle carried on board a ship;
(*c*) Any convention governing the carriage of goods by rail to the extent that such convention according to its provisions applies to carriage of goods by sea as a supplement to the carriage by rail; or
(*d*) Any convention governing the carriage of goods by inland waterways to the extent that such convention according to its provisions applies to a carriage of goods without trans-shipment both by inland waterways and sea."

[113] Charles Debattista, "Cargo Claims and Bills of Lading," in *Southampton on Shipping Law*, chapter 3.

[114] Michael E. Crowley, "The limited scope of the cargo liability regime covering carriage of goods by sea: The multimodal problem," 79 *Tul. L. Rev.* 1461, p.1504.

[115] John Mo, p.130: "The Chinese Maritime Law (Code) is an example where the international conventions on the carriage of goods by sea do not apply."

[116] Michael E. Crowley, The limited scope of the cargo liability regime covering carriage of goods by sea: the multimodal problem, 79 *Tul. L. Rev*. 1461, p.1504.

Accounting Issues on Emissions Trading

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Abstract

The Kyoto Protocol aims to stabilize global emissions of carbon dioxide (CO2) by inventing a carbon trading system. With a price on air pollution, businesses can compare the costs of buying carbon allowance permits with the costs of purchasing low CO2 emission technologies. As trading items, carbon credits become the world's hottest, yet least understood commodities. The international carbon trading market was about US$100 million total value about 10 years ago. Now it is about US$18 billion. This paper will discuss the Kyoto Protocol and the related accounting issues relate to carbon trading.

Keywords: Kyoto Protocol, Emissions Trading Scheme (ETS), Estonia case, carbon financial statement accounting, IFRS, US GAAP.

1. Introduction

Ample scientific evidence[1] has created an "overwhelming consensus among leading climate scientists" that current global warming has been chiefly caused by the emission of CO2 and other greenhouse gasses (GHGs) produced by human activities.[2] Increases in CO2 emissions are a result of either nature (e.g. volcanic eruptions) or the actions of mankind (e.g. the burning of fossil fuels such as coal, oil and natural gas). In recent times the burning of fossil fuels like oil-in which CO2 has been stored for millions of years - has led to unprecedented levels of greenhouse gas emissions in the atmosphere. Scientists have predicted that the emission of GHGs will continue to cause further increases in world temperatures unless substantial steps are taken to reduce the root causes of global warming.

As a result of growing concern over global warming, the international community has begun to take increasingly authoritative steps to curb GHG emissions. The first major international treaty addressing global warming, the United Nations Framework Convention on Climate Change (UNFCCC), was agreed in 1992 to impose limits on greenhouse gas emissions.[3] EU member nations were obligated to comply with this treaty.[4] However, the UNFCCC itself was nonbinding and did not impose legal obligations on any nations.

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[1] There has been an increase of 0.76°C in average global temperature since 1850 and a near doubling in the rate of sea level rise from 1993-2003. Also, twelve of the warmest years ever recorded have occurred since 1995. Press Release, Eur. Comm'n, Climate Change and the EU's Response (Nov. 28, 2008), available at http://europa.eu/rapid/pressReleasesAction.do?

[2] Greenhouse gases refers to "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation." United Nations Framework Convention on Climate Change art. 1, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

[3] Id. art. 2.

[4] Id. art. 4.

The third session of the Conference to the UNFCCC took place in Kyoto, Japan in 1997, resulting in the Kyoto Protocol. The Kyoto commits developed countries to reduce their collective emissions of six greenhouse gases by at least 5% of 1990 levels by 2012. The UNFCCC adopted the Kyoto Protocol to correct for deficiencies in the previous treaty.[5] The purpose was to establish an association of member nations and bind them to make specific commitments to reduce emissions.[6] For example, by ratifying the Kyoto Protocol, all member nations of the European Union became obligated to reduce their GHG emissions.[7]

To meet their targets, member nations were permitted to take advantage of international emissions trading mechanism endorsed by the Kyoto Protocol.[8] The mechanism works in the following way: a member nation can emit more CO2 than its assigned amount (which, is defined as being 8% above its emissions in 1990) only if it can simultaneously sequester the equivalent amount in 'allowable' carbon sinks. The most common activity of allowable carbon sinks is reforestation. The reforestation will be measured by how many new trees planted after 1990, and pre-1990 trees still existing are not considered carbon credit purposes. The main response to removing CO2 from the atmosphere is to grow more forests.

Due to the possibility of trading, carbon credits become the world's hottest, yet least understood commodity. The carbon trading market internationally was about US$100 million total value about 10 years ago. Now it is about US$18 billion. Therefore, one of the fastest growing commodity markets in the world of any kind (Ratnatunga, 2008).

In the business level, business entities need to compare the costs of trading in carbon permits[9] and the cost in purchasing low CO2 emission technologies.

This paper first explains why the Kyoto Protocol makes the trading of carbon credits the world's hottest, yet least understood commodity. Then it predicts that the next round Kyoto Protocol will apply to CO2 emissions in shipping. Next, the paper discusses the Emissions Trading Scheme (ETS) on national level with the *Estonia* case. It follows by discussing the ETS in business level, with briefly evaluate the three ways of regulation means. Then the paper will look at Carbon Financial Statement Accounting, this section will investigate those issues such as whether emissions be seen as an asset and the three treatments thereof. The paper ends with the four US views on recording emissions rights in the financial statements. This paper concludes that market participants in the emissions trading remain confused about the appropriate accounting treatments under both the International Financial Reporting Standards ("IFRS") and generally US accepted accounting principles ("US GAAP").

2. Carbon Dioxide Emissions in Shipping

CO2 emissions from shipping are double those of aviation, which will have a serious impact on global warming (Vidal, 2007). For example, BP owns 50 tankers, and researchers at the Institute for Physics and Atmosphere in Wessling, Germany reveal that annual emissions from shipping range between 600 and 800m tonnes of CO2, or up to 5% of the global total. This is nearly double Britain's total emissions and more than all African countries combined.

Shipping is responsible for transporting 90% of world trade which has doubled in 25 years, and CO2 emissions in shipping have risen nearly as fast in the past 20. Dr Veronika Eyring, a researcher at the Institute of Physics and Atmosphere, calculates that the global fleet used 280m tonnes of fuel in 2001 and that could reach 400m tonnes by 2020. An IMO study of greenhouse gas emissions has estimated that emissions from the global fleet would increase dramatically in the next 20 years as globalisation leads to increased demand for

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[5] Kyoto Protocol to the United Nations Framework on Climate Change, Dec. 10, 1997, 37 I.L.M. 22 [hereinafter Kyoto Protocol].
[6] Id. art. 3.
[7] Council Directive 03/87, 2003 O.J. (L275) 32 (EC) [hereinafter Directive 03/87].
[8] Kyoto Protocol, art. 6.
[9] Carbon trading refers to the buying and selling of the right to emit CO2. The basic unit is one metric tonne of CO2 per year.

bigger, faster ships. Without action the IMO predicts that by 2020, emissions from ships would increase up to 72%.

Although CO_2 emissions from ships do not come under the current Kyoto agreement, greenhouse gas emissions from ships would be a likely target in the next commitment period of the Kyoto Protocol. For example, the Norwegian government opined that there are no technical obstacles to bringing international shipping under a post-Kyoto Protocol.[10] Therefore, it would be beneficial for shipping managers to get themselves familiar with the emissions trading scheme under the Kyoto Protocol.

3. Emissions Trading Scheme (ETS)

Some countries will be net-sequesters of CO_2 whilst other would be net-emitters, and a market will be developed for trading of CO_2 emissions where 'carbon credits' are sold by net-sequesters to net-emitters. Theoretically, if a country is incapable of meeting its target, it can buy credits (or permits) from countries that are under their targets. Non-compliance will invite a monetary penalty.

The most common type of emissions trading systems are known as „cap and trade" schemes. Under such a scheme, the government determines limits on greenhouse gas emissions (that is, the government sets a cap) and issues tradable emissions permits up to this limit. Each permit represents the right to emit a specified quantity of greenhouse gas. Businesses must hold enough permits to cover the greenhouse gas emissions they produce each year. Permits can be bought and sold, with the price determined by the supply of and demand for permits.

By placing a price on emissions, trading allows market forces to find least-cost ways of reducing emissions by providing incentives for firms to reduce emissions where this would be cheapest, while allowing continuation of emissions where they are most costly to reduce (DPMC 2007).

The Kyoto Protocol provides the mechanism of carbon trading known as International Emission Trading (IET). Countries with surplus credits can sell them to countries with reduction commitments in the international carbon credit market.[11]

In Europe, in order to help EU member nations meet their commitments under the Kyoto Protocol, the Commission issued Directive 2003/87/EC (Directive), launching the Greenhouse Gas Emissions Trading Scheme (EC 2007) as a "market-based solution to provide incentives for curbing [GHG] emissions."[12] The goal of this program was "to promote reductions of [GHG] emissions in a cost-effective and economically efficient manner."[13] The ETS established the largest carbon-trading system in the world, and under this program the EU's twenty-seven member nations were able to trade in carbon emissions by buying and selling allowances and credits.

4. Issues in Member State Level – National Allocation Plan (NAP)

Under the ETS, the Directive required that each member nation develops a National Allocation Plan (NAP).[14] The NAP has two components:

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[10] The Norwegian government made such opinion in the 2007 Oslo workshop co-organised by the Norwegian government and EEA. EEA stands for European Environment Agency, which is an agency of the European Union.
[11] Credits can be bought and sold in international carbon credits trading markets at the prevailing market price, such as the Chicago Climate Exchange and the European Climate Exchange (CCE 2010).
[12] Ved P. Nanda, Comment, The European Union's Multinational Carbon Trading Program, 85 Denv. U. L. Rev. 995, 995 (2008).
[13] Council Directive 03/87, 2003 O.J. (L275) 32 (EC) [hereinafter Directive 03/87].
Directive 03/87, art. 1.
[14] Directive 03/87, art. 9.

(1) The total quantity of CO2 emission allowances that a member nation intends to allocate, and
(2) A plan on how the member nation will distribute those allowances.[15]

Although member nations have the liberty to design their own NAP, the Commission must approve each NAP before it is implemented.[16] After reviewing a member nation's proposed NAP, the Commission may offer criticism and recommendations, and a member nation may not implement its NAP unless "proposed amendments are accepted by the Commission."[17]

Additionally, the Commission retains the right to conditionally approve a member nation's NAP, offering specific recommendations to be undertaken prior to implementation.[18]

Responding to these controls, several member nations initiated litigation. Overall only a few cases have been decided on the matter because of the immense backlog in the European Court system.

For example, the Republic of Estonia submitted its NAP for the period 2008 to 2012 to the Commission. After the Commission objected to several elements of Estonia's proposed NAP, Estonia subsequently submitted a new version of its NAP. The Commission issued its contested decision regarding Estonia's NAP because Estonia proposed to distribute too many emission allowances and to allocate allowances to certain industries beyond their expected needs.

Accordingly, the contested decision called for Estonia to reduce the quantity of emission allowances by 47.8%.[19] Moreover, the contested decision stated that if Estonia adopted several specific amendments (for instance, to reduce Estonia's total quantity of allowances by approximately 11.6 million tons of CO2) to its NAP, the Commission would withdraw its objections and permit Estonia to proceed with implementing its NAP.[20]

In response, Estonia petitioned the European Court to annul the contested decision by alleging that the Commission had exceeded its authority by imposing a cap on Estonia's emissions. The European Court held that the Commission exceeded the limits of its power by imposing a specific ceiling on the total quantity of allowances permitted under Estonia's NAP.[21]

In making its decision, the European Court considered the factors that Estonia, like many recently-joining member nations from Eastern Europe, are more reliant on fossil fuels to run their economies, and are relatively poor compared with their Western European counterparts. Such economic condition supported Estonia‟s argument that the Commission infringed their sovereign rights to manage their own economy in violation of the EC Treaty.[22]

In the short term, the Court's decision in *Estonia* may lead to an oversupply of emission allowances in the market, thus a depression in the market price. In the long term, the result of this decision may hamper the Commission‟s ability to reduce its GHGs emissions in accordance with its commitments under the Kyoto Protocol.

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[15] Id.; see Cinnamon Carlarne, Climate Change Policies an Ocean Apart: EU & US Climate Change Policies Compared, 14 Penn St. Envtl. L. Rev. 435, 464 (2006).
[16] Id.
[17] Id.
[18] Id.; see Press Release, European Union, Questions and Answers on Emissions Trading and National Allocation Plans for 2008 to 2012 (Nov. 29, 2006), available at http://ec.europa.eu/environment/climat/pdf/m06_452_en.pdf.
[19] Case T-263/07, *Estonia v. Comm'n* (Ct. First Instance, Sept. 23, 2009), http://curia.europa.eu/jcms/jcms/j_6.
[20] Id.
[21] Case T-263/07, *Estonia v. Comm'n*, 2009 ECJ EUR-Lex LEXIS 803.
[22] See, e.g., Case T-369/07, *Latvia v. Comm'n*, 2007 O.J. (C 269) 67.

5. Issues in Business Level

In order to meet the quota targets set by the Kyoto Protocol with regards to the amount of greenhouse gases countries can produce; countries in turn, set quotas on the emissions of business entities. There are three principle ways to set such regulations:

> *1. Taxation. The advantage of a straight tax on CO2 emissions is that it is immediately enforceable and transparent. The disadvantage is that some businesses may have the market ability to pass the tax to consumers, and not cut emissions (Ratnatunga, 2008).*
>
> *2. Carbon emission rationing system. This system allocates carbon credits or 'permits' to business entities for the emission of a certain quantity of greenhouse gases in a particular period. These permits may be given away free or sold at a predetermined price.*
>
> *3. Cap-and-trade scheme. Companies are told how much CO2 they can emit (the cap) for a period. If the companies produce less than the cap, they have surplus credits for sale. If they emit more than their cap, then they can buy credits from other businesses that come in under their cap (the trade).*

Theoretically, a carbon credit needs not have a monetary value, and it can be 'bartered' across nations. The problem is that different state authorities within a country may issue these carbon credits based on a monetary price. For Example, in Australia, the state authority Forests NSW issues carbon credits in New South Wales, such credits may not be fungible[23] with the credits being traded in Europe.

Janek Ratnatunga, Chair in Business Accounting at Monash University, opined that these 'carbon credits' are similar to 'taxi licenses' issued by a local authority that can be traded for money. However, even though the underlying basis of calculating a carbon credit is international, just like taxi licenses, the pricing of carbon credits varies from country to country and state to state (Ratnatunga, 2008).

In other words, significant arbitrage opportunities exist, and 'CO2 emitters' in high cost countries can buy credits from trading exchanges in low-cost countries.

In theory, businesses that are over their quotas could buy carbon credits for their excess emissions, while businesses that are below their quotas can sell their remaining credits. By allowing credits to be bought and sold, a business for which reducing its emissions would be expensive can pay another business to make the reduction for it. If all entities reach their quota, then the country itself can reach its Kyoto Protocol quota.

Carbon credits thus create a market for reducing greenhouse emissions by giving a monetary value to the cost of polluting the air. This means that carbon becomes a cost of business and is seen like other inputs such as raw materials.

High CO2 emitting entities, such as ocean carriers and manufacturing factories, will have an extra cost of running their businesses. On the other hand, the carbon trading will create new business opportunities for others, such as foresters and timber companies, who do not consider CO2 as a separate line of business.

If carbon emission trading becomes a widespread phenomenon, there will be significant changes in many business practices. In the country level, agricultural countries as trees may no longer be seen as hinder to farming. Planting trees for conservation purposes will provide more long-term benefit to the global carbon cycle than will plantings for commercial harvesting, such as trees for logging and pulping. But even trees for conservation purposes may be lost, for example, most of the stored CO2 in trees would return to the atmosphere in a forest fire. Furthermore, a new forest will realize its benefit until it reaches maturity, at which time new growth is compensated by death and decay.

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[23] Where one unit of commodity or currency may be substituted for the other with no loss of value.

6. Carbon Financial Statement Accounting

From the foregoing discussion, it can be seen that interesting Financial Accounting issues arise depending on if a credit is acquired:

1. free from government
2. in a government auction with a cost
3. in a free-market with cost

The issue is whether if the Kyoto requirements give rise to an asset or a liability. If the government rations CO2 emissions via a 'cap and trade' allowance scheme, then that allowance will have a monetary value. An accountant will have to determine the follow issues:

1. *Is the 'allowance' an asset?*
2. *What are the different treatments of carbon allowances?*
3. *What model shall it be used if the allocated allowances remain off-balance sheet?*
4. *What model shall it be used if the allocated allowances are recognized in the balance sheet?*
5. *Is offsetting of assets and liabilities be permitted?*

1. Is the 'allowance' an asset?

The GHG Protocol Corporate Accounting and Reporting Standard (World Business Council for Sustainable Development 2004), which aims to provide a step-by-step guide for companies to quantify and report their GHG emissions; however, the entire standard does not suggest any accounting treatment for carbon allowance. Carbon allowance can be treated as an intangible asset (*Ratnatunga, 2008*), and if it is treated as an intangible asset, then it would be reasonable to measure it at cost when the business acquired the carbon allowance through a third party transaction, since such a transaction will meet the reliability test.

2. What are the different treatments of carbon allowances?

The current thinking of the financial accounting profession gives three treatments of carbon allowance (*Ratnatunga, 2008*):

<u>*Treatment 1*</u>:
If the carbon allowances are allocated by governments for less than fair value, the accountant should debit intangible asset, and credit revenue). The carbon allowance is in the nature of government grant, and it shall be measured at cost when received from the government. The grant of allowances is recognized in income on a systematic basis over the compliance period.

<u>*Treatment 2*</u>:
If a trading scheme exists, the accountant should debit intangible asset, and credit equity reserves at fair value. The fair value will be the market value.

<u>*Treatment 3*</u>:
If the business wants to treat the carbon allowance as an obligation, then the account will treat it as a liability (debit: expense; credit: liability) at fair value; and the subsequent purchase in an open market 'carbon credits' equal to the shortfall (debit: liability; credit: cash) at market value.

3. What model shall it be used if the allocated allowances remain off-balance sheet?

A net model has been proposed if an entity keeps allocated allowances off-balance sheet, and the business only accounts for actual emissions by the amount of insufficient allowances through carbon credits purchase from the market, the accountant should debit expenses, and credit cash at market price.

4. What model shall it be used if the allocated allowances are recognized in the balance sheet?

An amortising model has been proposed if an entity recognizes allocated allowances as an asset (debit: asset, credit equity reserves) at cost price. Subsequently, the entity amortizes the allowances as it pollutes (debit expense, credit asset).

5. Is offsetting of assets and liabilities be permitted?

Most approaches treat carbon allowances (assets) independently to the obligations (liabilities), and accordingly, offsetting of the assets and liabilities is not likely to be permitted. Thus carbon allowances/liabilities could represent a significant figure and thus have an impact on the "bottom line" volatility of a company's reported financial statements (*Ratnatunga, 2008*).

7. United States

US did not rectify the Kyoto Protocol, but there are active markets provided for trading of emission rights in the US.

In 2003, the Emerging Issues Task Force (EITF) added in its agenda on providing a comprehensive accounting model for cap-and-trade emissions reduction program, which plan to address asset recognition, measurement and impairment, cost allocation, liability recognition, presentation (gross versus net), and disclosures.

On analyzing whether a cap-and-trade emissions reduction program be recognized an asset for emissions credits, the Task Force noted that most US companies had been accounting for emissions allowances similar to the requirements established in 1993 under the Federal Energy Regulatory Commission"s ("FERC") Uniform System of Accounts.

FERC requires emission allowances to be recorded on a historical cost basis (e.g., allocated allowances would be recorded at zero cost basis) as inventory with recognition of cost in earnings as pollution occurs based on a weighted-average cost.

If emissions rights were considered assets, the issue considered four views as to the nature of the asset, which would determine the appropriate accounting guidance.

> *View #1: Emissions rights are intangible assets as defined under Statement of Financial Accounting Standard ("SFAS") No. 142.[24] Reason: Since emissions rights lack physical substance, they cannot meet the definition of a financial asset under SFAS 140.[25]*
>
> *View #2: Emission rights are financial assets because the trading of emissions rights in the market provided evidence that they qualified as financial assets, and such emissions rights would be readily convertible to cash.*
>
> *View #3: Emissions rights are inventory, as they are part of the necessary costs to comply with environmental regulations.*
>
> *View #4: The asset nature of the emissions rights depend on the intended use by the entity. If the entity uses the emissions rights for operational purposes, then it should be recorded as intangible assets or inventories.. On the other hand, if the entity uses the emissions rights for trading purposes, then it should be recorded as financial assets.*

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[24] *SFAS 142 Goodwill and Other Intangible Assets.*
[25] *SFAS 140 Transfers and Servicing of Financial Assets and Extinguishments of Liabilities.*

Although the Task Force dropped the emission credit project from its agenda with no plans for further discussion in November 2003, the American Institute of Certified Public Accountants seems to fill the gap by issuing the Statement about attest engagements on greenhouse gas emissions Information two years later (AICPA, 2005). The statement provides AICPA‟s views on issues such as (a) reporting an assertion relates to GHG emissions inventory, and (b) recording the emission reduction with a registry.

8. Conclusion

Accounting for emissions trading remains a challenge, and market participants continue to wait for clear guidance from accounting standards setters. Formative efforts have been unsuccessful.

In an attempt to guide participants how to account for cap and trade emission trading schemes, the International Financial Reporting Interpretations Committee published the "*IFRIC 3: Emission Rights*". IFRIC 3 stated that allowances are intangible assets and should be measured at fair value when received from the government. The grant of allowances is recognized in income on a systematic basis over the compliance period.

Unfortunately, considerable pressure from both the business community and European politicians, led to the withdrawal of "*IFRIC 3: Emission Rights*" by the International Accounting Standards Board (IASB) within a year of its issuance.

In the US, the Emerging Issues Task Force ("EITF") also attempted to address the accounting issues relate to emissions trading, however, it was never finalized, and ultimately removed from the EITF‟s agenda.

As a consequence, many companies remain confused about the appropriate accounting treatments under both International Financial Reporting Standards ("IFRS") and generally accepted accounting principles in the United States ("US GAAP").

The consequence of more than one acceptable accounting treatment for emission rights is that: the effect on the different components of financial reports (i.e. balance sheet, profit or loss or cash flow statements) will be different depending on which treatment is adopted (Concessi, 2007). This could have significant implications on how a company manages its participation in the emissions trading scheme. The investors in the market may expect accounting results for emissions rights be comparable across the sector. However, in practice a company‟s choice of accounting policy may affect the entity‟s method in revaluing emission rights quite differently, particularly where it is not only an emitter but also a trader.

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Comparison of Two Outsourcing Structures under Push, Pull and Two-Wholesale-Price Contracts

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Abstract

In this paper, we study the performance of a multi-tier supply chain consisting of an original equipment manufacturer (OEM), a contract manufacturer (CM) and a supplier under push, pull and two-wholesale-price contracts. For each contract, two vertical outsourcing structures are considered: Control and delegation. We derive the equilibrium ordering quantities and capacities for all the combinations of the outsourcing structures and contracts.

Due to the space constraint, we only present our results on push and pull contracts here. Our analysis shows that under the push contract, the OEM prefers delegation to control if the wholesale price it pays to the CM under delegation is no more than the sum that it pays to the CM and the supplier under control. As to the pull contract, we find that the OEM is more likely to prefer delegation if the wholesale price under delegation is in a moderate range and the customer demand has low uncertainty. Lastly, we compare the performance of push and pull contracts under the two outsourcing structures. We show that pull contract is more likely to be preferred over push contract by the OEM if the prebook wholesale prices are high or at-once wholesale prices are in a moderate range.

Keywords: Pull, Push, Outsourcing, Control, Delegation

1. Introduction

Nowadays, there are unprecedented opportunities for original equipment manufacturers (OEMs) to outsource all of the assembling function to contract manufacturers (CMs). However, outsourcing activities enlarge the distance between the supply chain parties and lengthen the lead time. This gives rise to greater risk in production planning and capacity decisions for those CMs and suppliers, as such decisions need to be made well before demand is observed. It is therefore interesting to consider risk-sharing mechanisms among the supply chain parties such that the supply chain capacity can be increased. In particular, it is interesting to explore whether the OEM can be better off by bearing some inventory/capacity risks. The sharing of inventory/capacity risks can be affected by multiple factors, which, can be summarized into three questions: Who will order? When to order? And how much to order?

Who will order? Consider a serial three-tier supply chain consisting of an OEM, a CM and a supplier. Compared with the two-tier supply chain, this multi-tier supply chain provides one more layer of flexibility to the OEM by allowing the OEM not only deciding how to share the inventory/capacity with the upstream parties but also choosing the way how it outsources the manufacturing: the OEM can either outsource just the product manufacturing function to the CM and continue procuring the component from the supplier, or it can outsource both the product manufacturing and component procurement functions to the CM and let the CM handle the component procurement with the supplier. We call these two outsourcing structures *control* (C for the superscript) and *delegation* (D for the superscript), respectively, and they are depicted in Figure 1.

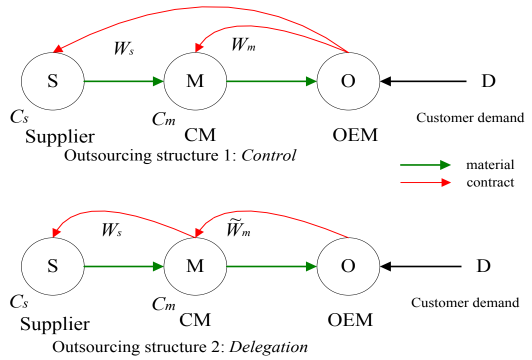

Figure 1: Control and Delegation

When to order? The sharing of inventory/capacity risks is also affected by the timing of orders. In practice, some OEMs ease the uncertainty of their CMs and suppliers by adopting *push* contract; that is, they place the order before the selling season and hence bear all the inventory risk. In contrast, there exists another *pull* contract, under which OEMs place the order in the selling season, and the CMs and the suppliers have to bear all the inventory risk.

How much to order? The inventory responsibility of the supply chain parties is also affected by the quantity of orders. Ordering too much or too little may both bring big cost for the OEM. Hence, the questions here we are interested in are the supply chain parties' *optimal* decisions on quantity:

- What are the OEM's optimal ordering quantities under the different combinations of the outsourcing structures and contracts?
- What are best responses for the CM and the supplier in capacity decision?

We consider four scenarios according to the combinations of two vertical outsourcing structures (control and delegation) and two contracts (push and pull). Under each scenario, we analyse the performance of three supply chain parties, the OEM, the CM and the supplier. To draw some managerial insights, we conduct two types of comparison among the results in different scenarios: For each contract, which outsourcing structure is more beneficial to the OEM and under which conditions? For each outsourcing structure, what is the best timing of ordering for the OEM and under which conditions? Section 2 reviews the related literature. Section 3 introduces the model and preliminaries. Sections 4 and 5 study performance of push and pull contracts, respectively. In each section, we consider the supply chain parties' quantity ordering and capacity building decisions under both control and delegation. Sections 6 compares the supply chain capacities and the OEM's profits under push and pull contracts. Section 7 summarizes and concludes the paper. All the proofs are omitted.

2. Literature Review

Our work is closely related to the literature on quantity commitment and advance purchase. Push, pull and advance-purchase contracts are first studied in Cachon (2004). Later Dong and Zhu (2007) consider a unified two-wholesale-price (TWP) contract. Both Cachon (2004) and Dong and Zhu (2007) consider a two-tier supply chain while we consider a three-tier supply chain. Besides these two work, Lariviere and Porteus (2001), Ferguson (2003), Ferguson et al. (2005), Ozer and Wei (2006), Netessine and Rudi (2006), Taylor (2006), Bernstein et al. (2006) and Chen (2007) are also related. See the reviews by Cachon (2003) and Lariviere (1998) for a more detailed discussion.

Our work is also closely related to the research on the decentralized capacity decisions in multiple-tier supply chains. Bernstein and DeCroix (2004) investigate a modular assembly system in which the final assembler oursources some of the assembly tasks to subassemblers, and the subassembler buys the components from suppliers. Bernstein et al. (2007) consider the equilibrium price and capacity decisions in an assembly system with multiple-type products and different types of suppliers.

The study on delegation and control is also related with our work. Mookherjee (2006) provides a comprehensive review. Kayis et al. (2009) consider delegation and control in a three-tier supply chain under the Newsvendor setting. They compare the optimal menu contract with the price-only contract and find that either delegation or control may be preferable, depending on the degree of manufacturer's prior information on the suppliers' costs. Guo et al. (2010) study the impact of information distortion induced by different outsourcing structures. They show that, with a long-term contract, delegation performs better than control even with information distortion. Chen et al. (2010) consider a situation in which a manufacturer either decides how to allocate its capacity among multiple retailers or delegates this decision to its distributor.

3. Model Setting and Preliminaries

We use subscript *o*, *m* and *s* to label the OEM, the CM and the supplier, respectively. Customer demand for the end product is random and denoted by a random variable X with a density function f and a cumulative distribution function (cdf) F. Define $\bar{F}(x)=1-F(x)$. Besides, we assume that the demand distribution has increasing generalized failure rate (IGFR) property, see Lariviere and Porteus (2001), Cachon (2004), Dong and Zhu (2007) and the reference therein for further information. The market price for the end product is exogenously given and denoted by p. And one unit of the end product the CM produces requires one unit of the supplier component. Assume the CM and the supplier incur a cost of c_m and c_s for building one unit of their capacities, respectively. The production costs of the OEM, the CM and the supplier are normalized to zero. We also assume that the related fixed costs are sunk. To guarantee a positive profit margin, $p>c_m+c_s$ is assumed. The demand distribution and capacity installing costs are all common knowledge (see Plarmbeck and Taylor (2007) and Nagarajan and Bassok (2008) for the discussion on this assumption).

Consider that a long lead-time is required for production and there exist two ordering opportunities, i.e. an early order before production and a late order just before or during the selling season. Denote the pre-selling period as period 1 and the selling season as period 2. Similar to Cachon (2004) and Dong and Zhu (2007), we assume the wholesale prices are set before orders and production take place. Then a downstream party can prebook in period 1, or it can place at-once orders in period 2. Specifically, for the control structure, we denote the wholesale price offered to player i in period t by w_{it}, $i=m,s$, $t=1,2$. For the delegation structure, we assume the wholesale price offered to the supplier by the CM is still w_{st}, $t=1,2$, the same as that offered by the OEM under control. However, the wholesale price offered to the CM by the OEM in this case needs to cover both the CM's manufacturing cost and its component procurement cost. We denote the wholesale price paid to the CM under delegation as $\tilde{w}_{mt}$, $t=1,2$ ($\tilde{w}_{mt} \geq c_m+w_{st}$, $t=1,2$). To avoid the trivial case, we focus on the wholesale price region $\{w_{m1}, w_{m2}, w_{s1}, w_{s2}\} \in [c_m, p] X [c_m, p] X [c_s, p] X [c_s, p]$. We also assume that $p-w_{mt}-w_{st}>0$ and $p-\tilde{w}_{mt}>0$, $t=1,2$.

Let $D(q)=E[min(X, q)]$ be the expected demand that can be satisfied by production quantity q. Then, given q_m and q_s, the customer demand that can be satisfied by the supply chain is $D(q_m \wedge q_s)$, where $a \wedge b= min(a, b)$. In the following sections, we are going to use superscript $j = C, D$ to represent the optimal solutions under control and delegation, respectively.

4. Push Contract

4.1. Push and Control

Under push and control, the game sequence is defined as follows:

- Given the unit wholesale prices w_{m1} and w_{s1} in period 1, the OEM announces its prebook quantity q to the CM and supplier. (It is never in the best interest of the OEM to prebook different quantities to the CM and supplier as the components are compliments.)

- The CM and supplier then install their capacities according to the OEM's prebook order.

In period 2, demand is realized and all revenues and costs are incurred. As a result, the profit functions of the three parties are, respectively:

$$\pi_o = pD(q)-(w_{m1}+w_{s1})q,\ \pi_m = (w_{m1}-c_m)q,\ \pi_s = (w_{s1}-c_s)q. \quad (1)$$

So the decision problem for the OEM is a newsvendor-type problem, and the optimal ordering decision of the OEM can be summarized below.

Proposition 1: *Under push and control, the OEM's optimal prebook* $q^C = \bar{F}^{-1}(\frac{w_{m1}+w_{s1}}{p})$.

Here, q^C is also the system capacity.

4.2. Push and Delegation

Under push and delegation, the game sequence is thus as follows:

- Given the unit wholesale price $\tilde{w}_{m1}$, the OEM announces its prebook quantity q to the CM. The CM then announces the OEM's prebook quantity q to the supplier. (It is never in the best interest of the CM to prebook a different quantity to the supplier because of complementarity between the CM and supplier's products.)
- The CM and supplier install their capacities according to their prebook order.

In period 2, demand is realized and all revenues and costs are incurred. Similarly, we can write the profit functions of the supply chain parties as

$$\pi_o = pD(q) - \tilde{w}_{m1} q,\ \pi_m = (\tilde{w}_{m1} - w_{s1} - c_m)q,\ \pi_s = (w_{s1}-c_s)q. \quad (2)$$

Again, the OEM's optimization problem is a newsvendor-type problem. Then we have the following proposition.

Proposition 2: *Under push and delegation, the OEM's optimal prebook* $q^D = \bar{F}^{-1}(\frac{\tilde{w}_{m1}}{p})$.

Note that q^D is also the system capacity.

4.3. Comparison of Control and Delegation under Push

Similar to Kayis et al. (2009), here we also focus on studying the preference of the OEM over control and delegation. Then we have

Proposition 3: *Under push contract , if* $\tilde{w}_{m1} \geq (w_{m1}+w_{s1})$*,* $q^D \geq q^C$ *and* $\pi_o^D \geq \pi_o^C$*; otherwise,* $q^D < q^C$ *and* $\pi_o^D < \pi_o^C$.

So if $\tilde{w}_{m1} \geq (w_{m1}+w_{s1})$, delegating the component procurement function to the CM is more beneficial to the OEM; otherwise, the OEM shall keep this function in-house. The reason is that $\tilde{w}_{m1} < (w_{m1}+w_{s1})$, on the one hand, implies that the OEM can obtain a lower unit wholesale price and achieve cost saving by delegating the procurement function to the CM, and on the other hand, also implies that the OEM is willing to bear more inventory risk since $q^D \geq q^C$. This joint cost saving and higher system capacity leads to a higher expected profit for the OEM under delegation than that under control.

5. Pull Contract

5.1. Pull and Control

Under pull and control, the game sequence is defined as follows:

- In period 1, given the unit wholesale prices w_{m2} and w_{s2} in period 2, the CM and supplier install their capacities q_m and q_s in anticipation of the OEM's at-once order. The CM and supplier then install their capacities according to the OEM's prebook order.
- In period 2, the market demand is observed. The OEM makes the at-once orders to the CM and the supplier to satisfy the observed demand.

We are going to solve this game by backward induction. First in period 2, the OEM makes the at-once order $x \wedge q_m \wedge q_s$, where x is the realized demand. Actually $x \wedge q_m \wedge q_s$ represents the effective demand that the whole supply chain can satisfy by using the available capacities of the CM and the supplier.

Next, in period 1, anticipating the OEM's at-once order, the CM and the supplier decide how much capacities to build up to maximize their respective expected profits:

$$\pi_m (q_m \mid q_s) = w_{m2}\, D(q_m \wedge q_s) - c_m\, q_m, \quad \pi_s (q_s \mid q_m) = w_{s2}\, D(q_m \wedge q_s) - c_s\, q_s. \tag{3}$$

Here, the capacity game between the CM and the supplier is a simultaneous one. We first derive the best response function of the CM given the supplier's capacity decision q_s. Since the CM and the supplier's products are complements, it is never optimal for the CM to install a capacity $q_m > q_s$. We can show that given the supplier's capacity q_s, the best response function of the CM is to install

$$q_m^*(q_s) = \min(K_m^C, q_s), \text{ where } K_m^C = \bar{F}^{-1}\left(\frac{c_m}{w_{m2}}\right) \tag{4}$$

and is the CM's optimal newsvendor capacity decision by assuming the supplier's capacity q_s is ample (much larger than q_m). It represents the maximum amount of the capacity that the CM has incentives to build up under control. Similarly, the best response function of the supplier is

$$q_s^*(q_m) = \min(K_s^C, q_m), \text{ where } K_s^C = \bar{F}^{-1}\left(\frac{c_s}{w_{s2}}\right) \tag{5}$$

and also represents the maximum amount of the capacity that the supplier has incentives to build up under control. Solving these two best response functions simultaneously yields the equilibrium capacities of the CM and the supplier under pull and control as $q_m^C = q_s^C = K_m^C \wedge K_s^C$ Consequently, the system capacity is also this value.

Proposition 4: *Under pull and control, the equilibrium capacities of the CM and the supplier are* $q_m^C = q_s^C = K_m^C \wedge K_s^C$.

5.2. Pull and Delegation

Under pull and delegation, the game sequence is defined as follows:

- In period 1, given the unit wholesale prices $\tilde{w}_{m2}$ and w_{s2} in period 2, the CM and the supplier install their capacities q_m and q_s in anticipation of the OEM's at-once order.

- In period 2, the market demand is observed. The OEM makes at-once order to the CM and then the CM makes at-once order to the supplier.

Similarly we solve this game backwards. Again the OEM and the CM make the at-once order $x \wedge q_m \wedge q_s$ in period 2. And in period 1, the CM and the supplier make their respective capacity decisions by maximizing their expected profit functions:

$$\pi_m (q_m \mid q_s) = (\tilde{w}_{m2} - w_{s2}) D(q_m \wedge q_s) - c_m q_m, \quad \pi_s (q_s \mid q_m) = w_{s2} D(q_m \wedge q_s) - c_s q_s. \tag{6}$$

Similar to K_m^C and K_s^C in section 5.1, define

$$K_m^D = \bar{F}^{-1}\left(\frac{c_m}{\tilde{w}_{m2} - w_{s2}}\right) \quad \text{and} \quad K_s^D = \bar{F}^{-1}\left(\frac{c_s}{w_{s2}}\right) \tag{7}$$

Then they are the optimal capacities the CM and the supplier are going to invest in under delegation assuming that the other party has ample capacity. It represents the maximum amount of the capacity that the CM or the supplier has incentives to build up under delegation. Naturally, we observe that the supplier's capacity building incentives remain the same under the two outsourcing structures as it receives the same wholesale price no matter whether paid by the OEM or the CM. Analogously, the equilibrium capacities of the CM and the supplier under pull and delegation and the corresponding system capacity are $q_m^D = q_s^D = K_m^D \wedge K_s^D$.

Proposition 5: *Under pull and delegation, the equilibrium capacities of the CM and the supplier are* $q_m^D = q_s^D = K_m^D \wedge K_s^D$.

5.3. Comparison of Control and Delegation under Pull

First we compare the supply chain system capacity under the two outsourcing structures and obtain the following corollary.

Corollary 1: *Under pull contract , if* $\tilde{w}_{m2} \le (w_{m2}+w_{s2})$, $K_m^D \le K_m^C$ *and* $(K_m^D \wedge K_s^D) \le (K_m^C \wedge K_s^C)$; *otherwise,* $K_m^D > K_m^C$ *and* $(K_m^D \wedge K_s^D) > (K_m^C \wedge K_s^C)$.

So compared with control structure, if the total unit wholesale price (covering both manufacturing and procurement cost) is lower under delegation structure, then the CM will build up less capacity and as a result, the supply chain capacity under delegation is also lower.

Next in order to compare the performance of the OEM under control and delegation, we define the relative gain of the OEM by switching from control to delegation as

$$\gamma = \frac{\pi_o^D - \pi_o^C}{\pi_o^C} = \frac{(p - \tilde{w}_{m2}) D(K_m^D \wedge K_s^D)}{(p - w_{m2} - w_{s2}) D(K_m^C \wedge K_s^C)} - 1 \tag{8}$$

Lemma 1: γ *is quasi-concave in* $\tilde{w}_{m2}$.

By the quasi-concavity of γ *function, it must crosses 0 at most twice. Note that when*

$\tilde{w}_{m2} = w_{m2} + w_{s2}$,

$\pi_o^D = \pi_o^C$. So γ crosses 0 at $\tilde{w}_{m2} = w_{m2} + w_{s2}$. Denote the other possible point that γ crosses 0 as $\underline{\tilde{w}_{m2}}$. Then we have the following proposition.

Proposition 6:

If $\tilde{w}_{m2} \in [\underline{\tilde{w}_{m2}} \wedge (w_{m2} + w_{s2}), \max(\underline{\tilde{w}_{m2}}, (w_{m2} + w_{s2}))]$, *then* $\gamma \geq 0$; *otherwise,* $\gamma < 0$.

Proposition 6 shows that compared with the total wholesale price the OEM pays under control, $w_{m2}+w_{s2}$, when the wholesale price paid to the CM under delegation is moderate, falling in a medium range, then delegation is more beneficial to the OEM, but if the wholesale price paid to the CM under delegation is either too high or too low, then control is more beneficial to the OEM. The possible driving force behind this is the tradeoff between the cost saving of the unit wholesale price and the potential loss of the high demand. Under delegation, when $\tilde{w}_{m2}$ is too high, then the OEM has a small profit margin and when the realized demand is small, it may hurt the OEM's profits. Similarly, when $\tilde{w}_{m2}$ is too low, the CM is not willing to build up a large capacity and as a result, the system capacity is small, and the OEM will lose the sales when the realized demand is high. That may explain why the OEM prefers control over delegation when $\tilde{w}_{m2}$ is either too high or too low.

Assume the customer demand follows truncated normal distribution with a mean μ and the standard deviation σ. Then the coefficient of variation CV is $CV = \frac{\sigma}{\mu}$. Let p=20, w_{m2}=4, w_{s2}=4, c_m=0.4 and c_s=0.8, by varying $\tilde{w}_{m2}$ and CV, we numerically examine how the customer demand and the wholesale price paid to the CM under delegation affect γ, a measurement of the OEM's preference over the two outsourcing structures under pull contract, see Figure 2. We observe from Figure 2 that delegation is more likely to be preferred by the OEM if the customer demand has small CV. That is, it is better for the OEM to control the procurement function instead of delegating to the CM when facing high demand uncertainty. Next, Figure 2 also confirms our Proposition 6 that delegation is preferred by the OEM when $\tilde{w}_{m2}$ is in a moderate range.

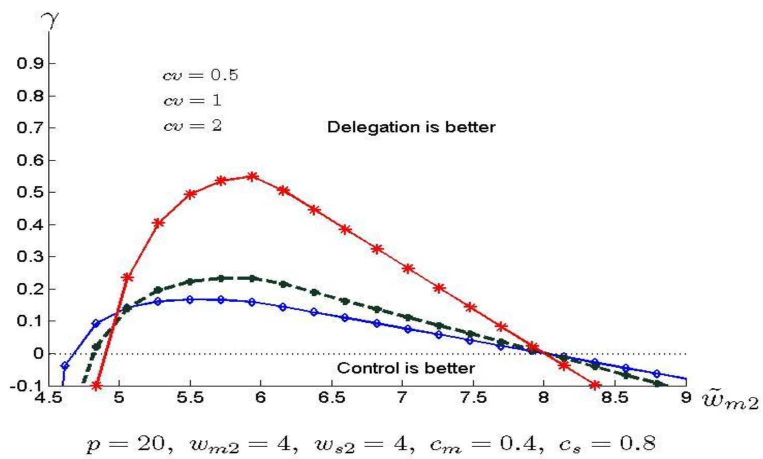

Figure 2: Impact of $\tilde{w}_{m2}$ and CV on γ

6. Comparison of Push and Pull Contracts

In this section, we compare the supply chain's performance across the three contracts.

Table 1: Supply Chain Capacity under Push and Pull Contracts

	Control	Delegation
Push Contract	$\bar{F}^{-1}(\frac{w_{m1}+w_{s1}}{p})$	$\bar{F}^{-1}(\frac{\tilde{w}_{m1}}{p})$
Pull Contract	$K_m^C \wedge K_s^C$	$K_m^D \wedge K_s^D$

First we list the supply chain capacity (the minimum of the capacities of the CM and the supplier) under the various combinations of push, pull contracts and two outsourcing structures in Table 1. As to the system capacities under pull and push contracts, we have the following corollary.

Corollary 2: $\bar{F}^{-1}(\frac{w_{m1}+w_{s1}}{p}) \geq K_m^C \wedge K_s^C$ *if* $\frac{w_{m1}+w_{s1}}{p} \leq \max(\frac{c_m}{w_{m2}}, \frac{c_s}{w_{s2}})$*; otherwise,* $\bar{F}^{-1}(\frac{w_{m1}+w_{s1}}{p}) < K_m^C \wedge K_s^C$*. Similarly,* $\bar{F}^{-1}(\frac{\tilde{w}_{m1}}{p}) \geq K_m^D \wedge K_s^D$ *if* $\frac{\tilde{w}_{m1}}{p} \leq \max(\frac{c_m}{(w_{m2}-w_{s2})}, \frac{c_s}{w_{s2}})$*; otherwise,* $\bar{F}^{-1}(\frac{\tilde{w}_{m1}}{p}) < K_m^D \wedge K_s^D$.

So for both outsourcing structures, whether the supply chain system capacity under push contract is higher or lower than that under pull contract depends solely on the relative magnitude of the market price, the wholesale prices in two periods and the capacity installation costs. It is independent of demand distribution.

Next we investigate the OEM's preference over the pull and push contracts under the two outsourcing structures by comparing the profits of the OEM.

Under control structure, we have

$$\pi_o^C(pull) = \pi_o^C(push) = (p - w_{m2} - w_{s2})D(K_m^C \wedge K_s^C) - [pD(q^C) - (w_{m1} + w_{s1})q^C] \quad (9)$$

Lemma 2: $\pi_o^C(pull) - \pi_o^C(push)$ *is quasi-concave in* w_{m2} *and* w_{s2}*, and increasing in* w_{m1} *and* w_{s1}*.*

Therefore, under control structure, if the at-once wholesale prices w_{m2} and w_{s2} are in a moderate range and/or the prebook wholesale prices w_{m1} and w_{s1} are high, then it is more likely that the OEM prefers pull contract over push contract. The reason is that the wholesale prices affect not only the OEM's profit margin and ordering decisions but also the CM and the supplier's capacity building incentives. Those decisions then jointly affect the supply chain capacity and thus the amount of demand that can be satisfied. If the wholesale prices in periods 1/2 are high, the OEM can only obtain small profit margin. Thus the OEM will not prebook much under push contract. And if the wholesale prices in period 2 are low, then the CM and the supplier have small profit margin and thus would not install much capacity in advance under pull contract. Therefore, under those cases, the system capacity will be low, and the OEM is unable to satisfy all the demands if the realized demand is high, which hurts the OEM's performance.

Similarly, under delegation structure, we have

Lemma 3: $\pi_o^D(pull) - \pi_o^D(push)$ *is quasi-concave in* $\tilde{w}_{m2}$*, and increasing in* $\tilde{w}_{m1}$.

So under delegation structure, the OEM will prefer pull contract over push contract if the at-once wholesale price $\tilde{w}_{m2}$ is in a moderate range and/or the prebook wholesale price $\tilde{w}_{m1}$ is high. And the reason behind is similar to that under Lemma 2.

7. Concluding Remarks

We considered the issue of inventory/capacity risk allocation in a multi-tier supply chain composed of an OEM, a CM and a supplier by allowing the OEM to choose between different outsourcing structures. As to the preference of the outsourcing structures, we showed that under push contract, the OEM prefers delegation to control as long as it can achieve a cost saving of the total procurement price advantage by delegating the component procurement function to the CM. For the pull contract, we showed that the OEM may prefer control over delegation when the wholesale price it pays to the CM under delegation is either too high or too low. Only when the wholesale price under delegation is in a moderate range and the demand for the final product is stable can delegation be more preferable. We also found that control is more beneficial to the OEM if the market has high uncertainty and the pull contract is adopted.

As to the preference over the contract, we showed that the OEM will prefer pull over push if the prebook wholesale prices are high or at-once wholesale prices are in a moderate range.

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ICT Implementation in Facilitating International Transport

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Abstract

Numbers of international carriers, denoted as mega-carriers, like to integrate the transport into a network to provide a total solution for international traders. They use information and communication technology (ICT) in managing intra-/inter- organisational business, forming Intranet and/or Extranet to provide a successful global logistics service. Many governments also develop their national plans to upgrade their management systems and to facilitate cargo processes in their countries. In this paper, results of a thorough case study on the use of ICT in international transport chain, including port industries and a set of semi-structured interviews with representatives from international carriers, shipping agents, freight forwarders, terminal operators and port operators in Taiwan are presented. The results examine the challenges to current system integration and support the fact that government and industries on the basis of public-private participation (PPP) should work together to create web-portals for shipping and port industries providing business to government (B2G), business to business (B2B), business to consumer (B2C) and government to consumer (G2C) services.

Keywords: ICT, Logistics, International Transport, E-Commerce, Public-Private participation

1. Introduction

The world has witnessed the growth of global economy, international trade, supply chain management and global logistics services in the past years. Sea transport is the most dominating mode in international trade. More than two-third of total international physical distribution in weight is moved by sea. Coping with the growing global logistics demands, numbers of international carriers evolved into global logistics service providers (GLSPs) to gain competitive advantages by building a global strategy based on: (1) the development of global logistics expertise and services; (2) the development of global network distribution, in which hub-and-spoke infrastructure plays a central role of interconnecting markets; and (3) the use of information and communication technology in order to interconnect all the firms within the net (Lemoine and Dagnæs, 2003).

How important is information and communication technology to a firm? Towill (1997) noted that a winner in today's highly competitive marketplace should have the ability to respond rapidly to the end consumer demand. To maximize competitive advantage all members within the supply chain need to seamlessly work together to serve end consumers. Mason-Jones and Towill (1999) describe that the use of advanced ICT can move the information decoupling point as far upstream as possible, help in making better planning decisions and give competitive advantage to companies. Indeed, computer, EDI and Internet technologies have been mostly used in intra-/inter-organisational business transactions in governments and business industries.

In this paper an attempt has been made to identify the implementation of ICT and its integration in international transport; especially, the use of management information system, value added network and Internet. More than that, the need of international and regional cooperation in ICT development for trade and transport will also be discussed. This paper will firstly introduce the methodology and review the development of ICT, then examine the use of ICT in international transport and analyse the results of the survey.

2. Methodology

The methodology used for this research includes literature review, case study, and semi-structured interview. Literature review also includes governmental reports, feasibility studies and ICT development plans which are an important resource for this research. Case studies of ICT implementation in international transport are conducted in Taiwan and the results of interviews on the use of ICT in international trade and transport industries are also included in the analysis. The companies and organisations selected for case studies and interviews of this research are the world's leading shipping companies and agents, port authorities, value-added networks, logistics companies and web portals as shown in Table 1. The selection of these companies and organisations are based on their roles in international transport. A semi-structured interview is conducted with senior managers who have been working in IT related departments of international transport industry.

Table 1: Companies/Organisations selected for Case Studies and Interviews

Shipping Co.	Port Authorities	VANs	Logistics Co.	Wet Portals
Yangming	Hong Kong	Trade-Van	Yes Logistics	INTTRA
Evergreen	Singapore	Tradegate	Round-the-World	GT Nexus
Maersk	Kaohsiung	TradeNet	Nice Shipping	CargoSmart
APL	Keelung	CNS/UK	APL Logistics	Nice Shipping
NYK	Felixstowe	MCP/Felixstowe	NYK Logistics	
		Portnet/PSA	Exel	

3. The Development of ICT and Business Networks

The ICT development can be separated into different stages. The use of mainframe and workstations was the initial stage of computers in use. The advent of personal computer and its operating systems widely increased the use of computers, and then, the advent of Internet technology had dramatic impacts on the use of computers in business management. Currently, the personal computer (PC) is available as both standard desktop models and net PCs (NC). With the increase in processing power and decrease in costs, more and more operating systems are set up in interconnecting computers and form a computer network. At present, personal computers or network computers can easily boot the organisational networks, query/update databases, browse the Internet, or compose documents.

In general, the information systems used for managing business can be characterised into three categories: intra-organisational management system, inter-organisational transaction system, and community network system. They even form Intranets (Intra-organisational systems) interconnecting the enterprise's departments, Extranets (Inter-organisational systems) linking their worldwide offices and agents, and VANs for specific trade community. An **Intranet** is a private network that is contained within an enterprise. It may consist of many interlinked local area networks and also use leased lines in the Wide Area Network. The main purpose of an Intranet is to share company information and computing resources among employees. An **Extranet** is also a private network that uses Internet technology and the public telecommunication system to securely share part of a business's information or operations with suppliers, vendors, partners, customers, or other businesses. An Extranet can be viewed as part of a company's Intranet that is extended to users outside the company. It is a computer network that allows controlled access from the outside for information sharing and e-commerce. Besides, Electronic Data Interchange (EDI) has been developed to facilitate the structured data through agreed messages and communication standards between the computer systems of trading partners. These EDI messages are prevailing in trade process, customs clearance, port entry, shipping, and air transport. The implementation of EDI normally is based on the use of Value-added Networks (VANs) to provide services among the same trade community.

EDI implementation is not just a technical issue in the industry as it could involve in changes in business practices and relationships. The use of EDI for a business has the following advantages: (1) some of the problems associated with traditional information flow could be eliminated; (2) the delay associated with making documents is eliminated; (3) since data is not repeatedly keyed, the chances of errors are reduced; (4) time required to re-enter data is saved; (5) as data is not re-entered at each step in the process, labour costs can be reduced; and (6) because time delays are reduced, there is more certainty in information flow (Bajaj and Nag, 2000).

The advent of Internet technology has made way of communicating between a company server and PC network inexpensive and easy. Other related technologies, such as worldwide web (WWW), file transfer protocols (FTPs), PC software standardisation and improved cabling, have assisted in facilitating the use of Internet in logistics (Stopford, 2002). It also drives the emergence of Electronic Commerce in business transaction. Electronic Commerce (EC) refers to the paperless exchange of business information using electronic data interchange, electronic mail, electronic bulletin boards, electronic funds transfer, and other network-based technologies. The use of Internet has made EC simple for Business to Business (B2B), Business to Consumer (B2C), and Business to Government (B2G) applications. Figure 1 presents the ICT development from personal computer (PC), management information system (MIS), value-added network (VANs) to Internet. The use of the Internet technology can make information integration higher and cost less.

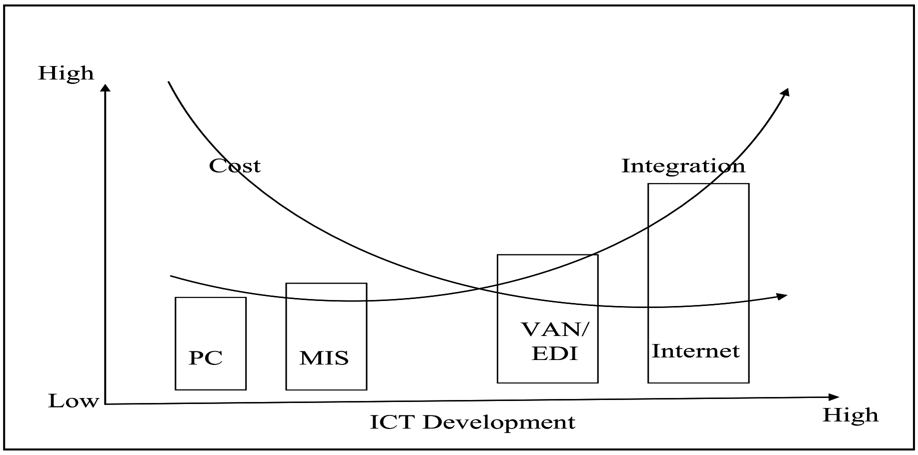

Figure 1: The Development of ICT Integration

In addition, transactions through different computers within different organisations need standards in data interchange and computer communication. Since the 1960s, different organisations in Europe and US have developed different messaging standards for inter-organisational communication of business transactions. In 1985, North American and European EDI interests began to discuss the possibilities of setting up a joint syntax for an international standard format to be used in international trade. In 1990, the organisation of Electronic Data Interchange for Administration, Commerce and Trade (EDIFACT) was established to promote EDI implementation in the industry. Coping with the advent of Internet, the EDIFACT was re-structured into CEFACT (Centre for Administration, Commerce and Trade) in 1996, responsible for trade facilitation and electronic business. A working group, joined by SMDG from Europe, TRADEGATE from Australia and other interests is dedicated to develop international transaction standards for shipping, port and aviation industries. Currently, CEFACT and other international organisations are jointly developing numbers of standards and infrastructure enabling authorised global use of electronic business information over Internet. Besides, the computer systems are a medium for transferring information and data. The medium should be trustworthy for the guaranteed and secure delivery of transactions. Many countries have National Information Infrastructure (NII) plans, responding to the Global Information Infrastructure (GII), which was initiated by the US government, to strengthen national backbones for telecommunication and bring the networking and applications thereby developed to the general public and specific purposes (Wang, 1999).

4. The Use of ICT in International Transport

International trade has significantly increased in the past years. The key forces driving the growth of international trade can be the growing global economy, the relaxation of trade barriers, and the development of logistics management (Tavasszy et al, 2003). It is observed that many companies expand their participation in foreign markets because of their own global strategy which can assist to achieve one or more of the following benefits: (1) cost reductions; (2) improved quality of products and programs; and (3) increased competitive leverage (Yip, 1989). International carriers have also adopted this global strategy in conducting international transport. In order to cope with the growing logistics demands of multinational enterprises, international carriers evolve to provide global logistics service. However, providing transport service to move cargo from exporting countries to importing countries encompasses many challenges. For examples, there are differences between the trading nations, such as transport and customs regulations, infrastructure, exchange rates, culture, and language. Therefore, global logistics service providers should have expertise in providing services to the global shippers. Especially, in the era of business outsourcing, global enterprises demand full logistics service rather than just physical transport. Their demands include the market coverage, the level and the flexibility of the service to meet the changing requirements. They also demand logistics service that can integrate with their supply chains. In this regard, international carriers have to expand their range of service provision through acquisition or partnership and some of them have evolved into "mega carrier", providing "one-stop shopping" of transport and logistics via the use of Internet and computer systems (Stone, 2001; Semeijn and Vellenga, 1995).

There are a number of reasons that international carriers like to embrace the information and communication technology to provide information visibility in their transport chain. **Firstly**, international carriers are scattering branches, offices, and agents in their geographically segmented routes. Transport communication was based on postal system, telephone, telegram and telex through public networks in the early days. The advent of computer and automatic telecom networks can help to managing their whole international transport chain, especially in the provision of efficient worldwide transport service. **Secondly**, the trade processes and cargo movement in the whole international transport chain is comprised of a great number of processes and documentation, such as cargo consolidation in the exporting countries, cargo handlings in ports and terminals, customs clearance and cargo distribution in the importing countries. The use of ICT in international transport can help the international carrier to managing its business easily and integrating all the participants of its international transport chain in one. **Thirdly**, the technological development of ICT has made the implementation of information and communication system easier and cheaper. Most companies can afford and would like to use these highly efficient and reliable computer systems. Currently, international carriers are using Internet and computer systems to controlling the movement of shipments, taking bookings, printing out bills of lading and invoices, and transmitting advice and information. They also have to make their information systems compatible to Customs' systems, helping the declaration of cargo to the customs ease and quick. Table 2 presents the EDI messages implemented by most container shipping companies. These standards messages are developed by EDIFACT or ANSI (American National Standards Institute). By the way, X12 is a standard for defining EDI transactions from the ANSI. In 1997, X12 merged with EDIFACT and the Accredited Standards Committee (ASC) X12 is responsible for developing, maintaining, and promoting the proper use of American national standards and UN/EDIFACT international standards for electronic data interchange (EDI).

Table 2: EDI Messages Implemented by Shipping Companies

Business process	EDIFACT	ANSI X12	Business process	EDIFACT	ANSI X12
Booking Request	IFMBF	300	Loading list/loading report	COLOIN COLORE	319
Booking confirmation	IFTMIN	301	Vessel loading/unloading	COARRI	322
Import release information	COREOR	301	Vessel schedule	IFTSAI	323
Booking cancellation		303	Stowage plan	BAPLIE	324

Shipping instruction	IFTMIN	304	Gate in gate out operations	CODECO	622
Bill of lading	IFTMCS	310	Hazardous Manifest	IFTDGN IFTIAG	
Arrival notice		312	Remittance advice	REMADV	820
Customs inbound manifest	CUSCAR		Acknowledgment		
			Application level	APERAK	824
			Translator level	CONTRL	997
Status information	IFTSTA	315			

Source: Authors, collected from Yangming line

A number of information systems have also been implemented in the ports. Normally, a port has its specific management system, called Port Management Information System (PMIS). The PMIS can help the port with a variety of functions, such as port user management, vessel management, berth planning, voyage management, cargo operations, resource management, and risk management. Many VAN systems in leading ports, for examples, FCPS in port of Felixstowe, INTIS in port of Rotterdam, SEAGHA in port of Antwerp, TRADENET and PORTNET in Singapore maritime, KL-NET and KT-NET in Korea maritime and TRADEGATE in Australia, can provide EDI services to the Customs for cargo transiting through the port, port service functions for ships and cargo handling in the port, and trading partner validation services among others. All of these VAN systems apply EDI standards (ANSI 12, UNEDIFACT/now CEFACT), have to be made compatible to local format and are modified for domestic implementation. However, an EDI/VAN system is different from port management information system, like CITOS System (Computer Integrated Terminal Operations System) and PORTNET in the Port of Singapore, CITOS System is an enterprise resource planning system, coordinating and integrating all aspects of port operations. PORTNET System is a nation-wide e-commerce system, linking the entire shipping community in Singapore. The PORTNET system enables customers to book berths, order marine services, transact bills and receive alerts and many other innovative services. The Port of Singapore also uses automated systems - Container Number Recognition System and Auto-Paging, to help container going through terminal gates, this paperless flow-done through efficient Gate system processes with only 25 seconds.

In addition to the information systems used by international carriers and seaport operators, governments of many countries have already developed the VAN/EDI systems for customs clearance and trade facilitation in the ports and their trade communities. Some VAN/EDI systems, for examples, TRADENET in Singapore and TRADEGATE in Australia, provide not only customs clearance services but also trade facilitation functions. In Asia, a Trade Facilitation Plan has been initiated by Asia-Pacific Economic Cooperation (APEC) since 1990s. It is intended to simplify and rationalise customs and administrative procedures that hinder, delay and increase cost of moving goods among APEC member economies. The actions and measures taken are in the areas of customs procedures, standards and conformation, business mobility and e-commerce.

5. Challenges to Current System Integration

5.1 Systems Used in International Transport

Conducting international transport from exporting countries to importing countries, like international trade, comprises a great many of processes and documentations. Figure 2 briefly presents the processes and participants of the international transport chain. It shows that at least five key participants, i.e. shippers/manufacturers, terminal/port operators, customs, international carriers and consignees/consumers are involving in international transport. Other participants, such as international traders, shipping agents, cargo forwarders, warehouse operators, inland transporters and banks, are also playing very important roles in the whole international transport chain.

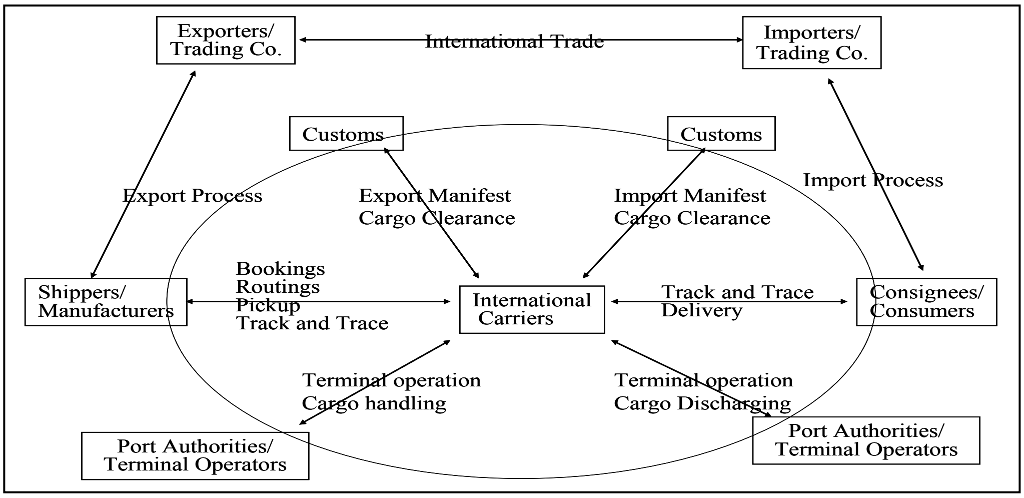

Figure 2: The Processes and Participants of the International Transport Chain

Therefore, the most relevant information systems used in conducting international transport are:

- Procurement System, an information system which handles the procurement of products or materials for the trading company or manufacturer.
- Warehouse Management System, an information system for managing the movement and storage of materials throughout the warehouse.
- Inventory Control System, an integrated package of software and hardware used in warehouse operations to monitor the quantity, location and status of inventory as well as the related shipping, receiving, picking and delivery processes.
- Banking System, a system which manages the transfer of money between banks, provide inter-bank information services and e-payment among enterprises.
- Customs Clearance System, an automotive information system which helps traders or customs agents submit clearance data to Customs for processing or release of goods through the country.
- Port Management Information System, a system or systems which deal with a number of port activities and resources, such as the movement of ships, containers and other cargo, the loading and unloading of ships and containers, customs activities, human resources, anchorages, channels, lighters, tugs, berths, warehouses, and money involved between the agents providing and using port facilities. Many separate computer management and information systems will be involved in port management. Integrated port management is concerned with integrating these separate systems.
- Terminal Operation System, a system which manages the planning, storage and movement of cargo or containers in the terminal.
- Shipping Management Information System, an information system or systems which shipping company uses for managing business of the ships and the transportation of goods.

Other web portals, such as INTTRA, GT Nexus, and CargoSmart, are active platforms providing shipping services for Small and Medium Enterprises (SMEs). These web portals are supported by the world's leading shipping companies. Through these portals, SMEs can easily arrange and track their cargo movement in the whole pipeline of the international transport chain.

5.2 Surveys Results

In order to understand the challenges to current information integration in shipping industries, a survey through semi-structured interviews was conducted with 15 senior managers who were working in IT departments of the international transport related companies and organisations. These 15 persons were selected from 15 different companies and organisations according to their positions and working experience. As Table 3 shows, these companies and organisations have already had information links to their business partners and the managers interviewed have been working in the area for more than 14 years.

Table 3: Background of Managers and Organisations Surveyed

Background	Carriers	Agent	Forwarders	Ports	IT Providers	Total
Companies Interviewed	7	3	2	2	1	15
Information links to Partners	7	3	2	2	1	15
Managers Interviewed	7	3	2	2	1	15
Average working experience/years	16.2	11.3	10.6	16.0	10.1	14.0

Three questions were used as basis for discussion in order to gain the opinions and suggestions from these senior managers; the questions are:

- The challenges to IT integration
- The use of e-services
- The ideas for Public-private participation in web portal for transport industry

Table 4 presents the summary of the results of interviews. It shows that four items which the managers frequently mentioned regarding challenges to information integration are: too many information systems, complications in processes, links to customs, and information and data sharing among different systems. The Table also shows that 13 out of 15 companies provide e-services to their customers, but 9 of 10 carriers and shipping agents mentioned that the use of e-service is still low. It also presents that 14 of them support the government on the base of public-private participation to establish a web portal. The main idea for the establishment of the government-supported web portal is that the portal could not only provide e-government services for shipping and port industries but also work as a platform with B2C, B2B and C2B functions for shipping and port industries.

Table 4: Results of Interview

Numbers of Interviews Questions	**Carriers (7)**	**Agent (3)**	**Forwarders (2)**	**Ports (2)**	**VAN/Customs (1)**	**Total (15)**
Challenges to IT integration						
Too many information	3	1	0	2	0	6
systems	3	1	1	1	1	7
Complications in processes	5	3	0	2	0	10
Links to Customs	3	0	0	1	1	5
Information and data						
sharing						
Provision of e-services	7	3	0	2	1	13
Use of e-services						
High (>65%)	0	0	0	2	1	3
Medium (35-65%)	1	0	0			1
Low (<35%)	6	3	0			9
Government supports Web						
portal	7	2	2	2	1	14
Agree	0	0	0	0	0	0
Disagree	0	1	0	0	0	1
No comment						

5.3 Discussions on Challenges to Information Integration

According to the responses from the interviews, there are four challenges to system integration in international transport communities. As many information systems are involving in international trade and transport, the **first** challenge to the current system integration is the varieties of information systems. Especially, in the era of seamless supply chain, multi-national enterprises need supply chain integration via seamless operations, customer focus via the matching of supply chain strategy and product type, and the effective management of multiple supply chains by a single organisation (Childerhouse, 2002). Information integration among different participants becomes a challenge to forming a seamless supply chain.

Reviewing the processes and documents of international transport, the whole transport chain comprise of five key areas/participants; namely, shipping ordering of exporters, terminal operations of seaports, customs clearance of Customs, cargo movement of international carriers, and cargo distribution of importers The **second** challenge to information integration is that these systems are different and proprietary. Information sharing and data exchange among two different systems becomes a big task for system engineers. Even though some VAN/EDI systems are there for the community, they are also unique and dedicated to specific purposes. System integration is still a problem at the moment.

It is believed that customs clearance is the most time-consuming procedure in international transport chain. This process could take several days to a month. Most countries solve this problem by simplifying or rationalising customs and administrative procedures from the use of information system for Customs. Some countries even adopt free port policy to eliminate this customs barrier to trade. Therefore, the **third** challenge to information integration is the use of ICT for customs and administrative procedures in the government. Indeed, a number of customs clearance systems or VAN systems in the world are installed very successfully.

The **last** but not the least challenge to information integration is the information sharing with large numbers of small shippers. For a container transport, what the international carriers not only do business with big shippers but also with small shippers in this competitive era. In order to do business with small shippers, many international carriers have established logistics departments or companies. Their information solutions can provide these small shippers with the functions of shipping and logistics management for their materials and products.

6. Conclusions

The changing environment in global trade implies competition, advanced technologies and efficient management of supply chains. To accommodate this change it is imperative that new trade processes and the applications of ICT in the industry must be developed fully and major process re-designs and extended collaborative efforts are put in. Especially, right now, high-speed transmission solutions with the mobile/wireless telecommunications are being used more commonly and advanced applications are available. Computer and information technologies are advancing and are innovative. One of the most important factors for providing efficient and effective international transport in global trade is the integration of ICT application systems both for the industry and for its communities.

Transport plays an important role in the international trade and global logistics chain. At present, many international carriers are endeavouring to provide global logistics services. They try to integrate the transport into a kind of a system to provide a total solution for international traders that could be major exporters/importers or small shippers/consignees. This research concludes that different types of management information systems, VANs and other IT systems are being used in international transport and this causes problems in integration of transport within supply chains. This research has also identified some of the challenges being faced for information integration and the use of e-service within international transport communities. Thus, the research recommends the establishment of a web-portal on the basis of public-private participation to facilitate the government and industries for conducting information integration in port and shipping industries and providing B2G, B2B, B2C and G2C services.

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Abbreviations

ANSI, American National Standards Institute
APEC, Asia-Pacific Economic Cooperation
ASC, Accredited Standards Committee
CEFACT, Centre for Administration, Commerce and Trade
EDI, Electronic Data Interchange
EDIFACT, Electronic Data Interchange for Administration, Commerce and Trade
FTP, File Transfer Protocol,
GII, Global Information Infrastructure
GLSP, Global Logistics Service Provider
ICT, Information and Communication Technology
NII, National Information Infrastructure
PMIS, Port Management Information System
PPP, Public-Private Participation
SMDG, User Group for Shipping Lines and Container Terminals
SME, Small and Medium Enterprise
VAN, Value-added Network

Succeed in Wine Storage Management Systems Certification Scheme

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Recent years, Hong Kong has been the world's second largest wine auction centre after New York and the global first Wine Storage Management System Certification Scheme (WSMS) is developed to support local wine logistics. So, whether to succeed in wine logistics or not depends greatly on how the firms meet the requirements and specifications of WSMS. The paper aims to resolve this and plan to develop a type of software system "WSMS-A" for the comprehensive indication and guidance of wine storage management performance in order that the logistics companies are able to meet WSMS in a technically and economically feasible way. The WSMS-A well incorporates the programming paradigm, design engineering method and OBM concept. Through the examination, it resolves the problem on high costs of separate operations regarding specifications on an integrated graphical user interface (GUI) efficiently and effectively and it holds the benefits including: uniqueness, low cost, high value-added, compatibility to existing central computer, etc.

Keywords: Wine Storage Management Systems Certification Scheme (WSMS), the Code of Practices, Graphical User Interface (GUI)

1. Introduction

Hong Kong government has abolished the import duty on wine in order to promote local wine industry development in 2008. What would we expect? Yes, Hong Kong has developed into a regional wine centre in trade, warehousing, auction, etc. In accordance with government statistics, the value of wine imports exceeded HK$ 4 billion in 2009, up 41% compared to 2008; wine transited overseas accounted for a total of HK$ 760 million, up 10% year-on-year. To support Hong Kong in growing into a wine centre regionally and globally, certain wine standardization, especially in the wine storage, is urgently required in the industry. Under this circumstance Hong Kong Quality Assurance Agency (HKQAA) developed the Wine Storage Management Certification Scheme (WSMS) based on ISO 9001 requirements that overcame shortcomings of previous standards and was operated by local logistics companies. The interesting question is how the local firms are able to meet the WSMS requirements in a quicker and more economical manner.

The paper aims to develop a type of software system "WSMS-A" for the comprehensive indication and guidance of wine storage management performance in order that the logistics companies are able to meet the Wine Storage Management Scheme (WSMS) in such a technically and economically feasible way. Earlier we did the market survey and found that rare resolution package concerning WSMS, or to say, an integrated graphical user interface (GUI) that include the whole relevant specifications (temperature, humidity, lights, vibrations, etc) available for purposes of indication and guidance was found. The word "the whole" is emphasized due to the accumulated costs of investigating, recording, managing respective specification are high. In this manner, we plan to design, implement and adjust the software system that well incorporates the programming paradigm, design engineering methodology and OBM concept and holds the benefits including: uniqueness of the software, low cost and high value-added, market demand, compatibility, etc. for the logistics companies and the WSMS.

2. Product Development Of The WSMA-A

2.1 Hong Kong Ranking the World's No.2 Wine Auction Centre

In accordance with well-known websites, Hong Kong has overtaken London as the world's second largest wine auction centre after New York nowadays. Before 2005, Hong Kong is a transition market and a springboard between mainland, Taiwan and international wine traders. After 2005, the advantages of intermediary trade in Hong Kong gradually disappeared. So the Hong Kong government expected to strengthened local wine industry by establishing a branch of London International Vintners Exchange (Liv-ex) by employing the wine tax-free policy from February, 2008, since when the wine industry in Hong Kong is developing rapidly, especially in three main fields-trading, storage and auction. Regarding government statistics, the value of wine imports exceeded HK$ 4 billion in 2009, up 41% compared to 2008; wine transited overseas accounted for a total of HK$ 760 million, up 10% year-on-year.

In near future, Hong Kong is expected to become a good landing point of entering the mainland China's wine market. In accordance with the Decanter, mainland's current annual wine consumption was about 2 million boxes, and expected to grow by 60% in sales by 2013 and nearly 50 million by 2017 and in February 2010, the "Cooperation Arrangement on Customs Facilitation Measures for Wine Entering the Mainland through Hong Kong" was signed to expedite customs clearance of wine imported into the mainland through Hong Kong. We can foresee that Hong Kong will continue to stabilize the regional wine centre in Asia and the globe, relying on the excellent geography, convenient transportation, wine knowledge, the wine tax-free policy and the related industries, such as wine cellar, the wine agency, the hotel industry, logistics, finance, tourism, etc will be benefited. [1] [2] [3] [4] [5]

2.2 Global 1st Wine Storage Standardization

Drinking wine has formed a popular lifestyle in Asia and Hong Kong has become the one of international wine centres with the benefits of the wine tax-free policy. However, local wine traders, agents, warehouses distributors, even multi-national logistics companies are constantly challenged with the intention for the wine storage standardisation. So Hong Kong Quality Assurance Agent (HKQAA) surveyed, designed and developed the Wine Storage Management Systems Certification Scheme (WSMS) that fits Hong Kong wine situations and is currently operated in local logistics companies. Previously, traditional or internal inherited practices and even the state-of-art practices (i.e. ISO 9001) were adopted while some shortcomings were found continuously due to intelligence limit, experience limit, scope management, etc and the WSMS is a program based on ISO 9001 that assists the companies to standardize the wine storage procedures and is applicable to all wine storage facilities. The WSMS contains requirements, such as policy, performance measure indicators, wine storage management plan, implementation, monitoring and measurement, etc and 9 core controls in the Code of Practices, such as temperature, humidity, lights, vibrations, maintenance, security, inventory management, hygiene, insurance, etc. [6]

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[1] Teresa Hung. (2010), Hong Kong's Wine Auction Market after New York. *Website of HKTDC*, 2010-5-20, (In Chinese).

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[6] Hong Kong Quality Assurance Agency. (2010), Wine Storage Management Systems Certification Scheme. *Hong Kong Quality Assurance Agency Manuals,* 2010.

2.3 The Necessity of the WSMS-A

The real question is how local logistics are able to meet the standardisation of wine storage, or to be exact, the WSMS in a quick, more efficient and economical manner. Current fact is that each specification is met based on the separate work. For instance, temperature data is acquired from the temperature sensors through manual work or central computer system for further operations while other relevant work humidity, maintenance, security, etc are done separately; And some work (e.g. temperature) is easily to quantify while other work (e.g. investment management) is suitable to qualify; And some work should be put into the specifications part for discussion and vice versa…It is a kind of system engineering, involving materials, time, cost, human resources and so on many factors. It is apparent that separate operations of each specification are comparably high and rare resolution package concerning WSMS is found nowadays. In this manner, we plan to design and develop correspondingly an integrated graphical user interface (GUI) that include the whole relevant specifications (temperature, humidity, lights, vibrations, etc) available for purposes of indication and guidance. The word "the whole" is emphasized due to a feasible and economic integrated resolution is rarely seen in the market. The software system "WSMS-A" is for the comprehensive indication and guidance of wine storage management performance in order that the logistics companies are able to meet the Wine Storage Management Scheme (WSMS) in a quicker and more economical way and it incorporates the programming paradigm, design engineering methodology and OBM concept.

3. The Software System-WSMS-A

3.1 The Mechanism of WSMS-A

As spoken, the software system "WSMS-A" is designed, implemented and adjusted for the comprehensive indication and guidance of wine storage management performance in order that the logistics companies are able to meet the Wine Storage Management Scheme (WSMS) in a quicker and more economical way. The WSMS-A well incorporates the programming paradigm, design engineering methodology and OBM concepts.

The WSMS-A is based on the following fundamental requirements of WSMS, including:

- Policy
- Performance Measurement Indicators
- Wine Storage Management Plan
- Implementation of Wine Storage Management Plan
- Monitoring and Measurement
- Incident Handling
- Management Review and Improvement Action

The WSMS 9 nine controls in the Code of Practices which organizations shall fulfil in order to be successfully certified. The core controls are: temperature, humidity, lights, vibrations, maintenance, security, inventory management, hygiene and insurance. The specification requirements are summarized in Tab. 1 and considered in the mechanism of WSMS-A operations which are introduced in the next paragraph. [7]

[7] Hong Kong Quality Assurance Agency. (2010), Wine Storage Management Systems Certification Scheme. *Hong Kong Quality Assurance Agency Manuals,* 2010.

Table. 1 Specification requirements of WSMS

Specifications:

	Fine Wine	Commercial Wine
Min. storage temperature	11°C	-
Max. storage temperature	17°C	22°C
Max. daily fluctuation range	3°C	5°C
Max. annual fluctuation range	5°C	10°C
Humidity as a running average	55% - 80%	>50 %
Storage areas shall be isolated from external lights	Yes	Yes
Low UV lights (i.e. LED lights) shall be used to replace regular fluorescent lights	Yes	No
Storage areas shall not subject to continuous vibrations	Yes	Yes
Suspension systems underneath cellar floorings shall be installed if continuous vibrations occur	Yes	Yes
Regular maintenance shall be carried out on all requirements (refrigerators, humidifiers, etc)	Yes	Yes
Calibration of conditional controllers and sensors shall be carried out	Once/year	Once/3 years
Accuracy of temperature sensors Accuracy of humidity sensors	±0.5°C ±5%	±1°C ±5%
Insurance coverage shall satisfy with contractual agreements with clients	Yes	Yes

Source: Hong Kong Quality Assurance Agency (2010)

We now explain the operational mechanism of the WSMS-A. The corresponding logic diagram is shown as in Fig 1. Generally, we plan to provide the unprecedented "one key to see the whole" way in a straightforward graphical user interface (GUI) that displays the status of whole wine storage, such as temperature, humidity, lights, vibrations, maintenance, insurance, etc. In particular, among the indicators, the temperature indicators acquire the data from temperature sensors (contact sensors or non-contact sensors, which have been spread over the entire warehouse) manually or automatically and display the results on the screen. The manual acquisition requires some staffs to read the figures from the sensors, while in the automatic acquisition mode, data acquired from sensor will be directly transmitted to a central computer for further processing and displaying. The selection of manual or automatic operations is on the company basis. The humidity indicators work in a similar way as temperature indicators.

After acquisition, data obtained from sensors to indicators, including lights, vibrations, maintenance and insurance, will be transmitted to staff in charge who will determine the quality of the data. In case of any violation of the requirement or any incidence, further action will be performed. On the other hand, the indicators of security, inventory management and hygiene may be difficult to quantify or be given a range, so the subjective adjustment by indicating "Yes" or "No" is more appropriate to verify the data. Furthermore, we not only provide a real-time view of the wine storage status, but also monitor and control them on a daily, weekly, monthly and annually basis, so that a full picture of stochastic processes will be available to the logistics companies. In this manner, quicker and economically can logistics companies administrate the wine storage and can the concerning external examiners, such as HKQAA, better control of the quality of local wine storage industry.

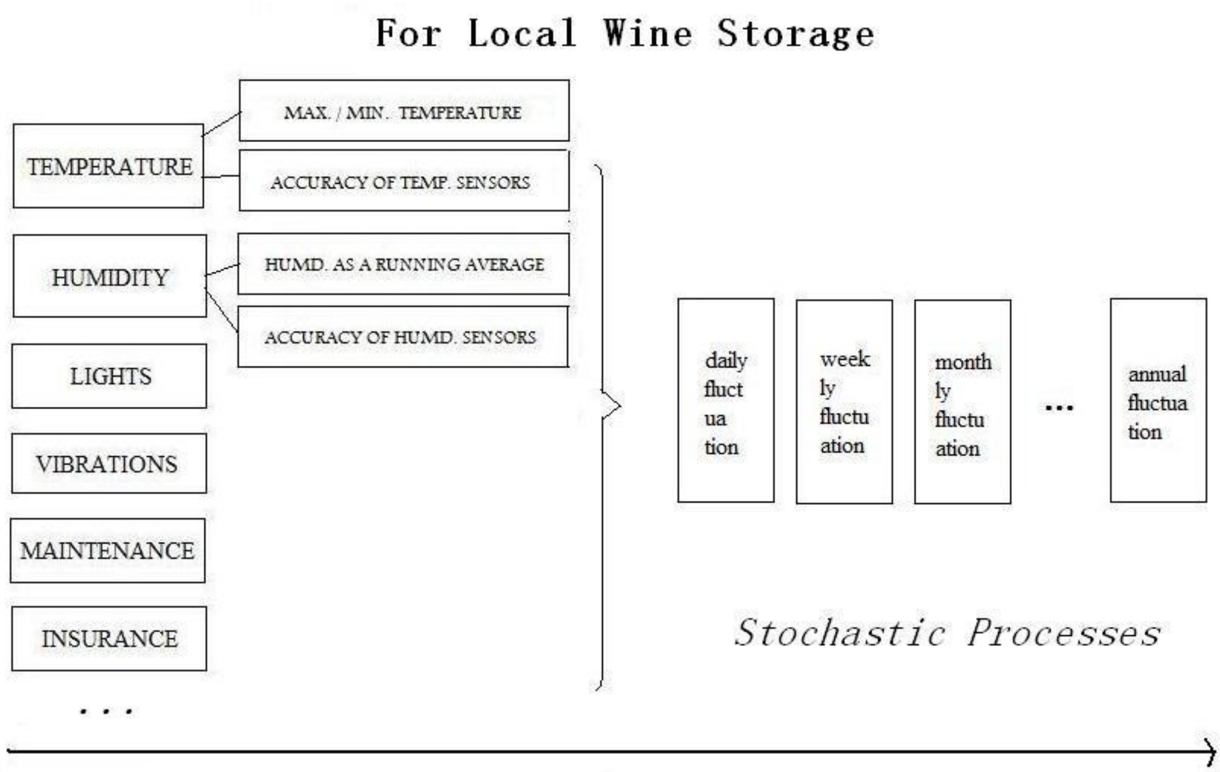

Figure 1. Logic diagram of WSMS-A

3.2 The Feasibility of WSMS-A

We analyze the feasibility of the "WSMS-A" by three different dimensions as follows.

First, the functionality of the WSMS-A is divided into two parts: indication and guidance. The indication part is well explained in the previous operational mechanism part; the guidance part is planned to give corresponding suggestions in accordance with expert panel and inputs of accumulated experience. We plan to implement an expert system in order to take use of current best practice.

Second, the contribution of the WSMS-A is four-fold: 1) provide an unprecedented comprehensiveness of indicators, including temperature, humidity, lights, vibrations, maintenance, insurance, etc that are WSMS standards in a "one key to see the whole" way; 2) lead to high value-added with low cost and short lead time; 3) link to existing database (e.g. the WMS), including the access to data and compatibility; 4) satisfy the prompt demands of local logistics companies to fulfil WSMS requirements and the trend of robust development of the wine industry.

Third, the software technology needed for WSMS-A is mature and has already been applied to similar products (e.g. medical performance monitor). Hence, the cost of the original WSMS-A should be within HKD 10,000 and the implementation will take about several months.

4. Summary

Hong Kong has become a wine centre in Asia, even in the world, since the Hong Kong Government abolished the import duty on wine in 2008, and certain standardisation to support local wine storage management-Warehouse Storage Management Systems Certification Scheme (WSMS) is developed.

So, whether to succeed in wine logistics or not depends on how the logistics companies meet the requirements and specifications of WSMS and how efficient corresponding operations are. The most concern of this paper is resolve this issue and develop a type of software system "WSMS-A" for the comprehensive indication and guidance of wine storage management performance in order that the logistics companies are able to meet

WSMS in such a technically and economically feasible way. The WSMS-A well incorporates the programming paradigm, design engineering methodology and OBM concept. After the examination, the WSMS-A resolved the problem-high cost of separate operations regarding specifications on an integrated graphical user interface (GUI) as proposed, it holds the benefits including: uniqueness of the software, low cost and high value-added, compatibility to existing central computer system, etc. and its feasibility is high for the logistics companies and the local wine industry.

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The Effects of Cost Change on Alliance Services for a Container Carrier

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Abstract

This paper addresses the effects of cost change for a container carrier and formulates cost models for self-operation services and alliance services. Shipping costs are made up of voyage fixed costs and freight variable costs. Fixed costs include port charge, bunker costs, containership costs and administration fee. Freight variable costs include handling costs, container costs, inland drayage, transshipment costs, commission of shipping agency and others. For alliance services, only fixed costs are influenced. In the pattern of fleeting sharing, fixed costs and capacity are shared by respective ratio of contributed containerships. In the pattern of slot exchange, the fixed cost in original service route should estimate and transfer to other alliance services. The results could provide container carriers to estimate price of slot charter, slot purchase and slot exchange for negotiation with partners. Otherwise, bunker prices have raised considerable and overcapacity drives down containership charter hire. This paper also simulates the impact of bunker cost and containership charter hires changes on costs. To demonstrate the application and the results, this study uses a typical container carrier operating the liner services in intra-Asia as an example.

Keywords: Cost Function, Alliance Service, Container Carrier

1. Introduction

In the last few decades, ever expanding global economy leads to rapid growth of container shipping. Container vessel carrying capacity and world container traffic both have maintainer two digits annual growth rates (Dong and Song, 2009). Container shipping is also a business with high capital cost, if overcapacity drives down freight rates; they have difficulty generating profits and even run deficits. Strategic alliances in the liner shipping industry gain importance and accelerate of necessity and they would enable individual firms to share risks, reduce cost, extend coverage, entry new market and improve service level (Midoro and Pitto, 2000). The costs are the main influential factors, as they adopt concrete collaborative patterns, such as fleet sharing, slot charter, slot purchase, and slot exchange. Otherwise, shipping costs are made up two components: voyage fixed costs and freight variable costs. Fixed costs will occur constantly and include port charge, bunker costs, containership cost and administration fee. Freight variable costs depend on the volume of freight and include handling costs, container costs, transshipment costs, commission of shipping agency and others. For alliance services, only fixed costs would be affected. In the collaborative pattern of fleet sharing, container carriers share the voyage fixed costs and capacity by respective ratio of contributed containerships in original service route. For the collaborative pattern of slot exchange, a container carrier gives partners slots in exchange for slots on the other service routes based on the relative ratio of these round-voyage sailing days. The voyage fixed costs should be estimated and transferred to other service routes. Additionally, liner shipping faces several uncontrollable factors. In the last five years, bunker prices have risen considerably and become a considerable expense. Charter hire of containership have descended for overcapacity in the last three years and it also occurs rapidly effects of change on voyage fixed costs.

The purpose of this paper is an internal operation of a container carrier to calculate the costs for a specific service route and estimate prices of slot charter, slot purchase and slot exchange. Therefore, the authors try to formulate mathematical models for evaluating costs for various types of collaboration. A short sea service route of the studied company will be the analysis case for an application and some efforts of sensitivity analysis for bunker price and containership charter hire are also presented.

2. Related Study on Strategic Alliance and Cost Analysis

The liner shipping strategic alliances has been studied by several authors. Previous studies seem to mainly concentrate on selecting partners of strategic alliance (Ding and Liang, 2005), evaluating strategic alliances (Shyr et al., 2003; Song and Panayides, 2002; Midoro and Pitto, 2000), and discussing strategic tools (Ryoo and Thanopoulou, 1999). Midoro and Pitto (2000) pointed out that the main motives for global shipping strategic alliances could be classified as follow: wider geographical scope, possibility to perform vessel planning and co-ordination on a global scale, risk and investment sharing, economies of scale, entry in new markets, increase in frequency of services, and by combing purchasing power and volumes. Many concrete collaborative patterns can be adopted in practice, such as pooling agreement, joint service, cross-slot charter, slot-space exchange and slot-space charter (Shry et al., 2003).

Some studies have been done on cost analysis. Cullinane and Khanna(1999) modeled ship costs for the major east-west trades. Nottebook and Vernimmen(2009) addressed that bunker costs constitute a considerable expense to container shipping lines due to high bunker prices. Song et al. (2005) noted that cost-efficiency of the global container shipping network have been investigated and built a model to reproduce the overall incomes, costs, and container movement patterns. Ting and Tzeng (2003) discussed that ship scheduling and cost analysis for route planning in liner shipping. Shintani et al. (2007) addressed to estimate shipping cost function including operating and capital costs. Ship related costs were estimated by regression analysis. Hsu and Hsieh (2007) reported that shipping costs can be divided into three main categories: capital and operating costs, fuel costs and port charges. While some literature is available on costs and strategic alliance, little information is available on the effects of cost change on alliance services.

3. Shipping Cost Functions

Shipping costs are made up of two components: voyage fixed costs and freight variable costs. These costs are defined as below:

$$C^T = C^F + C^V \qquad (1)$$

$$C^F = C^{port} + C^{bkr} + C^{ship} + C^{adm} \qquad (2)$$

$$C^V = C^{hdg} + C^{cntr} + C^{ts} + C^{com} + C^{oth} \qquad (3)$$

Where, C^T :Shipping costs; C^F :Voyage fixed costs; C^V :Freight variable costs; C^{port} ”Port charge; C^{bkr} :Bunker costs; C^{ship} :Containership costs; C^{adm} :Administration fee; C^{hdg} :Handling costs; C^{cntr} :Container costs; C^{ts} :Transshipment container costs; C^{com} :Commission of shipping agency; C^{oth} :Other costs

3.1 Voyage fixed costs

As long as a containership launches into one service route, fixed costs will occur constantly.

3.1.1 Port Charge

Port charge are paid for a containership dwelling in port, which includes Pilot age, Mooring / Unmooring, Towage, Shifting Vessel, Anchorage dues, Harbor dues, Tonnage dues, Berth dues, Berthing priority fees, Watchmen, Launch / boat service, and Car hire fees. The port operator collects it depends on gross weight of containership and stay time of mooring. The port charge for a round-trip is given by Eq.(4)

$$C^{port} = \sum_{n \in N} P_n^{th} \tag{4}$$

Where, P_n^{th} :the port charge for t -type containership and stay h hours in port $n \in N$. N: the number of calling ports in a service route, Ports are coded by number 1, 2,3,…N.

3.1.2 Bunker Costs

Bunker costs include marine diesel oil (A oil), heavy fuel oil (C oil), cylinder oil, engine system oil and lubrication oil consumption. The latter three items can be estimated and included in A oil daily consumption (Ting & Tzeng, 2003). The containership expenses C oil by sailing at sea and A oil by sailing at sea and stay in port. The bunker costs of a voyage are defined by Eq.(5).

$$C^{br} = \phi^C \cdot O_t^C \cdot T^{sl} + \phi^A \cdot O_t^A \cdot T \tag{5}$$

$$T = T^{st} + T^{pt} \tag{6}$$

$$D = \sum_{n \in N} D_{n,d(n)} \qquad d(n) = [(N + n \bmod N) + 1] \tag{7}$$

$$T^{st} = \sum_{n \in N} \frac{D_{n,d(n)}}{v_t} \tag{8}$$

$$T^{pt} = \sum_{n \in N} T_n^p \tag{9}$$

Where, ϕ^C :C oil price (USD/ton); ϕ^A :A oil price (USD/ton); O_t^C :C oil consumption for t -type containership (ton/day); O_t^A :A oil consumption for t -type containership (ton/day); T :Total shipping time (day/round-trip); T^{st} :Total sailing time at sea (day/round-trip); T^{pt} :Total stay time in port (day/round-trip); D :Total Shipping distance (nautical miles/round-trip); $D_{n,d(n)}$:Shipping distance from port $n \in N$ to port $d(n)$ (nautical miles); v_t :Average speed for t -type containership (knots); T_n^p :Stay time in port $n \in N$

3.1.3 Containership Costs

The costs of carriers' own containership include crew, maintenance, insurance, depreciation, and management fee. The above five items are contained containership daily costs. When containerships are chartered in on time-charter instead, containership daily costs include daily hire, P&I, and managements fees. The containership costs of a voyage are defined by Eq. (10)

$$C^{ship} = \gamma_t^{ship} \cdot T \tag{10}$$

Where γ_t^{ship} can be estimated t -type containership daily cost (USD).

3.1.4 Administration Fee

Carriers could set up offices and hire employees to manage and maintain a variety of administration operations. Generally, a liner shipping company divides working items into nine departments: HR department, treasurer department, control department, IT department, marketing & sales department, cargo flow department planning department, operations department, and marine department (https://www.cncline.com.tw). These expense could be computed as administration fee into voyage fixed costs and defined by Eq.(11).

$$C^{adm} = \rho^{adm} \cdot T \tag{11}$$

Where ρ^{adm} can be estimated administration fee (USD/day)

3.2 Freight Variable Costs

Freight variable costs depend on the volume of freight.

3.2.1 Handling Costs

Handling costs include full containers and empty containers loading fee in port of loading (POL) and unloading full containers and empty containers unloading fee in pot of discharging (POD). It is defined by Eq.(12).

$$C^{hdg} = \sum_{o \in N} \sum_{d \in N} \sum_{k \in K} \left(\delta_o^{fk} F_{od}^k + \delta_o^{ek} E_{od}^k \right) + \sum_{o \in N} \sum_{d \in N} \sum_{k \in K} \left(\delta_d^{fk} F_{do}^k + \delta_d^{ek} E_{do}^k \right) \tag{12}$$

Where, K :Set of container specifications. δ_o^{fk} :Handling cost per k -type full container at port $o \in N$ (USD); δ_o^{ek} :Handling cost per k -type empty container at port $o \in N$ (USD); F_{od}^k : k -type full container traffic from port $o \in N$ to port $d \in N$; E_{od}^k : k -type empty container traffic from port $o \in N$ to port $d \in N$

3.2.2 Container Costs

Containers are made up of two components: carriers' own containers and leased containers from leasing company. The costs of own containers include depreciation, insurance, maintenance and repair expenses. The above four items are contained container daily costs. The cost of leased containers is daily rental. The container costs of a voyage are defined by Eq.(13).

$$C^{cntr} = \sum_{o \in N} \sum_{d \in N} \sum_{k \in K} \left(\psi^k \cdot F_{od}^k \cdot T_{od}^{cycle} \right) \tag{13}$$

$$T_{od}^{cycle} = \eta_o^{ct} + T_{od} + \eta_d^{ct} \tag{14}$$

$$T_{od} = \sum_{i=o}^{d} \left(\frac{D_{i,d(i)}}{v_t} + T_i^p \right) \tag{15}$$

Where, ψ^k : k -type container daily costs (USD); η_o^{ct} :Container using time in port $o \in N$ (day); η_d^{ct} :Container using time in port $d \in N$ (day); T_{od}^{cycle} :Container cycle time from port $o \in N$ to port $d \in N$ (day); T_{od} :Shipping time from port $o \in N$ to port $d \in N$ (day)

3.2.3 Transshipment Costs

For wider geographical coverage, container carriers should transship containers to other service routes on specific ports and increase handling costs. The transshipment costs are defined by Eq.(16).

$$C^{ts} = \sum_{o \in N} \sum_{r \in R} \rho_r^k \cdot H_{or}^k \tag{16}$$

Where, ρ_r^k :Transshipment cost for k -type container in transshipment port $r \in R$ (USD); H_{or}^k :Transshipment traffic for k-type container from port $o \in N$ to transshipment port $r \in R$

3.2.5 Commission of Shipping Agency

Container carriers gain freight revenue by delivering containers and depend on shipping agencies around the world to seek cargo. Shipping agencies gain commission from a shipping company. The costs of commission are given by Eq.(17).

$$C^{com} = \sum_{o\in N}\sum_{d\in N}\sum_{k\in K}\theta^k \cdot TF_{od}^k \cdot F_{od}^k \tag{17}$$

$$TF_{od}^k = OF_{od}^k + SC_{od}^k \tag{18}$$

Where, θ^k :Commission rate for k -type container (%); OF_{od}^k :Ocean freight for k -type container from port $o \in N$ to port $d \in N$ (USD); SC_{od}^k :Surcharge for k -type container from port $o \in N$ to port $d \in N$, which includes bunker adjustment factor, currency adjustment factor, terminal handling charge, document fee and so on. (USD); TF_{od}^k :Total freight for k -type container from port $o \in N$ to port $d \in N$ (USD)

3.2.6 Other Costs

A variety of fee, such as tally, stowage, stevedore, and container storage would take account into other costs. It is defined by Eq.(19).

$$C^{oth} = \sum_{o\in N}\sum_{d\in N}\sum_{k\in K}\varepsilon^k \cdot F_{od}^k \tag{19}$$

Where ε^k could be estimated daily other costs for k -type container (USD)

3.3 Shipping Cost Functions for a Alliance Service

Many concrete collaborative patterns can be adopted in practice, such as fleet sharing, slot charter, slot purchase and slot exchange. Voyage fixed costs and capacity are affected. These cost functions are modified as below:

$$C_A^T = C_A^F + C^V \tag{20}$$

$$C_A^F = \frac{s}{S}\left(C^{port} + C^{bkr} + C^{ship} + C^{adm}\right) \tag{21}$$

Where, s :The number of contributed containerships; S :The number of deployed containerships for an alliance service; C_A^T :Shipping cost for an alliance service (USD); C_A^F :Voyage fixed costs for an alliance service (USD)

$$SP_A = CP \cdot \frac{s}{S} \tag{22}$$

$$OP_A = SP_A - \sum_{j\in\Gamma} SE_j - \sum_{j\in\Gamma} SS_j + \sum_{j\in\Gamma} SP_j \tag{23}$$

Where, Γ :The set of alliance partners; SP_A :Sharing-Capacity for an alliance service (TEU); CP :Containership Capacity (TEU); OP_A :Operation-Capacity for an alliance service (TEU); SE_j :Slot Exchange with $j \in \Gamma$ partner (TEU); SS_j :Slot Sell to $j \in \Gamma$ partner (TEU); SP_j :Slot Purchase from $j \in \Gamma$ partner (TEU)

4. Application

To demonstrate the application and the results of the proposed equations, this study uses a Taiwan liner shipping company (T Line) which runs short sea services in intra-Asia as a case study.

4.1 Background of Analyzed Case

The example of CHI service route serves seven ports among China, Hong Kong, Philippines, and Indonesia, and its port rotation is: Qingdao (TAO) - Shanghai (SHA) - north port in Manila (MNN) - south port in Manila (MNS) - Jakarta (JKT) - Surabaya (SUB) – MNS – HKG - TAO. This loop can be divided into south and north bounds from the naturally geographical directions. The round-trip takes 28 days and deploys four containerships with 1,100 TEUs of nominal capacities and 15,400 tons deadweight for weekly service, e.g. on every Wednesday there will be a containership calls TAO and leaves on Thursday (see Figure 1). The port of HKG is assigned as a transshipping port from/to southeastern Asia countries.

Port	ETA	ETD	Stay Time in Port (day)	Shipping Distance (nautical miles)	Sailing Time at Sea (day)
TAO	1600(WED)	1400(THU)	0.917	408	1.100
SHA	1800(FRI)	0200(SUN)	1.333	844	2.275
HKG	0600(TUE)	0600(WED)	1.000	634	1.709
MNN	0100(FRI)	1200(FRI)	0.458	1	0.003
MNS	1300(FRI)	1200(SAT)	0.958	1,582	4.264
JKT	1800(WED)	2000(THU)	0.958	390	1.051
SUB	2200(FRI)	2000(SAT)	0.917	1,526	4.113
MNS	2200(WED)	20000(THU)	1.333	634	1.709
HKG	1400(SAT)	1200(SUN)	0.917	1,111	2.994
Total			8.792	7,130	19.216

Notes: (1) Containersh speed: 15.46 KTS
(2) Total shipping time: 28 days
(2) ETA:Estimate Time of Arrival
(3) ETD:Estimate Time of Departure

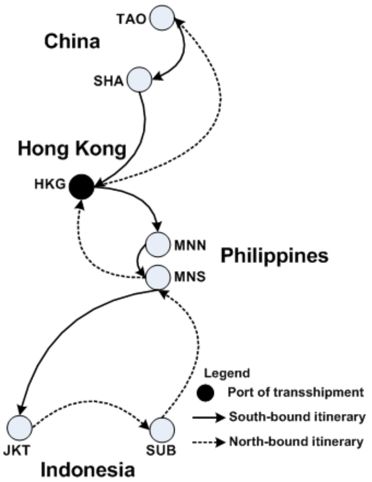

Figure 1: Port Rotation and Schedule of the CHI Service
Source: Authors

4.2 Computational Results

4.2.1 Alliance Patterns and Slot Distribution

To decrease overheads and share the cost of capital equipment, the T Line cooperates with other carriers T Line deployed two containerships and shares initial capacity of 550 TEUs according to the ratio of the contributed numbers of containerships. T Line exchanges slots of 15o TEUs with C Line and Y Line to get 100 TEUs in JTC service and 67 TEUs in CHT service. T Line also sells slots of 100 TEUs to W Line and purchases 50 TEUs from E Line. Finally, T Line gets operation-capacity of 350 TEUs in CHI service and also increases two service routes (JTC service and CHT service) to extend their service coverage. Figure 2 describes the alliance pattern and slot distribution for CHI service.

4.2.2 Cost Analysis over Studied Sample

The fixed cost of CHI service was shown in Table 1. Bunker price is still high and the total cost of bunker amounted to US$ 293, 991 for a round-trip and has a large share of 63.1% (see Figure 3). Due to exceeding supply of capacity, the charter hire for 1,100 TEUs containership was a decrease to US$4,000 per day and has a second large share of 24.04%. For shelf-operation, total fixed cost amounted to US$465,891 per voyage and unit of fixed cost amounted to US$424 per TEU. For alliance-operation, T Line just has share of 50% and total sharing fixed cost amounted to US$146,096 per voyage.

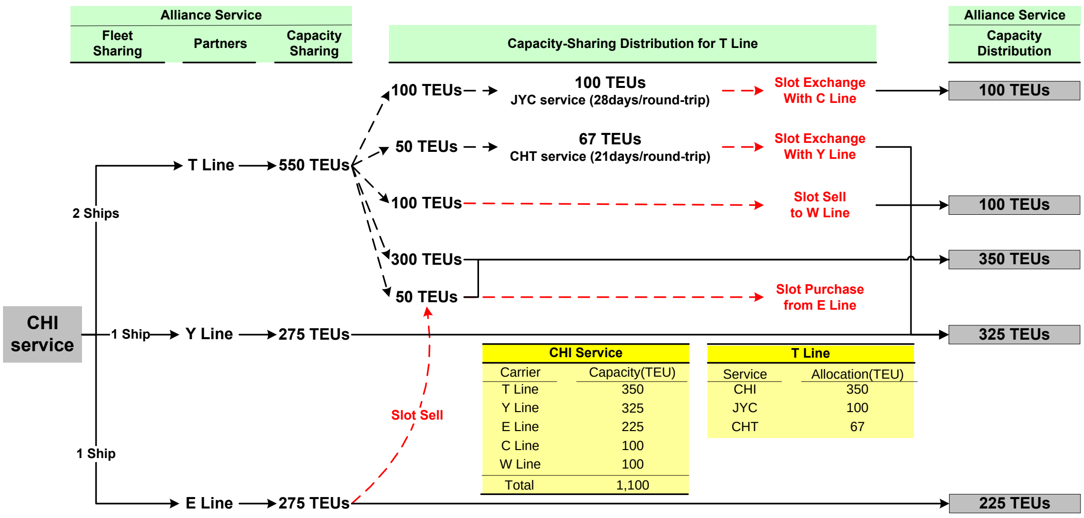

Figure 2: Alliance Pattern and Slot Distribution for CHI Service
Source: Authors

Table 1: Fixed costs for CHI service

1.Port Charge (c^{port})				**2.Bunker Costs** (c^{bkr})	
TAO	7,000	MNS	4,000	A oil	
SHA	9,000	JKT	9,500	A oil price (USD/ton)	673
HKG	4,000	SUB	6,000	A oil consumption (ton/day)	2
MNN	4,000			A oil consumption cost	37,688
Total			**51,500**	C oil	
Share			**11.05%**	C oil price (USD/ton)	494
				C oil consumption (ton/day)	27
3. Containership Cost (c^{ship})				C oil consumption cost	256,303
Charter Hire(USD/day)	4,000	Shipping Time(day)	28	**Total**	**293,991**
Total			**112,000**	**Share**	**63.10%**
Share			**24.04%**		
				4.Administration Fee (c^{adm})	
5. Slot Exchange (SE)				Administration Fee (USD/day)	300
Estimated cost (USD/TEU)			**424**	Shipping Time (day)	28
Total			**63,531**	**Total**	**8,400**
				Share	**1.80%**
7. Slot Sell (SS)					
Price (USD/TEU)			450	**6. Slot Purchase** (SP)	
Total			**45,000**	Price (USD/TEU)	435
				Total	**21,750**
Total fixed cost per voyage (c^F)				**465,891 (Self-Operation)**	
Unit of fixed cost per voyage (USD/TEU)				**424**	
Total sharing fixed cost per voyage (c^F_A)				**146,096 (Alliance-Operation)**	
Unit of sharing fixed cost per voyage (USD/TEU)				**417**	

Source: Authors

The freight variable cost of CHI service was shown in Table 2. Handling cost, which includes full containers and empty containers, has a large share of 71.96% and amounted to US$128,204 for a round-trip (see Figure 3). The total of freight variable cost accounted to US$178,176. Unit of variable cost for full container per voyage accounted to US$172, unit of variable cost of empty container per voyage accounted to US$109, and unit of variable transshipment container per voyage accounted to US$78. Song et al. (2005) pointed out that the cost of repositioning empties was 27% of the total world fleet running cost. Shipping lines' profitability very much depends on whether the cost of moving empties is redeemable or not. Therefore, most of container carriers have done well in managing to restrain the empty incidence. Feng and Chang (2010) addressed the container carriers should devote considerable energy to better matching of cargo flows and to sophisticated revenue management.

Table 2: Freight variable cost for CHI service

Full containers	**20'DC**	**418 boxes**	**40'DC**	**217 boxes**
Empty containers	**20'DC**	**91 boxes**	**40'DC**	**65 boxes**
Transshipment containers	**20'DC**	**50 boxes**	**40'DC**	**23 boxes**

1.Handling Cost (C^{hdg})

		Tariff (USD)	S/B (USD)	N/B (USD)
TAO	20'F	56	7,112	
	40'F	83	6,972	
	20'E	38	760	
	40'E	55	275	
SHA	20'F	79	10,191	
	40'F	117	5,382	
	20'E	54	594	
	40'E	80	3,200	
HKG	20'F	69	7,866	7,866
	40'F	104	9,776	6,864
	20'E	49		490
	40'E	75		750
MNN	20'F	54	1,836	
	40'F	75	675	
	20'E	45		
	40'E	58		
MNS	20'F	54	3,348	2,484
	40'F	75	3,150	2,700
	20'E	45		1,395
	40'E	58		3,825
JKT	20'F	95	11,495	
	40'F	142	6,532	
	20'E	84	5,040	
	40'E	125	2,500	
SUB	20'F	93		8,277
	40'F	139		1,529
	20'E	82		4,100
	40'E	122		1,220

Total Handling Charge (USD)	**128,204**
Share	**71.96%**
Total Handling Charge of Full Containers	**104,055**
Total Handling Charge of Empty Containers	**24,149**

2.Container Cost (C^{cntr})

Hire (USD/day)	20'DC	0.8
	40'DC	1.3
Using Time in POL (day)		7
Using Time in POD (day)		7
Total		**8,687**
Share		**4.88%**

3.Transshipment Cost (C^{ts})

Transit Port(HKG)		
Tariff (USD)	20'F	90
	40'F	130
Number of Transshipment Containers		
	20'F	50
	40'F	23
Total	**7,490**	
Share		**4.20%**

4.Commission (C^{com})

Commission rate: 5%	
Total freight	334,773
Total commission	**16,739**
Share	**9.40%**

5. Other cost (C^{oth})

Estimation of daily cost (TEU/day)		20
Total containers		
	20'F	418
	40'F	217
Total		**17,040**
Share		**9.56%**

Total variable cost per voyage (C^V)	**178,160**
Unit of variable cost for full container per voyage (TEU)	**172**
Unit of variable cost for empty container per voyage (TEU)	**109**
Unit of variable cost for transshipment container per voyage (TEU)	**78**

Source: Authors

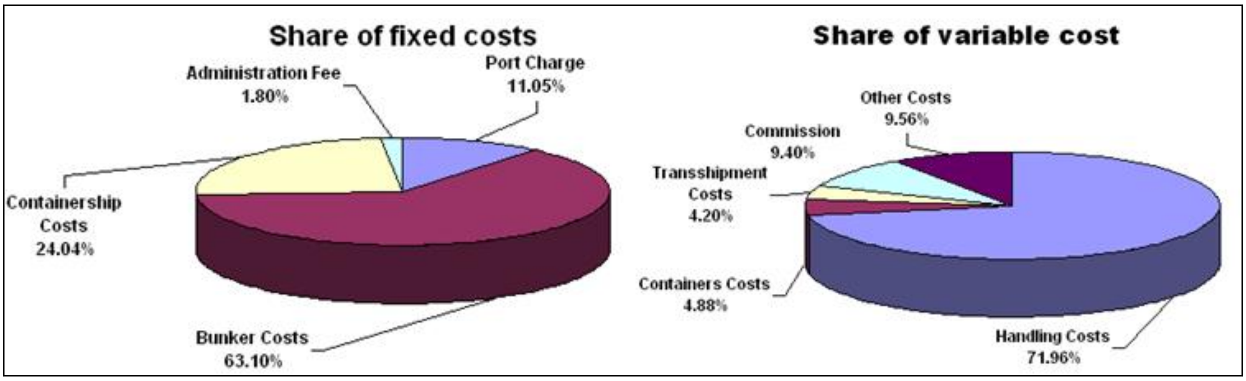

Figure 3: Share of Fixed Costs and Variable Cost
Source: Authors

4.2.3 Sensitivity Analysis

It can be observed from Table 3 and Figure 4 for making sensitivity analysis of containership costs and bunker costs. As charter hire was US$3,000, the expense of containership cost was US$ 84,000 for round-trip and average cost was US$76 per teu. As charter hire was US$ 17,000, the expense of containership costs were US$476,000 for round-trip and average cost dramatically increase to US$433 per teu. As each of charter hires increase US$1,000 per day, the total expense of containership cost increases US$28,000 for round-trip and average cost increases US$26 per teu. As bunker price of A oil was US$310, the expense of bunker costs were US$121,126 for round-trip and average cost was US$110 per teu. As bunker price of A oil was US$850, the expense of bunker costs were US$332,958 for round-trip and average cost was US$303 per teu. As each of bunker prices of oil increases US$100, the total expense of bunker costs increase around US$41,000 for round-trip and average cost increase around US$40.

Table 3: Sensitivity analysis of containership costs and bunker costs

Containership costs			**Bunker costs**			
Charter Hire (USD/Day)	Total (USD)	Average (USD/Teu)	Price A oil (USD/ton)	Price C oil (USD/ton)	Total (USD)	Average (USD/Teu)
3,000	84,000	76	310	200	121,126	110
4,000	112,000	102	350	225	136,337	124
5,000	140,000	127	380	250	150,988	137
6,000	168,000	153	420	275	166,199	151
7,000	196,000	178	450	300	180,850	164
8,000	224,000	204	500	325	196,620	179
9,000	252,000	229	550	350	212,391	193
10,000	280,000	255	580	375	227,042	206
11,000	308,000	280	620	400	242,253	220
12,000	336,000	305	650	425	256,904	234
13,000	364,000	331	700	450	272,674	248
14,000	392,000	356	735	475	287,605	261
15,000	420,000	382	775	500	302,816	275
16,000	448,000	407	810	525	317,747	289
17,000	476,000	433	850	550	332,958	303

Source: Authors

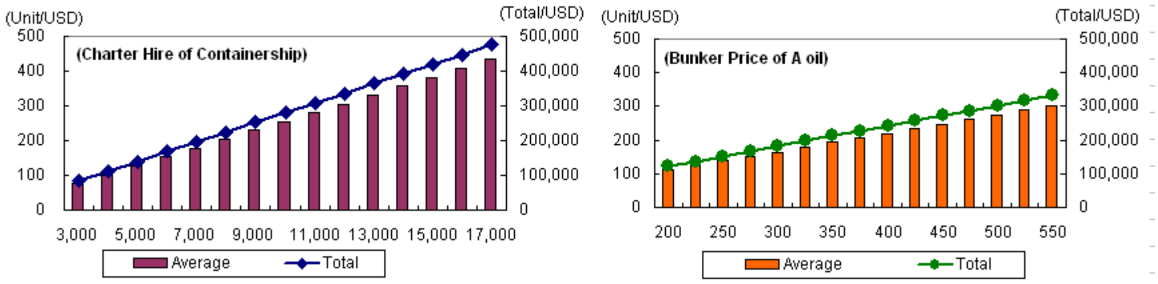

Figure 4: Variety of Charter Hire of Containership and Bunker Price of A Oil
Source: Authors

5. Conclusions

This paper considers cost models for self-operation services and alliance services for a container carrier and discusses the effects of cost change. Shipping costs include voyage fixed costs and freight variable costs. In the case study, bunker costs have a large share of 63.1% in fixed costs and handling costs are the most expense in freight variable costs. Fixed costs would be influenced on alliance services depend on the collaborative pattern. The main contributions of this paper are (1) we try to formulate the cost models and estimate the costs. (2) a container carrier needs to know the costs to negotiate with partners for the prices of slot charter and slot purchase. It also could estimate the costs on alliance services for slot exchange and fleet sharing. (3) we evaluate the impact of bunker price and container charter hires on cost effects and make the sensitivity analysis.

The main disadvantage of the evolution focuses on a round-trip voyage. In practical, container carriers could adopt various collaborative patterns, such as exchange or purchase partial legs on one service route. The costs of legs should be estimated for bargaining on conference table. At the same time, this cost for leg could provide container carriers to calculate profit or loss for carrying this shipment. The mitigation of evaluating cost for each leg may be an interesting topic for future research.

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An Empirical Analysis for Container Ship Investment

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Abstract

Understanding capacity investment behavior can benefit both private business operation and public policy development in the container shipping industry. This study investigates how global container shipping companies with different sizes decide to expand their fleets in a competitive market, using both theoretical and empirical approaches. In the theoretical part, important factors in firms' capacity investment are identified for both operational needs and strategic market competition. In the empirical analysis, all the identified factors were tested using the observed data on ship investment for existing shipping firms. The results show that market demand, rather than the market price, are the main factors in capacity investment. While the investment of small firms is more sensitive to demand change, larger firms are more sensitive to the change in market share. Firms' investment will increase with the competitor's capacity investment in a booming market, but not when it is in recession. The time-charter index and newbuilding price are not important for shipping capacity investment.

Keywords: Container, Optimal investment, Strategy, Utilization rate

1. Introduction

Capacity investment is a critical decision facing shipping companies in the competitive liner market. For a shipping company, failure to add sufficient capacity in a booming market can not only result in the loss of sales and market share, but also endanger its long-term competitive position. However, over-investment is also harmful to the business, because too many empty slots in a voyage can result in too low a profit to cover the high financial costs. This decision process can be further complicated by the uncertainties in future demand and the strategic behaviors of competitors. Due to the cyclic nature of the shipping market and the newbuilding lag (Luo et al., 2009), the individual optimal decisions based on the expectation of future demand can collectively create excessive capacity in the industry, which can accelerate the decrease of the freight rate. For example, before the global financial crisis, the fast growth in shipping demand motivated shipping companies to expand capacity. According to the news from Bloomberg (Wienberg & McLaughlin, 2009), Drewry has predicted that the global container market capacity will grow 8% in 2009 and 10% in 2010, even though the demand for shipping has decreased significantly due to the crisis. The total industrial loss amounted to $20 billion, compared with a $5 billion profit in 2008. According to an executive officer of Maersk Line, "If you start going for market share in a declining market, it will only create an even stronger downward spiral, at this level, we all lose substantially'. This exemplifies the importance of capacity investment to the container shipping market and private business operation.

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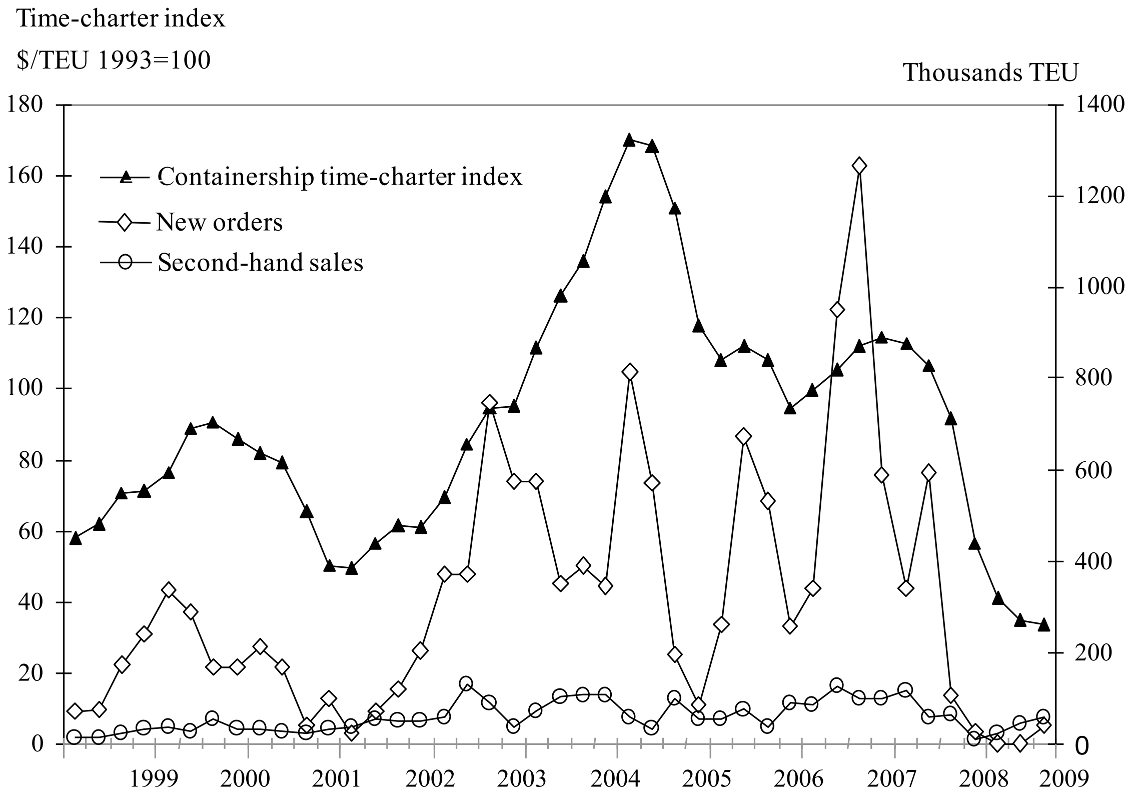

Figure 1: Container time charter index and orders
Source: Clarkson Research Services Limited 2009

Figure 1 displays the container ship time-charter rate and world total container capacity orders (in thousand TEU slots) from 1999 to 2009. When the freight rate (as represented by the time-charter index) is increasing, the expected high profitability in container shipping services motivates ship owners to order new vessels so as to attract customers with better services and gain a larger share in the global competitive market. When the capacity increase cannot keep pace with the demand, the market freight rate will fluctuate, which will exert negative impacts not only on shipping companies, but also on international trade, maritime safety and the environment (Luo et al., 2009). As industrial capacity is determined collectively by the investment behavior of individual shipping companies (Stopford, 2009), analyzing individual behavior in capacity investment in the liner shipping industry is essential to understanding economic factors that drive the industrial capacity change, and ultimately the fluctuation in the container freight rate.

According to Lloyd's Fairplay ship registration database, there are 926 containership owners on January 1, 2009. The biggest owner is Moller-Maersk A/S who owns 4.65% of the market capacity, followed by Offen C-P, COSCO, and CMA CGM Holding. These four biggest container companies, sharing 14.82% of the world container capacity, were active in investing vessels from 1999 to 2008. Their investment accounted for 15.68% of the total investment in the industry. This reveals the important contribution of the larger liner shipping companies to the world capacity growth. On the other hand, this database also reveals that around 85% of the world fleets are still controlled by many smaller shipping companies. To mitigate the influence of market competition, many shipping companies pooled their vessels together to form global alliances. The existence of alliances may to some extent influence the operation of individual firms. However, members in the alliance still need to make investment decisions by themselves. Therefore, we do not take the influence of the alliance into consideration in our capacity investment analysis.

Generally, there are two main types of capacity investment: non-strategic and strategic. The former invests to replace old ships, meet the increasing demand, or buffer possible demand shocks (Driver, 2000; Lieberman, 1987; Kamien & Schwartz, 1972). When the ship is getting bigger and future demand is uncertain, non-strategic investment can often lead to excessive capacity in shipping (Fusillo, 2003; Le & Jones, 2005). The latter invests to improve market positions in the competitive environment (Hay & Liu, 1998; Spance, 1979).

The purpose is to preclude the capacity expansion of competitors (Gilbert & Lieberman, 1987; Lieberman, 1987; Porter & Spence, 1982; Reynolds, 1986) and deter potential new entrants. Many game theory studies found that incumbents often use excessive capacity to threaten new entrants and prevent market entry (Dixit 1979; Dixit 1980; Haruna 1996; Lyons 1986; Spence 1977; Wenders 1971).

Despite the significant role of capacity investment in liner shipping, studies on modeling shipowners' investment behavior are limited. Among them, Fusillo (2003) used entry-deterrence to model excess capacity and tested the existence of excessive capacity using observed data. His empirical results show that the top four carriers added excessive capacity when there are entry threats. Wu (2009) formulated optimal fleet capacity for a shipping company assuming cost minimization, and computed optimal capacity for three carriers from 1992-2006. His findings suggest that the strategy of holding excess capacity and maintain market power may have implicitly played a crucial role in determining fleet capacity. Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis), in an express liner service. However, there is no existing research on modeling shipowners' investment behavior and analyzing the underlining factors for ship investment.

The importance of the capacity investment in the liner shipping industry and the lack of corresponding analyses inspired us to study the underlying key factors in capacity investment decision-making using the observed ship investment data. The motivations for capacity investment include not only the operational needs to meet market demand, but also strategic measures to keep the market position in a competitive environment. Different responses of the capacity investment to the market condition and competitors' strategy were tested for the shipping companies with different sizes. The results of this study not only extends the current understanding about capacity investment behavior in the container shipping market and provide empirical test about the existence of strategic investment behavior, but also highlights the underlining forces for the fluctuation of the container freight market. The results can also benefit both private business operation in shipping, ship operation, ship financing and ship trading, and for the public policies in national and international agencies for maritime transportation.

This paper starts with a theoretical analysis of the container ship investment behavior. It first investigates the factors influencing capacity investment without competition among firms. Then it analyzes the effects of competition among firms in investing behavior by a theoretical model assuming optimal utilization rate in the short run. The data used for this analysis, and the description of the variables are then presented, followed by the presentation of the empirical results and explanations. A summary of this study is presented in the last section.

2. A theoretical analysis on the capacity investment behavior of shipping companies

As stated in the introduction, shipping companies expand their capacity to meet the expected market demand and to improve their respective market condition. We define the capacity investment in both situations as the orders for new ships as well as the acquisition for second-hand ones. It is recognized that shipping companies can expand their capacity through chartering. However, short-term chartering is not a popular practice in container shipping (Gorton et al., 2009). Large shipping companies, such as Maersk, own all the ships in their operation. Smaller shipping companies may charter a ship to supplement short-term capacity shortage. Nevertheless, this cannot be a long-term solution as it decreases the charterer's market competitiveness by paying high short-term charter rate. In addition, this practice does not change the financial responsibility of the owner. Therefore, it can be treated as an irrelevant intermediate alternative, as the owner is facing the same market in their capacity investment decision. For the bareboat charter, normally it is the charterer who initiates the new order and will take control when the ship is delivered. This data is already included in the new order. Therefore, to study the capacity investment behavior in container shipping, we can safely neglect the ship chartering activity.

2.1. Non-strategic capacity investment

The fundamental reason for a shipping company to increase its capacity is to meet the market demand. When the demand is high and all the available ships are in service, the shipping company is better to purchase a ship if it is not economical to run the ship faster. To illustrate the decision factors under this situation, we analyze the investment behavior of one company running a fixed service between two ports.

Assume the shipping company has N identical container vessels of K TEU slots, and uses n vessels in transportation. For each vessel, the operation cost is C and the lay-up cost is LC. The distance between two ports is L. The voyage cost $V(s)$ is a function of ship speed s. Using ρ for the average working hours of one ship in a year, $s\rho/L$ is the total number of trips that a ship can sail in a year if it runs at speed s. For simplicity, assume capital and financial cost is part of the operating cost C. The shipping company is facing demand Q and the market freight rate is P.

Under these conditions, the shipping company's problem is to maximize its annual profit with respect to number of ships (n) it used and ship speed s.

$$\max_{n,s} \pi = \max_{n,s}\left[PQ - nC - n\frac{s\rho}{L}V(s) - (N-n)LC\right] \quad (1)$$

s.t. $n\frac{s\rho}{L}K \le Q$ and $n \le N$.

Solving this problem using the Kuhn-Tucker method, we can get $P = \frac{V(s) + sV'(s)}{K}$, which determines the optimal speed based on the freight rate and vessel condition; and $n\frac{s\rho}{L}K = Q$, which indicates that the shipping company will meet all its demand. Depending on whether there are layups, there are two possible results:

Case 1: $n<N$. In this case, $LC + sV'(s)\frac{s\rho}{L} - C = 0$, which describes the optimal vessel speed when there are layups in the company. Because the shipping company will not increase its capacity when there are lay-ups, no further discussion is necessary in this case.

Case 2: $n=N$. In this case, the speed is determined by $s^* = Q\frac{L}{N\rho K}$. In other words, the shipping company has to increase the speed of its ships to accommodate the increasing demand. However, technology limitations and the faster increasing rate in voyage cost make this option unsustainable. In this case, it is better for the shipping company to purchase additional ships, as long as the savings from the reduced speed can offset the incremental capital and financial cost, operation cost and voyage cost. Assume that the shipping company is a price taker and the quantity demanded is fixed, the problem is to determine the optimal number of vessels to purchase to minimize the total operation cost:

$$\min_I C(I) = (N+I)\left[C + \frac{s\rho}{L}V(s)\right] \quad (2)$$

where the speed is constrained by $s = \frac{QL}{(N+I)\rho K}$. The first order condition for this problem is:

$$C + \frac{s\rho}{L}V(s) + (N+I)\frac{\rho}{L}\left[V(s) + sV'(s)\right]\frac{ds}{dI} = 0 . \quad (3)$$

Differentiating the shipping speed constraint *w.r.t.* the new investment I, it is clear that:

$$\frac{ds}{dI} = -\frac{QL}{(N+I)^2\rho K} \quad (4)$$

Substitute ds/dI in equation 3 with the expression in equation 4, and eliminating Q using the speed constraint, the first order condition can be simplified to:

$$C = sV^{'}(s)\frac{s\rho}{L} \tag{5}$$

Equation 5 is the optimality condition of adding one more ship. The left-hand side is the additional capital, financial and operational cost, which are the fixed cost in a year with one more ship. The right-hand side is the annual incremental cost savings from the reduced speed with one more vessel. This condition determines the optimal speed of the vessels. From this optimal speed, assume equal revenue allocation to each vessel, then the optimal number of vessels the company needs to purchase is:

$$I = \frac{PQ}{C + \frac{s\rho}{L}V(s)} - N \tag{6}$$

Eq. (6) states that for non-strategic investment, the shipowners' capacity will increase with market demand (price, quantity demanded, and average haul length), and decrease with the capital and financial cost, operation cost, and voyage cost. The average size of the vessels also plays an indirect role in investment decision making, as shown from the speed constraint. As speed is relatively fixed, the larger the ship size, the fewer number of ships will be invested.

Finally, without considering the competitive behavior, the capacity investment in the container shipping market can be written as:

$$I = F(\overset{+}{Q}, \overset{-}{N}, \overset{-}{K}, \overset{+}{Tc}, \overset{+}{GTc}), \tag{7}$$

where the sign (+/-) on top of each parameter indicates the positive/negative relationship between the capacity investment and that parameter. *Tc* is the time-charter rate. It is used to represent the container freight rate for two reasons. First, these two variables are highly correlated: an increase in freight rate will bring up the charter rate, while a decrease in freight rate will push down the charter rate. The correlation coefficient between these two variables from 1993 to 2006 is 0.83 (Figure 2). Secondly, we need monthly data for statistical analysis. Monthly data is available for the time-charter rate, but not the freight rate. *GTc* is the growth rate of time-charter rate.

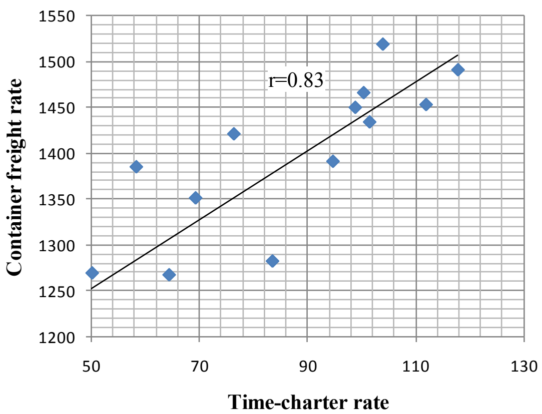

Figure 2: Correlation between container freight rate and time-charter rate between 1993 and 1996

2.2. Strategic capacity investment

In this section, we discuss capacity investment when there is market competition. As stated in the introduction, there are two types of strategic capacity investment. One is the competition among firms vying for market share, and the other is to preempt the market using excessive capacity. Because the latter type was studied in (Fusillo, 2003), this section concentrates on the first type.

There are many different assumptions on the structure of the liner shipping market (Shashikumar, 1995), and there is no commonly agreeable model that can be used to describe the market structure in practice. However, to identify important factors in the capacity investment decision under a competitive environment, it is sufficient to begin with a simple duopoly model and examine how one company's capacity decision affects its competitors.

2.2.1. Model assumptions

To simplify the analysis, we consider a market with two shipping companies, denoted with subscripts *i* (*i*=1, 2). We use k_i to denote their current capacity, q_i for their throughputs, and *Q* for the total throughput ($Q= q_1 + q_2$). To further simplify the process, similar to (Driver, 2000), we use variable u_i to represent the capacity utilization rate of the firm *i*. Then the throughput and capacity relationship of that firm can be written as $q_i = k_i u_i$.

We formulate the competition model in Cournot-fashion in which shipping companies compete with each other using the quantity of output (by capacity and slot utilization), in a market with a linear demand function $p = a - b(q_1 + q_2)$, where *p* is the market price, *a* and *b* are positive parameters representing base demand and demand sensitivity respectively.

On the cost side, following section 2.1, we assume that the cost function has two parts. The first part has constant marginal/average cost in the throughput, representing a fixed cost. The second part is the voyage cost that varies with utilization rate and output. As the fuel consumption increases faster than the speed increase at an exponential rate (Beenstock & Vergottis, 1989; Stopford, 2009), we assume the voyage cost function for company *i* is $V(q_i, u_i)=ru_i^2k_i$, where *r* is an adjust parameter in the voyage cost. Then the total cost $C_i=cq_i + V(q_i, u_i) = cu_ik_i + ru_i^2k_i$, where *c* is the average/marginal cost.

2.2.2. Quantity competition in the short run

When the carrying capacity is fixed, the quantity competition between shipping companies is to rationalize capacity utilization, i.e., each shipping company maximizes its profit by adjusting its u_i:

$$\max_{u_i} \pi_i = pq_i - C_i = [a - b(u_1k_1 + u_2k_2)]u_ik_i - cu_ik_i - ru_i^2k_i, \quad i = 1,2 \quad . \tag{8}$$

Since $\partial^2\pi_i / \partial u_i^2 = -2rk_i - 2bk_i^2 < 0$, the profit function of each firm is concave in its own utilization rate, then the utilization rate satisfying the first order condition

$$\partial\pi_i / \partial u_i = k_i[a - b(u_1k_1 - u_2k_2)] - bu_ik_i^2 - ck_i - 2ru_ik_i \equiv 0 \tag{9}$$

maximizes its profit. Solving the first order condition (Equation 9), the equilibrium utilization (u_1^*, u_2^*) can be obtained:

$$u_1^* = \frac{(a-c)(2r + bk_2)}{4r^2 + 4brK + 3b^2k_1k_2}, \tag{10}$$

$$u_2^* = \frac{(a-c)(2r + bk_1)}{4r^2 + 4brK + 3b^2k_1k_2}, \tag{11}$$

where $K = k_1 + k_2$. From Equation 10 and 11, it is clear that the capacity of a shipping company will not only affect the equilibrium utilization rate of its own, but also the competitors'. Using this as an intermediate result and understanding that there are limitations using this method to meet increasing demand, we consider next the implication on capacity investment decision under a competitive environment.

2.2.3. Capacity investment in the long run

In the long run, capacity can increase with continued investment when a shipping company expects future demand increase, and/or to compete with others for more cargoes. We distinguish the investment in capacity (I_{it}) with the existing capacity (k_{it}). For simplicity, we assume that the ships will be delivered in one year, i.e., $k_{it+1}=k_{it}+I_{it}$, and shipping companies will adjust the optimal utilization according to Equation 10 and 11 using the new capacity. In addition, the market price will also change corresponding to the market demand in $t+1$.

The net profit function after firm i gets the ships ordered can be written as

$$N\pi_{it+1}=[p_{t+1}(u^*_{it+1},k_{it+1})-c]q_{it+1}-V(q_{it+1},u^*_{it+1})-p^I dk_{it+1},\ \text{i=1, 2}$$

where $q_{it+1}=u^*_{it+1}k_{it+1}$; p^I is the unit price of the capacity, d the annualized capital cost rate. Actually, the last term is the capital cost of the cumulative capacity. Note that the price (p_{t+1}), outputs (q_{it+1}), utilizations (u_{it+1}) are all a function of the investment decision I_{it}. Therefore, the current investment (I_{it}) will determine, ceteris paribus, the profit in the next period. Hence, the optimal capacity investment can be determined by the first order condition for maximizing the profit of the subsequent period *w.r.t.* I_{it}:

$$\frac{\partial N\pi_{it+1}}{\partial I_{it}}=\frac{\partial N\pi_{it+1}}{\partial u^*_{it+1}}\frac{\partial u^*_{it+1}}{\partial I_{it}}+\frac{\partial N\pi_{it+1}}{\partial I_{it}}\equiv 0 \quad . \tag{12}$$

The second order condition, $\partial^2 N\pi_{it+1}/\partial I_{it}^2<0$ (refer to Equation 17), ensures profit maximization when I_{it} satisfies Equation 12. Using implicit function theorem and comparative statics, it is possible to determine how I_{it} changes with various variables in the model. The comparative static analysis is provided in Appendix A. The results are expressed in the next equation:

$$I_{1t}=F(\overset{+}{a_t},\overset{-}{b_t},\overset{-}{c},r,\overset{-}{d},\overset{-}{p^I},\overset{-}{k_{1t}},\overset{-}{k_{2t}},\overset{-}{I_{2t}})\ . \tag{13}$$

Some of the results from the comparative static analysis, such as the the influence of the market demand, operational cost, and investment cost, are straight forward and consistent with the results in section 2.1. In addition, Equation 13 also includes the effects of competition: capacity investment in one company decreases with its own capacity, competitors' capacity, and competitors' capacity investment. Furthermore, the level of impacts on the investment also varies with different firm capacity, which will be tested in the empirical analysis.

Combing the results from sections 2.1 and 2.2, the final function that illustrates the decision factors for capacity investment of firm 1 can be written as:

$$I_{1t}=F(\overset{+}{Q},\overset{-}{K},\overset{+}{Tc},\overset{+}{GTc},\overset{-}{b_t},\overset{-}{c},r,\overset{-}{d},\overset{-}{p^I},\overset{-}{k_{1t}},\overset{-}{k_{2t}},\overset{-}{I_{2t}})\ . \tag{14}$$

This theoretical result provides a starting point for an econometric analysis for the important factors in shipping companies' capacity investment behavior. Next, we explain the data used in the empirical analysis.

3. Data

Lloyd's Fairplay provided a database of detailed information on vessels, owners, orders, deliveries, and transaction information for over 120 thousand vessels over 100 GT. Among them, there were 5,724 container vessels owned by 926 shipowners as of January 1, 2009. For the purpose of this paper - to analyze the investment behavior of existing companies, new firms' investment record during this period were excluded. In other words, only the firms who have had capacity since 1999, or those who did not invest for the first time during 1999 and 2008 were included. In this analysis, a total of 767 companies were selected, which involved 4,591 observations, 4913 vessels, 60% (9.7 million TEU) newbuildings and 40% (6.5 million TEU) second-hand vessels. If an existing firm did not invest in a year, its total investment is 0; otherwise, it is the total number of TEU slots invested in this year. All the variables used in the estimation are listed in Table 1.

Table 1: Descriptive statistics

Variables	Unit	Observations	Mean	Std. Dev.
INV_{it}	000 TEU	4995	2.94	15.4
K_{it}	000 TEU	4995	20.5	60.45
$INVAVG_{it}$	000 TEU	4995	0.57	1.57
Q_t	000000 TEU	4995	379	112
$GROWQ_t$	%	4995	11.04	2.53
$SHARE_{it}$	%	4995	0.2	0.59
$CHSHARE_{it}$	%	4591	-0.28	31.23
OEX_{it}	%	4966	7.77	6.26
$OINV_{it}$	%	4966	16.22	11.19
TC_{it}[a]		4966	98.13	28.16
GTC_{it}[b]	%	4966	3.48	24.97
NBP_{it}[c]		4945	103.1	32.61
SEP_{it}[d]		4966	100.2	19.59

Note: a, b, c, and d are all form Clarkson Research Services Limited 2009
[a] Containership Time charter Rate Index: based on $/TEU for 1993 = 100.
[c] Containership New-building Prices Index: based on average $/TEU for Jan 1988 = 100.
[d] Containership Second-hand Prices Index: based on average $/TEU for Jan 1988 = 100.

The dependent variable, INV_{it}, is the new investment of container vessels including orders for new ships and second-hand ships for firm *i* in year *t*. Because of the new building lag, INV_{it} is not k_t-k_{t-1}. However, since we focus on explaining the investment decisions, we will not distinguish newbuildings and second-hand vessels, as they all express shipping companies' intention to increase their capacity.

K_{it}: the total capacity (Thousand TEU) of firm *i* at January 1 of year *t*. In the Lloyd's Fairplay database, we can only calculate the capacity level of each shipowner on January 1, 2009. However, the database provides detailed information for each vessel, including the order year, delivery year, and the acquired year if it is a second-hand ship. Unfortunately, it does not keep information about the scrapped ships.

Information about ship demolitions from 2004 to 2008 was obtained from the CSIN (Clarkson's Shipping Intelligence Network). Combining such information, we can calculate the capacity level of each company from 1999 to 2008 using the equation $k_{it-1}=k_{it}-ADDITIONS_{it}+SELLS_{it}+SCRAP_{it}$, where $ADDITIONS_{it}$ includes the delivery of newbuildings and second-hand ships, $SELLS_{it}$ is firm *i*'s selling of second-hand ships. We ignore ship demolitions before 2004 because of data unavailability. This will not influence the analysis as the market total demolition only accounted for 0.5% of the total capacity (TEU) from 1999 to 2008.

$SHARE_{it}$: firm *i*'s share of total industry capacity in year *t*, defined as $SHARE_{it}=K_{it}/\Sigma_i K_{it.}$
$CHSHARE_{it}$: the change of share for firm *i* from year *t*-1 to year *t*, which is defined as $CHSHARE_{it}=SHARE_{it}/SHARE_{it-1}$ -1. This value changes with both its own capacity and its competitors' capacity.

Q_t: industry demand which is the total container throughput in year *t*. Because there is no route specific demand information and ship deployment information for each individual shipping route, we assume that all the firms face the same global industry demand.

$GROWQ_t$: the demand growth rate, defined by $GROWQ_t=Q_t/Q_{t-1}$-1. This variable is included to test the impacts of the market trends, instead of the market status, on the investment behavior. It represents the non-strategic investment behavior in the container shipping companies as introduced in section 2.

TC_{it}: the container ship time-charter index. If a firm invested ships in year *t*, TC_{it} is the monthly average time-charter index in the months the ships are ordered. If not, it is just the time-charter index of that year.

GTC_{it}, NBP_{it} and SEP_{it} are calculated in the same way, but they represent the growth rate of time-charter index, newbuilding price index, and second-hand ship price index. The data for these three variables were obtained from Clarkson's Shipping Intelligence Network (CSIN).

INR_t: a dummy variable represents the market status. It is 1 if the time-charter rate is increased in year *t*, and 0 otherwise.

OEX_{it}: the capacity expansion of the competitors for firm *i*, defined as $OEX_{it}=\Sigma_{j\neq i}(K_{jt}-K_{jt-1})/\Sigma_{j\neq i}K_{jt-1}$. It is the increasing rate of all other firms' capacity except firm *i*, which is designed to test the competition among firms. Comparing with the variable $CHSHARE_{it}$ which takes into account its own and competitors' expansion, OEX_{it} captures only the influence of all the competitors' capacity expansion. The correlation between these two variables is -0.03, indicating that they are not perfectly correlated.

$OINV_{it}$: competitors' investment rate in year *t*, defined as $OINV_{it}=\Sigma_{j\neq i}INV_{jt}/\Sigma_{j\neq i}K_{jt}$. It represents the ratio of aggregated investment with aggregated capacity of all other firms. Unlike OEX_{it} which is the actual capacity expansion rate of the competitors, $OINV_{it}$ is the rate of investment of the competitors, which could lead to the increase of competitors' capacity in the next time period. This variable is designed to capture firms' responses to the investment activities of the competitors.

$INVAVG_{it}$ is a variable representing the average investment size of firm *i* in year *t*. It is used to capture the impact of ship size on the capacity investment behavior of the investor.

Finally, companies with different sizes may respond to the capacity investment of the competitors differently. To detect this behavior, we created interaction terms using the capacity share of each firm ($SHARE_{it}$) and some other independent variables, including $CHSHARE_{it}$, $GROWQ_t$, OEX_{it}, and $OINV_{it}$.

4. Estimation and results

Table 2 summarizes the result of three different models for the capacity investment behavior. Model (1) included all of the independent variables and omitted interaction terms. Because NBP_{it} and SEP_{it} are highly correlated, only NBP_{it} was included in the mode. Model (2) included the interactions using the $SHARE_{it}$ variable. Since market trends may influence shipowners' investment behaviors, in model (3), we added the interaction of the dummy variable for increasing market, INR_t, with OEX_{it} and $OINV_{it}$.

Table 2 Regression results for three capacity investment models.

	Dependent variable: INV_{it}					
	Model (1)		Model (2)		Model (3)	
Independent variables	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	3.8752	0.0502	0.6226	0.3178	-10.3268	0.0001**
$INVAVG_{it}$	4.2274	0000**	3.1230	0000**	3.1290	0000**
$SHARE_{it}$	8.2651	0000**	15.7629	0000**	12.3311	0000**
$CHSHARE_{it}$	-0.0071	0.1812	-0.0049	0.7252	-0.0026	0.6210
$SHARE_{it}\times CHSHARE_{it}$			-0.0389	0.0033**	-0.0752	0.0043**
Q_t	-0.0233	0.0063**	-0.0023	0.2272	0.0465	0.0001**
$SHARE_{it}\times Q_t$			-0.0916	0000**	-0.0741	0000**
$GROWQ_t$	-0.1304	0.2982	0.0102	0.9529	0.2052	0.0460*
$SHARE_{it}\times GROWQ_t$			-0.0110	0.6064	0.0494	0.6392
OEX_{it}	0.5984	0.0001**	0.0603	0.1787	-0.5516	0.0068*
$SHARE_{it}\times OEX_{it}$			2.2354	0000**	2.0940	0000**
$OEX_{it}\times INR_t$					2.1411	0000**
$OINV_{it}$	0.0788	0.0715	-0.0395	0.1708	-0.2577	0000**
$SHARE_{it}\times OINV_{it}$			0.6946	0000**	0.7071	0000**
$OINV_{it}\times INR_t$					-0.7436	0000**

TC_{it}	0.0077	0.2289	0.0068	0.2552	0.0175	0.2695
GTC_{it}	3.2909	0.0042**	0.3076	0.6955	1.9948	0.1217
NBP_{it}	-0.0213	0.2069	-0.0124	0.4002	-0.0380	0.0698
Observation	4591		4591		4591	
R-squared	0.409		0.594		0.598	
Adjusted R-squared	0.407		0.593		0.596	
Durbin-Watson	1.770		2.253		2.253	
Log likelihood	-18049		-17187		-17165	
F-statistic	316		446		400	

* Significant at the 0.05 level, two-tailed test.

** Significant at the 0.01 level, two-tailed test.

The significance of including the interaction terms in models 2 and 3 was tested respectively using the likelihood ratio test. The test statistics between model 2 and model 1 was -2[-18,049 - (-17,187)] = 1,725, while that between model 3 and model 1 was -2[-18,049 - (-17,165)] = 1,770. The 1% critical value from the chi-squared distribution with 2 degrees of freedom was 9.21. Hence, the hypothesis that there is no difference with or without the interaction terms was rejected. Models (2) and (3) with interaction terms are appropriate. Since model (3) includes the most interaction terms, it is the basis for the following discussion.

Judging from the results in Table 2, the signs on the estimated coefficients for most of the variables conform to the theoretical model, especially in the full models of (2) and (3). The coefficient of $INVAVG_{it}$ was positive and significant at the 1% level in all of the three models. This result is consistent with previous research that the lumpiness in ship investment may cause excessive capacity in the shipping industry (Fusillo, 2003; Le & Jones, 2005). The coefficient of $SHARE_{it}$ was positive and significant in all of the three models. This is reasonable because larger firms could earn more to support capacity investment. This result is also consistent with (Fusillo, 2003), who found that large firms in the shipping industry, especially the top four companies, are using preemptive capacity to deter the new entrants, which may require the larger firms to invest more.

Comparing models (1) to (2) and (3), it can be seen that larger firms tend to respond to the market share change differently in the investment decision-making. The coefficient on $CHSHARE_{it}$ was not significant in all the three models, indicating that this variable is not an important factor in investment decision making. However, in models (2) and (3), all the interactions between $SHARE_{it}$ and $CHSHARE_{it}$ were negative and significant. Because the dependent variable is the quantity of investment and $CHSHARE_{it}$ is the current share change, the result suggests that large shipping companies are trying to compensate their past market share changes. If they find their share reducing, they will try to invest more; if they have already experienced an increasing market share, they will be more conservative in investment.

The coefficient estimates on Q_t and $SHARE_{it} \times Q_t$ were both significant, but their signs were different, positive for the first and negative for the second. This shows that while high market demand can motivate capacity investment, smaller firms are more responsive than larger ones. Whenever there is a demand increase, smaller firms will first feel the capacity shortage, and also the needs to acquire more vessels. In contrast, larger firms have more available capacity to buffer demand increase. Therefore, they are comparatively less responsive to the demand increase in the ship purchasing decision. The positive and significant coefficient on demand growth rate ($GROWQ_{it}$) suggests that high demand increasing rate will motivate capacity investment. The non-significant coefficient on ($SHARE_{it} \times GROWQ_{it}$) suggests no obvious difference in capacity investment between large and small firms facing a growing demand.

The coefficients on OEX_{it}, $OEX_{it} \times INR_t$ and $SHARE_{it} \times OEX_{it}$ were all significant, indicating strategic capacity investment in a competitive environment. From the first two variables, it is clear that although a firm's capacity investment will decrease with competitors' capacity expansion, when the market is increasing, its investment will increase with competitors' investment. The result of the last variable indicates that the investment of a larger company increases with competitors' expansion. This explains the shipping companies' strategy in maintaining their market share.

The coefficients on $OINV_{it}$, $OINV_{it} \times INR_t$, $SHARE_{it} \times OINV_{it}$ were also significant, indicating the importance of the competitors' investment rate on capacity investment of a shipping company. The negative coefficients on the first two variables indicate that shipping companies are trying to avoid investing at the same time with the competitors, especially when the freight rate is increasing. This result implies that there may be some rationality in capacity investment in the container shipping industry. The positive coefficient on $SHARE_{it} \times OINV_{it}$ indicates that larger companies are less influenced by the negative impact of competitors' capacity investment decisions.

The above analyses confirm the mass psychology of capacity investment in shipping (Stopford, 2009) when the demand is increasing. In addition, our study also reveals obvious strategic behavior in capacity investment. Furthermore, there are distinct differences between the market players with different sizes, and there are different responses to the observed capacity change of the competitors, and their investment level. The finding indicates that strategic investment reduces the immediate capacity expansion in competing firms. It could reduce over investment in shipping capacity and promote market efficiency by avoiding industry oversupply. However, this efficiency improvement diminishes with firms' long-term strategy in keeping market shares, especially the larger firms'.

Finally, three variables, TC_{it}, GTC_{it}, and NBP_{it}, were not significant. TC_{it} and GTC_{it} were not significant, possibly because they are not as direct a factor in firm's capacity investment as market demand: firms based on the market demand for their capacity investment strategy, not the market price. NBP_{it} was not significant, which may be because new building market is a derived market: firms order more ships not because the price is low, but because the demand for transportation services is high. Therefore, the newbuilding price is not a significant factor in capacity investment.

5. Summary and Conclusion

This study indentified and tested some major factors determining capacity investment behavior in the container shipping industry, using both theoretical and empirical analyses. The theoretical part analyzed the capacity investment behavior from two different aspects: operational considerations for cost minimization and strategic behavior in market competition. For the operational requirement, the decision for investing another ship is made through comparing the gain from reducing ship speed and the additional operating and capital costs. For the strategic behavior, we adopted a Cournot-like model where shipping companies compete by utilization-rate in short term, and in long term using capacity investment. The empirical analysis used actual existing shipping company investment data, which included 767 containership owners over the period 1999-2008, with a total of 4,591 observations.

Results from the empirical analysis suggest that when existing companies make capacity investment decisions, they consider both the operational needs to supply the demand growth, and the strategies for market competition. The positive and significant impacts on capacity investment from market demand and its growth rate reveals the investment behavior in meeting the operation requirements. Furthermore, firms with different sizes have different responses to demand, although they are both inclined to invest more when demand is increasing. Small companies tend to be more responsive to demand change than the larger ones, as they have less existing capacity to accommodate the high demand.

A firm's investment behavior facing market competition includes the responses to its market share, change of market share, competitors' capacity expansion, and investment. Market share has a positive and significant impact on capacity investment. The change of market is not a significant factor for smaller firms' investment decisions, because their market share is very small anyway. However, large firms always try to compensate their past market share changes: If they find their market share decreasing, they will invest more.

The response to other firms' capacity expansion reveals shipping companies' competitive capacity investment behavior with respect to the actual capacity change of the competitors in the previous year. Generally, a firm's capacity investment decreases with the capacity expansion of competitors. However, larger firms will increase their capacity investment to keep their market share. In addition, in a booming market, a company will invest more even the competitors' capacity is expanding. This could be a major factor for overcapacity in container shipping.

The response to other firms' capacity investment, which is different from the response to the competitors' capacity expansion, reveals the competitive investment behavior with respect to others' investment. A company will refrain from investing more while others make aggressive investment plans, especially when the market freight rate is increasing. However, for larger companies, the aggressive investment of others will increase their investment, in order to avoid the loss of market share.

Finally, this paper provides insights into capacity investment behavior for shipping companies with different sizes and market share under different market situations, which could benefit not only private sectors associated with the shipping industry, but also the public policy-makers in national and international maritime agencies. Understanding the current practice in shipping capacity investment can help the shipping companies, shipowners and ship-operators to find the best opportunity to expand their capacity, so as to secure their market position. For the institutions providing ship financing and organizations in ship trading, this could help them understand the individual investment behavior in shipping capacity, so as to provide better service to their customers and reduce the risk in ship financing. In the public sector, knowing the capacity investment behavior could help the national and international agencies to advise appropriate maritime policies to regulate the capacity investment activities so as to mitigate the impact of alternative over-capacity and supply shortage in the container shipping industry.

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Appendix A

The comparative static analysis of the investment equation of section 2.2.3 are developed in detail here. Substitute all the variables into the net profit equation and simplify it, we get

$$N\pi_1 = \frac{(a-c)^2(2r+bI_2+bk_2)^2(I_1+k_1)(r+bI_1+bk_1)}{M^2} - p^I d(k_1+I_1) \tag{15}$$

Where $M = 4r^2 + 4brk_2 + bI_1(4r+3bk_2) + 4brk_1 + 3b^2k_2k_1 + bI_2(4r+3bI_1+3bk_1)$.

The first order condition in equation 12 is

$$F = \frac{\partial N\pi_1}{\partial I_1} = \frac{\begin{Bmatrix}(a-c)^2 r(2r+bI_2+bk_2)^2[4r^2+4brk_2+bI_1(4r \\ +5bk_2)+4brk_1+5b^2k_2k_1+bI_2(4r+5bI_1+5bk_1)]\end{Bmatrix}}{M^3} - p^I d \equiv 0 \tag{16}$$

It is relatively easy to calculate the second differential of the net profit which is negative

$$\frac{\partial^2 N\pi_1}{\partial I_1^2} < 0 \tag{17}$$

The effect on the optimal investment *I* of changes in the various parameters in the model can be determined by taking the total differential of equation A2 and setting the appropriate partials equal to zero. For example, since

$$F(I_{1,t}; a, c, b, r, d, p^I, k_{1,t}, k_{2,t}, I_{2,t}) \equiv 0, \tag{18}$$

$$(\partial F / \partial I_{1,t})(\partial I_{1,t} / \partial a) + (\partial F / \partial a) = 0 \tag{19}$$

Solving for $\partial I / \partial a$ from equation A.4, we get

$$(\partial I_{1,t} / \partial a) = -F_a / F_{I_{1,t}} \tag{20}$$

The elements of all the total differentials can be calculated from equation A.2. We only list their signs below.

$F_{I_{1,t}} < 0$, $F_a > 0$, $F_b < 0$, $F_c < 0$, $F_r ?0$, $F_d < 0$, $F_{p^I} < 0$, $F_{k_{2,t}} < 0$, $F_{k_{1,t}} < 0$, $F_{I_{2,t}} < 0$.

The comparative statics for each of the other parameters can be easily determined similar to Eq. A.6.

Ship Financing Practices in Hong Kong: What Changes Has the Financial Tsunami Wrought?

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Abstract

We survey Hong Kong-based shipowners and banks about their ship financing practices before and after the recent financial crisis. Results obtained from the survey of shipowners suggest that bank loan remains the most preferred source of financing for shipping companies in Hong Kong, with the major perceived advantages being low cost, easy access, and relatively flexible terms and conditions as well as non-disclosure of sensitive business information. Results obtained from the survey of banks suggest that they have reduced their exposure to the shipping industry since the financial crisis struck. In addition, banks are now placing greater emphasis on loan quality and security and are less concerned about market share. The changes in financiers' attitudes and in the wider economic environment have important implications both for the industry's long-term survival and for the competitive position of individual shipping companies.

Keywords: *shipping finance, banking, financial crisis, capital structure, competition*

1. Introduction

Shipping is an extremely capital-intensive industry, with its 30,000 world wide companies needing, by rough estimation, about 80 billion dollars per year for financing new buildings alone (Goulieloms and Psifia, 2006). Thus shipping finance has a significant bearing for the shipping industry that is known for its fluctuating earnings, volatile vessel prices and technical complexity. However, due to the "public-shy" nature of the shipping business (Stokes, 1996), systematic research on how shipowners make their financing choices and the associated governance arrangement is rather limited.

After experiencing drastic fluctuations in the shipping market over the past decades, shipping companies are now putting more emphasis on financial liquidity in the rapidly changing environment while pursuing profit maximization, operational flexibility and managerial efficiency. Correspondingly, ship financing instruments have evolved to meet the varying market demand (Stopford, 1997). Diverse financing approaches and instruments are currently available for fleet expansion and working capital requirements, including shipping funds, IPOs, bonds, leasing schemes, private placements, venture capital and shipbuilding credit (Orfandis, 2004). Among all the available choices, bank loan has remained the primary source of financing for the shipping industry despite the trend for some of the largest companies to resort to the public equity and bond markets in recent years (McConville and Leggate, 1999; Grammenos and Arkoulis, 2003). Recently, due to the financial crisis, the global economy is experiencing a downturn and banks are facing a serious credit squeeze. The shipping market has also experienced heavy fluctuations, with the BDI reaching historical 11067 points in May 2008 before dropping to only 663 points in December.

Against such a macroeconomic and industrial backdrop, in this paper we aim to explore several questions from a practical point of view. Specifically, what are the major factors of consideration for shipping companies in choosing their financing methods? Is bank loan still the most favored financing method for shipping companies after the financial crisis? What are the key differences, if any, in banks' lending practices or credit assessment criteria before and after the financial crisis?

To address these questions, we adopt a survey design that aims to solicit responses from both shipowners and banks with a ship financing operation in Hong Kong. The key findings are summarized as follows. First, bank loan remains the most preferred source of financing for shipping companies in Hong Kong, with the major perceived advantages being low cost, easy access, and relatively flexible terms and conditions as well as non-disclosure of sensitive business information. However, since the crisis struck banks have substantially reduced their overall exposure to the shipping industry, and are increasingly concerned about loan quality and collateral security and less concerned about market share. Whereas the banks' shift towards greater prudence may be good news for both bank regulators and shareholders (and, to a lesser extent, may help with long-needed industry consolidation), their more stringent lending requirements could mean shipowners will need to incur higher borrowing costs and/or resort to alternative sources of financing. The changes in shipowners' financing costs and options may have important implications for the industry's long-term survival as well as individual companies' competitive position.

The main contribution of this study is to provide a timely assessment of the impacts of the recent financial crisis on ship financing practices in the region, which may also reflect the industry landscape elsewhere. On the academic front, we contribute to the finance literature on determinants of capital structure by uncovering real-life factors that companies and financiers consider in their respective decision-making. Our joint treatment of firms' financing constraints, the interaction between providers and suppliers of finance, and capital structure determination is in contrast with typical finance studies that take firms' financing opportunities as given when examining capital structure choices (e.g. Fama and Miller, 1972), but is in line with the growing stream of research that looks to the field for a better understanding of the theory and practice of corporate finance (e.g. Graham and Harvey, 2001).

The remainder of this paper is structured as follows. Section 2 briefly reviews the literature on capital structure theories and financing choices in general and in the shipping industry. Section 3 discusses the survey design. We present and interpret the empirical results in Section 4 and offer some concluding remarks in the final section.

2. Literature review

Corporations typically have four main means of financing their capital investments: internal or outside equity, private or public debt, leasing, and hybrid securities (Brealey and Myers, 2003). A firm's choice of these financing methods shapes its capital structure (i.e., how its value is sliced up among different providers of funds). Taking as given the available financing options, financial economists have advanced four mainstream theories to explain firms' capital structure choices.

In their seminal paper, Modigliani and Miller (1958) show that in the absence of market imperfections such as taxes and agency cost, the value of a company depends solely on the earning power of its assets and is independent of its capital structure (the renowned MM Proposition I without taxes). A large literature has since developed. Among the major theories advanced to explain firms' capital structure choices, the Trade-off Theory argues that the choice between debt and equity depends on balancing the costs against the benefits of borrowing. The major benefits of borrowing include tax savings, and the major costs include financial distress/bankruptcy costs and agency costs. According to this theory, firms should target an optimal debt-to-equity ratio, which is reached when the marginal benefits of borrowing is equal to the marginal costs. Such a theory, while intuitively appealing, offers companies very little practical guidance (apart from a degree of awareness) since one cannot normally observe or quantify the marginal benefits and marginal costs. The dichotomy between debt and equity as financing instruments is also overly simplistic and does not adequately reflect the real-life complexities faced by companies in practice (for example, the need to consider governance issues simultaneously with the financing choice).

In contrast, the Pecking Order Theory proposed by Myers and Majluf (1984) argues that managers (acting on behalf of shareholders) prefer internal financing when this is available. If it is necessary to use external financing, companies will issue the safest securities first, such as debt and convertible bonds, and will consider outside equity only as a last resort. The key reasons supporting the Pecking Order Theory are mainly behavioral: managers prefer internal financing because it preserves their managerial autonomy and requires the least effort on their part. And by relying on internal financing companies do not need to disclose potentially sensitive business information (which is a more serious concern in flotation of shares), or have restrictive terms and conditions imposed upon them by bondholders (Myers, 1984). By taking into account asymmetric information and agency costs, the Pecking Order Theory offers a plausible explanation of firms' general preference for internal financing over external financing. However, it cannot explain, for example, why many companies are strongly motivated to float their shares[1]. An implication of the Pecking Order Theory is that companies do not have a target debt-to-equity ratio, in sharp contrast with the prediction of the Trade-off Theory, which posits an optimal debt ratio.

Neither the Pecking Order Theory nor the Trade-off Theory is able to explain why capital structure tends to vary systematically across industries or across different types of companies. Williamson (1996) approaches firm's capital structure choice from a transaction cost economics (TCE) perspective. He contends that the financing method employed by companies is determined by minimizing overall transaction costs. The TCE approach is featured by 3 characteristics: (1) the specific transaction (as opposed to the whole company) is the basic unit of analysis and costs are determined by transaction frequency, specificity, uncertainty, limited rationality, and opportunistic behavior; (2) the contractual or governance arrangements are emphasized and treated simultaneously with the financing choice such that the capability of different financing methods matches the specific transaction's attributes in a transaction-cost-minimizing manner; (3) the TCE approach explicitly recognizes the interaction of the wider economic environment, transactional attributes of specific industries and status of the transaction entities with the choice of financing and governance mechanisms. In transaction cost economics theory, as the asset specificity increases in one transaction, the terms and conditions of rule-based financing (e.g. debt) become more stringent for the debtor (i.e. increase transaction costs), so that at some point the company may turn to discretion-based financing (e.g. equity). TCE predicts that rule-based financing should be used for redeployable assets or assets with low specificity, while discretion-based financing is suitable for non-redeployable assets or transactions with high asset specificity. It is worth emphasizing that in the TCE approach, firms make the financing and governance choices *simultaneously* on a transaction-by-transaction basis, and thus there is no target capital structure for the whole firm.

It is now generally accepted that capital structure is affected by a number of factors such as asymmetric information, taxes, agency cost considerations, and industry or firm-specific characteristics such as growth opportunities and volatility of cash flows (see Brealey and Myers, 2003). It is also accepted that there is no optimal capital structure that applies to all firms under all circumstances. Gong, Firth and Cullinane (2005) propose that the choice of the financing and governance mechanism the transport industry should be viewed in the light of various economic, institutional and industrial as well as firm-specific factors, and should take into consideration the interaction of the supply side and the demand side. We next discuss the evolution of financing and governance mechanisms in the shipping industry. This provides the basis for designing our survey instrument and subsequently interpreting the results.

Before the Second World War, retained earnings were the primary source of ship financing. As the vessels grew bigger and prices soared, internal funds were not sufficient to support fleet acquisition, and shipping companies have since relied predominantly on commercial bank loans for their funding needs. Nowadays, although there are various alternative forms of financing (e.g. public equity, corporate bonds, and tax-based leasing), bank loan still remains the most favored form of financing in the shipping industry (McConville and Leggate, 1999; Grammenos, 2002; Grammenos and Arkoulis, 2003; Syriopoulos, 2007). Table 1 describes the five phases of ship financing evolution.

Table 1: Five phases of ship financing evolution

Phase	Period	Characteristics
Cash-based	1950's	The main source of financing new investments is retained earnings. The practice was prevalent among European shipowners with abundant capital reserves.
Charter-bac	1960's	Internal financing could no longer meet the growing capital needs due to the

[1] In China, for example, it is observed that many companies (not limited to shipping companies) prefer a public listing to other forms of financing. While this has to do with the institutional environment (e.g. the quota system in China for initial public offerings), it suggests that firms' financing decisions must be examined in the broader context of the evolution of the financial system because this affects firms' financing opportunity set, itself a key determinant of the observed capital structure (see Gong, Firth and Cullinane, 2005 for a similar point).

ked		soaring ship tonnages and ship prices. Thus shipowners turned to bank term loan, using charters and mortgage of ships as security.
Bubble	1970's	To take advantage of the market boom, shipowners started "asset play" disregarding the availability of time charters. Meanwhile, banks accepted ship mortgages as sufficient collateral, which led to an oversupply of capacity.
Distress	1980's	The consequence of unlimited expansion revealed itself. During 1983 to 1987 borrowers defaulted on $10 billion worth of shipping loans, and banks had to write off books with a value between $3 and $4 billion. Some banks quitted the shipping finance market.
Convalescence	1990's--	Financing tools become sophisticated and diversified, including both debt and equity from the public markets, tax-driven lease finance and so on. Shipping finance now attracts various financial institutions.

Source: Stopford (1997) and Grammenos and Xilas (1996)

Many factors have contributed to the dominance of bank loan in ship financing, including the capital intensive nature of the industry, the erosion of shipping companies' capital reserves due to shipping cycles, reluctance of shipowners to dilute company control and disclose sensitive information, and the general unattractiveness of shipping stocks to public investors (Stokes, 1996, 1997; Grammenos, 2002;). Stopford (1997) notes that the evolution of financing methods for shipping companies is in line with the industry's own characteristics, such as the industry's volatility and cyclicality, changes in the financial community's perception of risk-return in shipping, as well as other developments in the wider financial environment (e.g. capital adequacy requirements). Nevertheless, to date there is very limited empirical research into how the providers of funds and the shipping companies interact to shape the capital structure. Specifically, little is known about what shipping companies perceive are the advantages and disadvantages of different financing methods, how banks make their financing decisions, and what changes might have occurred since the recent financial crisis broke out. This paper aims to inquire into the financing decision-making processes of both shipping companies and banks in Hong Kong, and provide a timely assessment of the impacts of the financial crisis on the shipping industry. Being both an international maritime center and an international financial center, Hong Kong is considered to be representative or indicative of the situation in other parts of the world.

3. Methodology

In view of the specific factors influencing financing choices in the shipping industry, and to achieve the stated research objectives, we adopt a survey methodology to probe into the major factors shipowners and banks consider in their financial decision-making. Given the exploratory nature of this qualitative study, such a research design is deemed to be appropriate. In designing the survey questionnaire, we attach particular importance to the following dimensions.

(1) Industry background

Shipping is a capital intensive industry characterized by high volatility and cyclicality. Thus the survey instrument should explore how shipping market cycle, company history and business strategy influence the financing and governance mechanisms chosen.

(2) Development of the financial system

The stage of development in the financial market, financial institutions' risk attitude toward shipping, and the capital adequacy rules as well as other regulatory limitations directly affect the financing options available to shipowners, and the relative costs and benefits of such options.

(3) Transaction-specific features

Due to its secretive nature and technical complexity, financing practices in the shipping industry may be unique compared with those in other industries. Thus transaction-specific characteristics (pertaining to shipping and navigation) and the effects on company's earning capability are considered.

(4) A holistic view of both the demand and supply sides

Following Williamson's (1985, 1996) argument that the supply of a good or service and its governance need to be examined simultaneously, the survey covers both shipping companies and capital providers. Moreover, since the financing opportunities/constraints and governance mechanisms may change in response to changing conditions (e.g. during a financial crisis), the survey explores the respondents' perceptions and practices both before and after the recent financial crisis[2].

The survey of the shipowners aims to solicit answers to the following key problems. What is the primary financing method actually used by Hong Kong shipowners? What would be the most favored financing method, if there were no constraints? What are the perceived advantages and disadvantages of the various financing methods? The questionnaire of shipowners consists of two main parts, each of which is briefly described below[3].

■ Part A. Companies' preference on financing instruments

Section 1- Company information
This part intends to collect some basic information about the respondent company, including its business area, history, fleet size, average age of fleet, acquisition activities in the past 5 years and whether the company is publicly listed.

Section 2- Preference over various financing methods
Respondents are required to indicate the primary financing approach that they rely on in vessel acquisition. Moreover, this part intends to find out the most preferred method for companies if there were no constraints on the available choices, as well as the factors that affect their choices.

■ Part B. Perception of financing instruments

Based on a careful review of the exiting literature, characteristics of various financing methods such as bank loan, public equity, bond issuance and leasing are listed in this part. The respondents are required to indicate the extent to which they agree with the statements. Through use of a scale in which number 9 represents "strongly agree" while number 1 stands for "strongly disagree", Hong Kong shipping companies' concrete perceptions of the specific methods are revealed. Moreover, it provides complementary explanations for their primary and most preferred choice in part A.

The draft questionnaires were distributed to a few industry practitioners for pre-testing. Valuable feedback and suggestions about the level of clarity, objectivity of questions, the accuracy or applicability of the answer options, and the amount of time spent on the questionnaire were collected. Some changes are made in the wording, scale and format, aiming to minimize ambiguity while maximizing the response rate. The respondents are also assured that all the data collected will be kept in strict confidentiality and the responses will be reported only in aggregate form.

The membership directory of shipowners, ship managers and ship operators in the Hong Kong Shipowners Association is used as the main source of the sampling frame, but other shipping companies with a presence in Hong Kong are also considered. A total of 32 ship-owning companies are selected as target. The questionnaire was delivered to a top manager by email and by post simultaneously. To encourage a higher response rate, the companies were assured that a copy of the final report would be provided to interested parties. Each questionnaire is accompanied by a stamp-addressed envelope which the respondent can use to return the completed questionnaire.

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[2] Our pre- versus post-crisis comparison focuses on the banks rather than the shipowners, as the impacts of the crisis are thought to be stronger and more relevant for the banks.

[3] The full questionnaires are available from the authors upon request.

The survey was conducted in late 2008 – early 2009. The response rate for shipowners is 47% and that for the banks is 42%. Given the relatively small population, these response rates are deemed to be reasonable and representative of shipowners and ship finance banks in Hong Kong.

One potential concern with survey research is the validity and reliability of the survey instrument. Reliability is defined as the extent to which the results are consistent over time and are an accurate representation of the total population under study (Golafshani, 2003). Internal consistency is one type of reliability measuring the extent to which the procedures assess the same characteristics. Cronbach's Alpha is usually used to assess internal consistency when the research instrument is uni-dimensional. In practical applications, a Cronbach's Alpha of around 0.5 is taken to suggest that the results obtained from the survey are highly correlated and that the instrument is stable (Nunnally, 1978). In this study, 30 statements are designed to measure shipowenrs' perceptions of 4 financing methods. The Cronbach's Alpha for each method is listed in Table 2. Overall, the results of the survey are correlated, indicating an acceptable level of reliability of the questionnaire, especially in the section of bank loan and leasing (Cronbach's Alpha exceeding 0.5), while the figures for public equity and bond are close to 0.5.

Table 2: Reliability test

Method	Bank loan	Public equity	Leasing	Bond	Total
Cronbach's Alpha	0.636	0.440	0.585	0.470	0.569

While reliability is concerned with the accuracy of the actual measuring instrument, validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. Criteria-related validity is one type of validity which assesses whether the items designed are representative of the research idea. In terms of contents of the questionnaire, the statements included in the questionnaire are all based on a thorough review of the literature and thus reflect specific characteristics of each financing method. Moreover, the correlation coefficients (Spearman's rho) between the score of each statement and the total score of each method are calculated to test whether the questions reveal shipowners' preference for a specific method. The results are shown in Table 3. Overall, there is a high correlation between the statements and the shipowners' preference for a specific method, especially for the items with correlations significant at the 1% level and 5% level. Thus the survey questionnaires are deemed to have good reliability and validity.

Table 3: Validity test of questionnaire for shipowners

Panel A. Correlations of statements of bank loan with shipowners' preference for bank loan

Spearman's rho	**Bank loan**
Relationship	0.423
Bank cost	0.600*
Terms	0.722**
Repayment	0.725**
Information	0.555*
Project	0.789**
Interest	0.415
Support	0.669**
Financial turmoil	0.020

Panel B. Correlations of statements of equity with shipowners' preference for equity

Spearman's rho	**Equity**
Quick funding	0.484
Equity cost	0.256
Attractiveness	0.271
Balance sheet	-0.038

Opportunity	0.309
Requirement	-0.026
Procedure	0.424
Control	0.653**
Disclose information	0.753**
Susceptible	0.335
Financial turmoil	0.544*

Panel C. Correlations of statements of leasing with shipowners' preference for leasing

Spearman's rho	**Leasing**
Leasing cost	0.366
Off balance	0.329
Exposure	0.549*
Residual	0.698**
Financial turmoil	0.754**

Panel D. Correlations of statements of bond with shipowners' preference for bond

Spearman's rho	**Bond**
Bond cost	0.431
Balloon	0.439
Tolerance	0.660**
Financial turmoil	0.713**

**, *: Correlation is significant at the 1% level and 5% level (2-tailed), respectively

4. Empirical results

4.1. Survey of shipowners

Respondents' information

The respondents' company profile is summarized in Figure 1 to Figure 6. Figure 1 suggests that the majority of the respondent companies are well established with a relatively long history. Figure 2 shows that the majority of the companies focus on the dry bulk and tanker sectors, accounting for 80% and 47%, respectively (companies may operate in more than one sector).

Figure 1: Company history

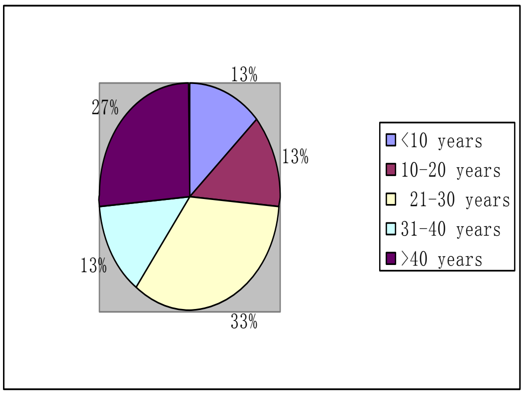


Figure 2: Business coverage

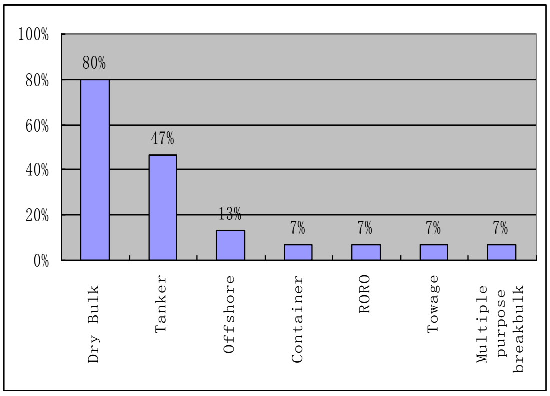


Figure 3 indicates that the majority of the companies (73%) possess fewer than 20 vessels. 13% of the companies have 31-40 vessels while 13% have more than 40 vessels. According to Figure 4, 47% of the companies have fleets with an average age of 3-10 years. For 20% of the respondent companies, the average fleet age is between 11 and 15 years. Another 20% of the companies have fleets with an average age between

16 and 20 years. Moreover, 13% of the companies have relatively young fleets, with an average age below 3 years.

Figure 3: Number of vessels

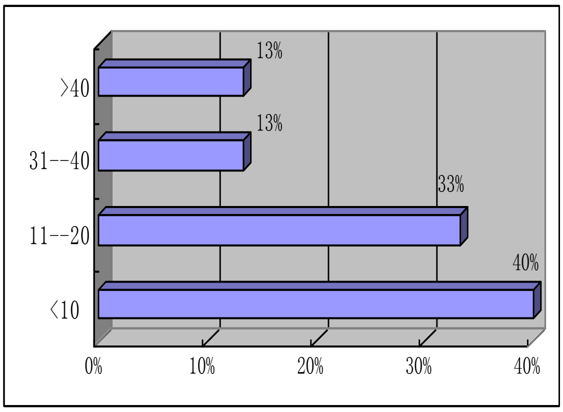
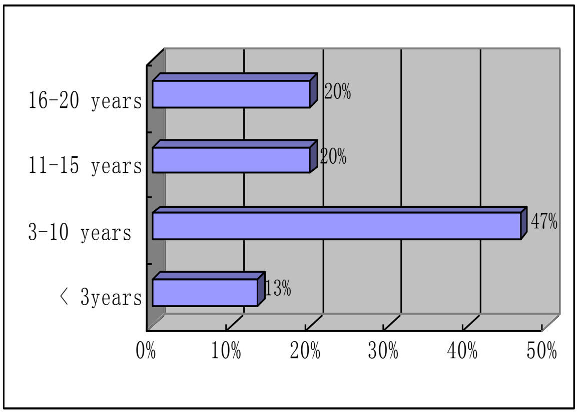


Figure 4: Average vessel age



The number of vessels acquired in the past five years is an indication of the extent of a company's participation in fleet expansion, which also drives the demand for financing instruments. Figure 5 indicates that most companies (40%) acquired fewer than 5 ships, suggesting a lack of active fleet expansion. 20% of the companies acquired 5-10 ships, and 40% of the companies purchased more than 10 vessels. As shown in Figure 6, 27% of the companies are public-listed while another 27% of them indicate a definite intention to go public.

Figure 5: No. of vessels acquired in the past 5 years

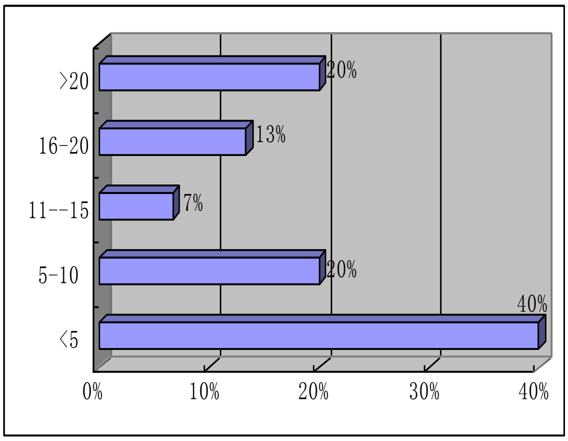
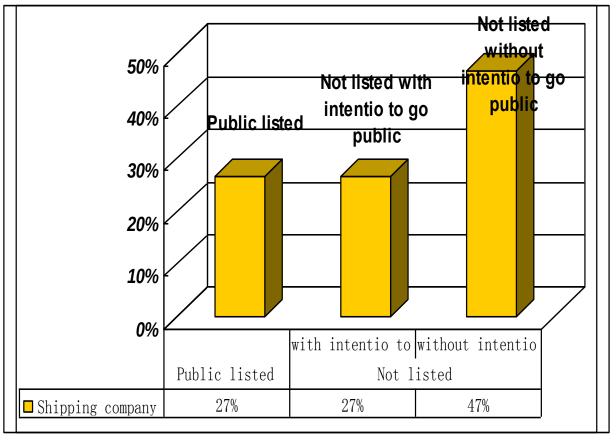


Figure 6: Companies' listing status

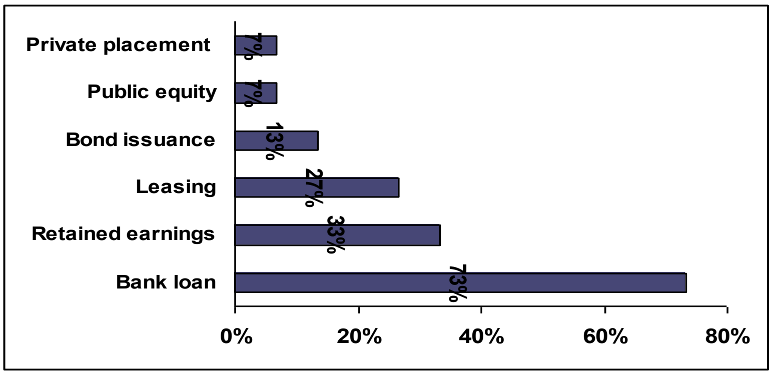


Shipowners' financing choices: what do they use, and why?

To facilitate an analysis of the perceptions of, and preference for, different financing methods and the characteristics of the respondent companies, the following definitions are adopted. Companies possessing more than 20 vessels are defined as large companies, while those with fewer than 20 vessels are defined as small companies. Meanwhile, companies with a history longer than 20 years and an average fleet age above 10 years are referred to as "long history" and "old fleet", respectively. Moreover, the companies which acquired more than 10 vessels in the past 5 years are deemed to be active in fleet expansion.

The respondents are required to indicate the primary financing methods which they rely on. The results are summarized in Figure 7. The majority of the respondents (73%) report using bank loan as the primary financing method. Next are retained earnings and leasing, which are the primary financing method for 33% and 27% of the companies, respectively. Bond issuance, equity and private placement are relatively less popular. There are four listed companies; interestingly, only one of them reports relying on equity issuance as its primary financing method.

Figure 7: Primary financing methods (Multiple choices allowed)



The preferences for various financing methods are further studied in terms of the companies' characteristics. The results are listed from Figure 8 to Figure 11.

Figure 8: Financing methods (history)

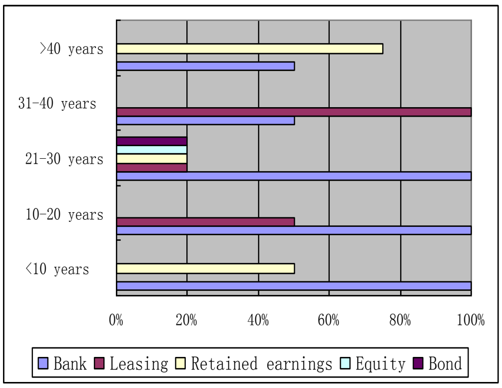


Figure 9: Financing methods (fleet size)

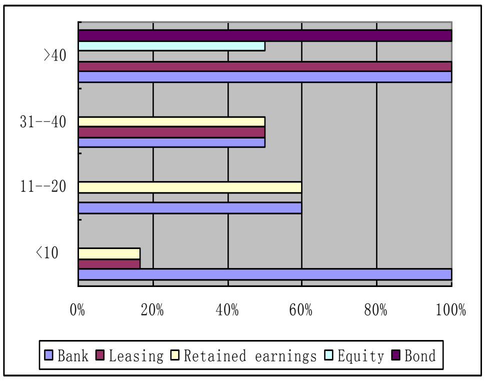


Figure 10: Financing methods (fleet age)

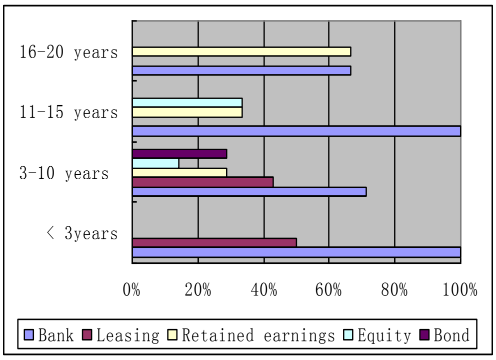
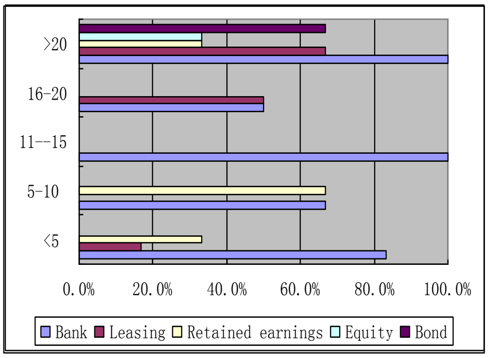


Figure 1: Financing methods (acquisition)



To explore the reasons behind shipowners' financing choices, the survey also asks the respondents to indicate the extent to which they agree or disagree with statements about the advantages and disadvantages of various financing methods. The results, summarized in Table 4, provide direct explanations for their reported financing choices.

Table 4: Comparison of shipowners' perceptions of different financing methods

Overall cost	Bank loan	✓ 43% of the respondents agree that the overall cost of bank loan is lower than that of the other methods.
	Equity	✓ Only 7% agree that the overall cost of equity is lower than that of the other methods.

	Bond	✓ Only 7% agree that the cost of bond issuance is lower than that of other financing methods.
	Leasing	✓ 20% of the respondents agree that the overall cost of leasing is lower than that of the other methods.
Access	Bank loan	✓ 93% of the companies agree that they have an existing relationship with banks.
	Equity	✓ 87% consider listing requirements as demanding. ✓ 80% consider the procedures for public offering as complicated.
Terms & Conditions	Bank loan	✓ 47% agree that terms & conditions are not rigid, especially for those companies that are not listed, those using bank loans as a primary method, and those with active acquisition. ✓ 53% of the respondents agree that repayment period is long. ✓ 27% agree that banks provide consistent support in periods of downturn, especially among companies using bank loans as a primary method and those with active acquisitions.
	Equity	✓ 93% agree that a listed company is susceptible to stock market conditions. ✓ Only 13% agree that shipping stocks are attractive to investors, indicating general disagreement.
	Bond	✓ 93% of the respondents show agreement with the statement "bond holders have low tolerance for default".
Impact on financial condition & management	Bank loan	✓ 67% of companies agree that information is not disclosed to outsiders. ✓ 53% agree that bank lending is project based with limited impact on group's financial condition.
	Equity	✓ The majority (60%) agree that disclosure of sensitive information in equity negatively affects the company, especially those with older fleets. ✓ 40% agree that equity dilutes company control and affects managerial efficiency, especially among those that are not listed, those with smaller sizes and older fleets.
Negative effect by the financial turmoil	Bank loan	✓ 60% agree preference for bank loan is negatively affected by financial turmoil, especially those with smaller and older fleets.
	Equity	✓ 67% agree that preference for equity is negatively affected by the financial turmoil, especially those with an intention to go public.
	Leasing	✓ Attitude toward leasing is slightly above neutral, with 53% agreeing that preference for leasing is negatively affected.
	Bond	✓ 60% agree that preference for bond is negatively affected by financial turmoil. There is no significant difference across groups.

The results suggest that bank loan is the main source of financing by shipping companies in Hong Kong, especially for the companies with shorter history (Figure 8), large-size fleets (Figure 9) and younger ships (Figure 10). Shipowners' reliance on bank loan is well known. Unlike equity financiers who require high rates of return (usually at around 15%-20% per annum) reflecting the industry's perceived high risk[4], shipowners can usually obtain a bank loan at around 1%-2% spread above LIBOR (Stokes, 1997). Flexibility is another advantage. As banks can expect to make a profit by lending to a credit-worthy borrower against sufficient security, the loan agreement is usually structured to give both the lender and the borrower the ability to adapt quickly to market changes. Such ex post cooperation and flexibility are of vital importance, especially when the market is in a downturn and borrowers are in need of consistent support. Moreover, as pointed out by Gong, Firth and Cullinane (2005), by using debt, shipping companies in effect obtain a valuable call option from the lender such that they have much to gain in a market boom but can limit their risk exposure in a market downturn[5].

[4] Contrary to conventional wisdom, however, recent research has found that shipping stocks have only about market average systematic risk. See Kavussanos and Marcoulis (2001) and Gong, Cullinance and Firth (2006).
[5] In effect, limited liability allows the borrower to default on the debt obligation. For this reason, the market value of debt is almost always lower (in some cases, substantially lower) than the face value (see Brealey and Myers, 2003). The problem is exacerbated

The above arguments are supported by shipowners' responses with respect to their perceived advantages and disadvantages of various financing methods, as summarized in Table 5. The shipowners report several advantages for a bank loan relative to other financing methods. First, the overall cost of bank loan is lower than that of the other methods, and access to bank loan is also easier. In contrast, the requirements and procedures for a public listing are deemed to be demanding while shipping stocks are not attractive to investors. Moreover, a public offering is thought to dilute company control and negatively affect managerial efficiency, especially for those companies with smaller sizes and older fleets. Second, unlike equity, sensitive information is not disclosed to outsiders in bank loan. Third, the terms and conditions in a bank loan are generally not considered rigid for the majority of the shipowners. In contrast, listed companies are susceptible to stock market conditions whereas bond holders have low tolerance for default. Overall, these results are consistent with the conventional wisdom, our above analysis and previous studies (e.g. Stokes, 1996, 1997; Grammenos & Arkoulis, 2003).

The survey also reveals some factors that may impede the use of a bank loan. First, the majority of the shipowners surveyed are of the view that the recent financial turmoil will negatively affect their access to bank loans, especially for companies with older vessels and small-size fleets. Second, for listed companies and those with small-size fleets, the terms and conditions of a bank loan are considered rigid. Third, the companies with small-size fleets are also of the view that banks do not provide consistent support in periods of downturn. While the first two pieces of feedback from shipowners inevitably reflect market reality, perhaps the last opinion expressed may be food for thought for service-oriented financiers, especially those looking for a long-term relationship.

4.2. Survey of banks

In order to gain a more comprehensive understanding of ship financing practices from both the demand side and the supply side, a survey targeting banks is conducted. A review of the literature (e.g. Grammenos and Xilas, 1996) suggests that in deciding whether or not to grant a loan, banks are primarily concerned with three main factors of consideration: security, marketing and quality.

- Security

A bank focusing on security seeks to minimize credit risk and maximize assurance. For example, banks seeking security are more concerned about the collaterals, such as a first preferred mortgage, assignment of insurance, and personal or corporate guarantees. In addition, a security-oriented bank focuses on shipowners' equity participation, shipping companies' debt-asset ratio, shipping market conditions as well as charter parties secured. We use 7 criteria in the questionnaire to gauge the importance banks place on security.

- Marketing

Marketing refers to a bank's appetite in fighting for market share. The marketing-oriented banks are more likely to devote a higher proportion of their loan portfolio to shipping, provide more competitive pricing, and participate in as many loans as possible (via syndicated loans). We use 5 criteria in the survey to gauge the importance banks place on marketing.

- Quality

As the shipping market often fluctuates sharply and the floor price of a vessel could be easily breached, banks may care more about the earnings potential and the quality of projects, that is, whether cash flows from the prospective investment can sufficiently meet the financing expenses[6]. Thus when assessing a specific

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when the borrower is a one-ship company. Recognizing this, lenders must conduct a very careful credit analysis and they often require various collateral securities from the borrower as well as guarantees from the parent company (see Grammenos, 2002). Nevertheless, a cost of borrowing at around 100 basis points above LIBOR is low, and some commentators have blamed "cheap finance" as fuelling industry over-supply (see, for example, Stokes, 1997).

[6] Note that quality as defined here is essentially equivalent to "cash flows" emphasized in Grammenos and Xilas (1996). They consider cash flows from the financed project as the "first way out" and security collaterals provided as the "second way out".

shipping transaction, the banks that focus on the quality of project will pay more attention to features such as profitability record, accident record, vessel type, age of vessel, flag of vessel, cash flow projection as well as pricing (margin & fees). We use 7 criteria in the questionnaire to gauge the importance banks attach to quality.

The three basic dimensions discussed above cannot be attained simultaneously, as pursuit of one goal will inevitably result in deviation from another. For instance, banks that care about the quality of a project sometimes may, to some extent, move away from the pursuit of market share, while banks that stress market penetration may sometimes sacrifice security. Thus in reality, one bank may place greater emphasis on one particular aspect over another.

In our survey of banks, we ask the respondents to indicate the extent to which they agree or disagree with statements related to one of these three dimensions. The results will add up to a total score for each bank, which allows us to identify to which dimension a bank attaches greater importance in its assessment of shipping loan applications. Moreover, in this survey, first-hand information about banks' attitudes before and after the financial turmoil is collected and compared. The aim is to examine whether there are differences (post- versus pre-financial crisis) in banks' lending practices, for example, with respect to loan-to-value ratio, tenor, repayment schedule, competitive factors as well as other major factors of consideration. The key findings are summarized below.

Financing products and service

As shown in Figure 12, all of the banks provide ship financing before the financial turmoil; however, one respondent bank quitted the ship financing market after the financial turmoil. Moreover, the number of banks that provide corporate loans and working capital line has also dropped after the financial turmoil.

Loan portfolio in Asia allocated to shipping

According to the survey, the number of banks that allocate more than 30% and 11-20% of their loan portfolio to shipping has significantly decreased after the financial turmoil while the number of banks in the 6-10% bracket has increased (see Figure 13).

Figure 12: Financial products/services provided by banks

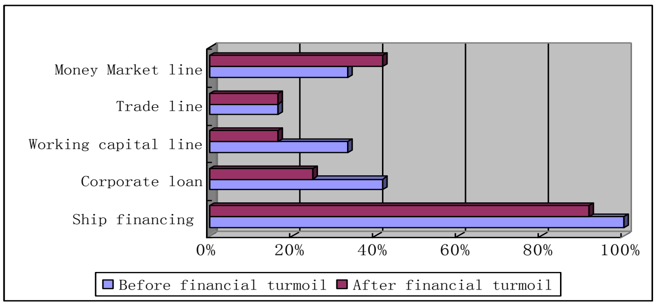
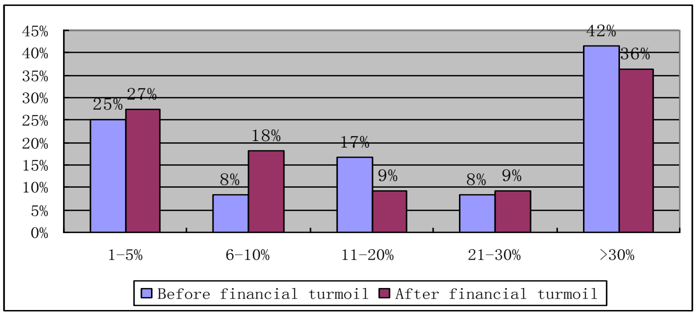


Figure 13: Percentage of loan portfolio in Asia allocated to shipping



Maximum ratio of the loan amount to vessel price

According to Figure 14 and Figure 15, 33% of the respondents indicate that before the financial turmoil, they allow the maximum ratio of loan amount to vessel price (LTV) to be above 80% for a new building; 58% of the banks have maximum LTVs between 70% and 80%. In contrast, after the financial turmoil, only 36% of the banks maintain maximum TLVs above 60%; for the majority of banks (64%) the maximum LTV has dropped to 50%-60%.

Figure 14: Max LTV (before financial turmoil)

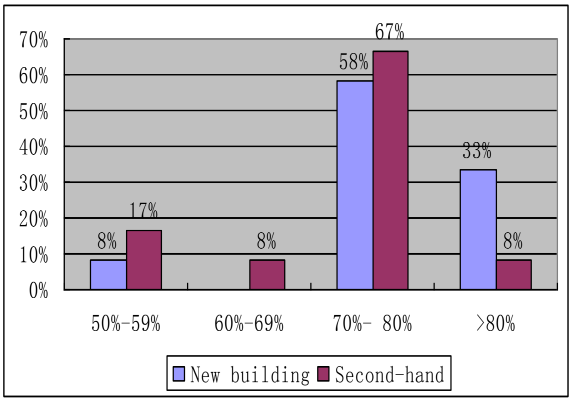
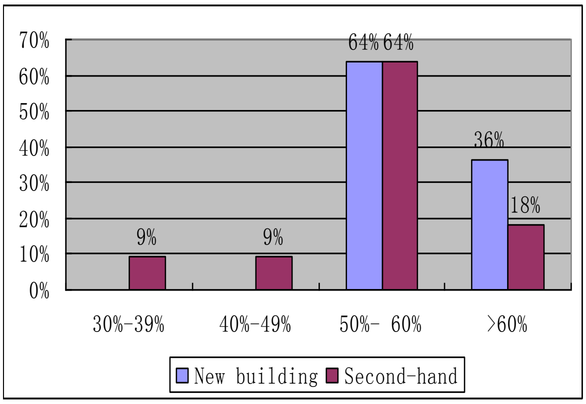


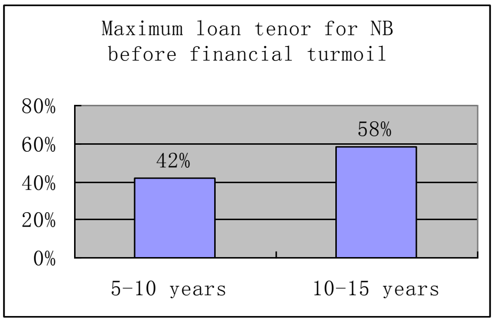
Figure 15: Max LTV (after financial turmoil)



Maximum loan tenor

Figure 16 and Figure 17 indicate that, before the financial turmoil, 58% of the banks indicate that the maximum tenor for a new building is between 10-15 years, and the maximum tenor for other vessel types is between 5-10 years. After the financial turmoil, none of the respondents lends money for more than 10 years. 45% of them have a maximum tenor between 8-10 years while another 45% have the maximum tenor falling between 5 and 7 years.

Figure 16: Maximum loan tenors for new building



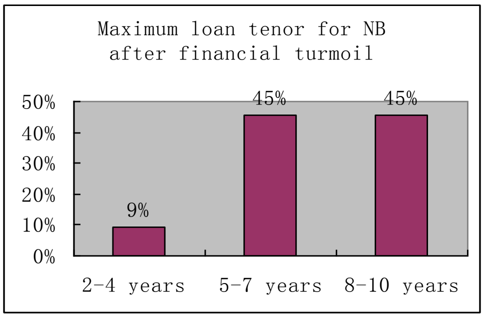
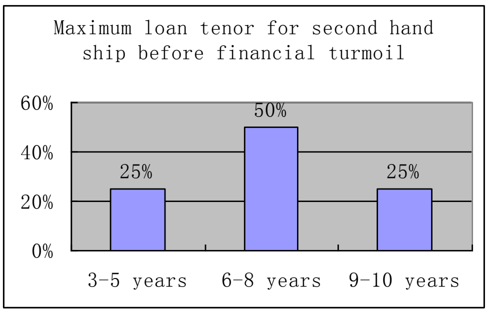
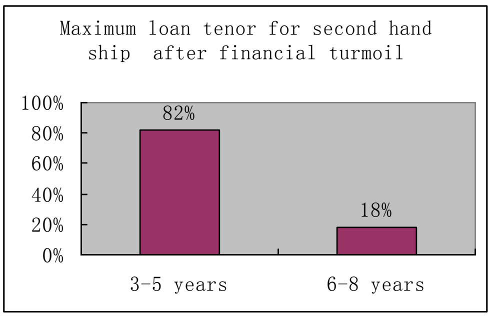


Figure 17: Maximum loan tenors for second hand ship (10 years old)

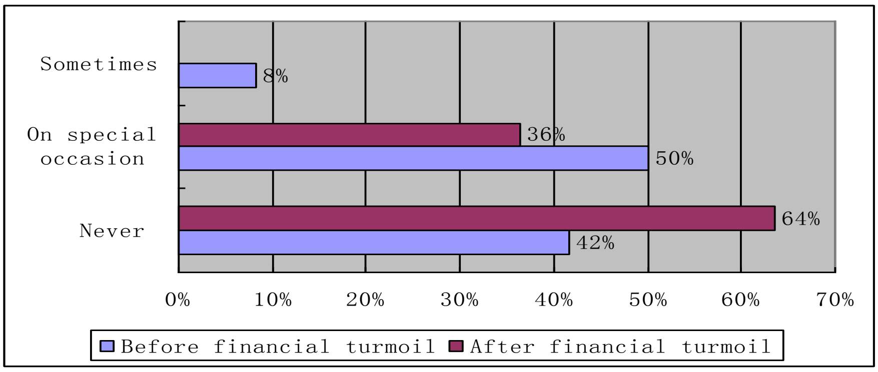




Participation in syndicated loans

Figure 18 shows that compared to the pre-crisis period, the percentage of banks that have never participated or do not intend to participate in syndicated loans has increased from 42% to 64%. This indicates that some banks have withdrawn from syndicated loans due to the credit squeeze.

Figure 18: Participation in syndicated loan



Thus, as an interim summary, the results of the survey clearly indicate that the financial turmoil has significantly affected banks' lending practices in shipping. The loan portfolio allocated to shipping has significantly shrunk. Moreover, there has also been a contraction in the extent of financing provided, as revealed by more conservative LTVs, shorter loan tenor, and fewer activities in syndicated loans. To a large extent, the retreat from shipping is an inevitable result of, and rational reaction to, the serious credit crunch faced by all financial institutions after the financial crisis. Future research is warranted that empirically examines the effects of banks' withdrawal from shipping on individual companies. Conceivably, larger shipowners, those with a long-term relationship with banks, and those with a stronger balance sheet (e.g. lower debt ratios), may be less severely affected. They may even gain a competitive advantage over other weaker competitors who are more seriously affected during the financial crisis. These, however, remain speculations until the empirical evidence comes in.

Ranking of three basic dimensions of bank lending before and after the financial crisis

To further examine the relative importance attached to different factors in banks' loan granting decisions, the Analytical Hierarchy Process (AHP) is used in the subsequent analysis. AHP, as put forward by Satty (1980, 1986) and others, is a multiple-criteria decision-making method designed to compare the alternatives evaluated with respect to several criteria. Briefly, AHP is based on hierarchies and relative comparisons of the attributes of the alternatives. The structure of hierarchies permits the decomposition of decision goals to criteria, which help the human mind to cope with the complexity of multiple goals. Once the hierarchy of a problem is set the decision maker is concerned with weighting the criteria and alternatives. Thus one must first establish priorities for the criteria with their relative importance and then proceed with the alternatives.

Based on the aforesaid three dimensions (security, marketing and quality) and the concrete criteria representing them, the analysis of the relative importance of these dimensions can be approached as a problem in multiple-criteria decision-making. By using the feedback from the 12 banks that completed and returned the questionnaires, an attempt is made to identify which dimension has been given high priority. Take the dimension "security" as an example; it is decomposed into 7 criteria in designing the questionnaire. These criteria receive ratings by the respondents. By applying AHP, the final score for security can be obtained. Moreover, by comparing the scores of the three dimensions, their relative importance can be determined. Applications of the AHP method in shipping and transportation studies have been growing in recent years (see, for example, Wong, Yan and Bamford, 2008; Song and Yeo, 2006). For brevity we report only the summary scores below but details are available from the authors upon request.

As reported in Table 5, before the financial crisis, the score for quality is the highest with a mean of 0.704, with 58% of the banks placing a priority on quality. The dimension accorded the second greatest emphasis is marketing with a mean of 0.578. 42% of the banks are most concerned most about marketing. Security received the least importance, with a mean score of 0.53. After the financial crisis, one bank quitted from ship financing. Among the remaining 11 banks, 91% give obvious precedence to quality, with the mean score increasing from 0.704 to 0.836. Security has received more attention, now taking the second place with the mean score increasing from 0.53 to 0.67. However, banks are now attaching less importance to marketing, with the mean score decreasing from 0.578 to 0.45.

Table 5: Summary scores for three key dimensions of bank lending

	Security	Marketing	Quality
Before crisis	0.532648307	0.5785536	0.7039023
After crisis	0.676550709	0.45378463	0.8357697

In summary, therefore, the AHP analysis reveals several interesting findings. First, quality is the most important consideration for banks. This is true both before and after the financial crisis. However, banks are placing even greater emphasis on quality after the financial turmoil. Overall, this indicates that banks are concerned about the earnings potential of specific transactions. Second, security is the least important aspect of the three dimensions before the financial turmoil. This suggests that before crisis struck, banks were not satisfied by the mere provision of guarantees, nor were they happy with the prospect of becoming shipowners in case of default. However, there is evidence that after the financial turmoil, more attention is being paid to security. Third, marketing was rated the second most important consideration before the financial turmoil. This indicates that there was fierce competition in the ship financing market and many banks were more concerned about market share. However, after the financial turmoil, banks are increasingly turning to security and lowering their appetite for risk.

5. Concluding remarks

This study provides direct evidence on the perceptions of, and rationales for, preferring different financing methods from the perspectives of Hong Kong shipowners. Results obtained from the survey of shipowners suggest that bank loan remains the main source of financing by shipping companies in Hong Kong, with the main perceived advantages being lower cost, easier access, relatively flexible terms and conditions as well as non-disclosure of sensitive information. Results obtained from the survey of banks suggest that the loan portfolio allocated to shipping and participation in syndicated loans have significantly shrunk since the financial crisis. As for the major factors of consideration in their credit assessment, banks used to focus on quality, followed by marketing and security. After the financial turmoil, the concern for quality has increased even more, but security has been attached greater importance, whereas marketing has received less emphasis.

Overall, the evidence indicates a lower appetite for risk-taking and higher requirements for collaterals and guarantees. For both bank regulators and shareholders, the apparent shift towards prudence may be good news, but for borrowers, this means that they will have to present banks with strong corporate fundamentals and incur higher borrowing costs, or they will have to turn elsewhere for their funding needs. While large shipowners with a close banking relationship and proven track record may be better able to weather the storms in the short turn, in the longer run it behooves all shipowners to more actively explore alternative sources of financing, perhaps by embracing modern concepts of corporate governance and making themselves more visible/transparent to the general public. Unless traditional shipowners adapt themselves to the continuously changing environment, their fortunes may rise and fall in the turbulent sea of changes. Some may not survive the next financial tsunami, especially if it coincides with a shipping downturn.

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An Analytic Hierarchy Process Approach in Formulating Growth Strategy of a Port System: A Case Study of Aceh Ports in Indonesia

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Abstract

The main objective of this study is to investigate the growth strategy of Aceh's ports in order to develop a better position of those ports in the dynamic and competitive environment along the Malacca straits. Using the analytic hierarchy process (AHP) approach, this study examines priority perspectives on strategy formulation from 25 individuals representing relevant parties in Aceh port industry such as government officials, port authorities and managements, experts, academicians and consultants, and port user associations. Six potential strategies related to resources, competencies, market share, opportunity share, cooperation, and competitiveness were examined. The findings show that the resource-based strategy and the competence-based strategy are ranked as first and second important strategy respectively while the opportunity share strategy ranked as the least important strategy. This study provides new insights into the implications of using various strategy formulations for port growth in developing countries and provides a significant practical contribution to the port authorities.

Keywords: strategy analysis, port system, AHP technique, infrastructure development, Aceh, Indonesia

1. Introduction

Many countries have relied very much upon the port and container system for their international trade especially through ocean liners. For instance, at least 85 per cent of China foreign trades (Peng & Xueyue, 2003) and 89.6 per cent of the global trades (UNCTAD, 2008) were transported using the sea transportation.

The number and type of vessels that pass through the Straits of Malacca is increasing rapidly. More than 50,000 ships use the Straits yearly (Zubir, 2007) and more than 30 per cent of the vessels are containerships (The National Maritime Portal Malaysia, 2008). Most of these containerships berth at several ports in the straits to load and unload their containers. However, traffic congestion, growing ship sizes, market growth, and depth limitation faced by the Straits contribute negatively to the future development of the ports (UNCTAD, 2008) especially in the region. As the statistics indicates, commodities demand through containerization has been increasing vastly (Port Aid, 2008). Therefore, well-defined strategies are needed for the growth of the ports in the region such as the development of new or up-graded ports in the deepwater of the region that may function as *transshipment* or *hub port.* This will perhaps be a sound strategy to sustain competitive advantage.

Concomitant with the increase in containerships, the throughputs activities at several ports in the region and the World are also significantly increasing (PSA, 2010 and Port Aid, 2008). The average increase of container throughputs for the world is at 6.7 million TEU per year. If we look at the throughputs activities at the top 10 main container ports in South Asia where the Malacca Straits is located, we will find that there is a 7.95 million TEU increase or 15.05 per cent for the year 2007 as compared to the year 2006 (Table 1).

Table 1: Comparison of throughputs activities and growth in South Asia's major ports

<table>
<tr><th rowspan="2">Port Rank*</th><th colspan="2" rowspan="2">Region, Country and Port Name</th><th colspan="2">Throughputs</th><th colspan="2" rowspan="2">Percent Growth</th></tr>
<tr><th>2007</th><th>2006</th></tr>
<tr><td>1</td><td>Singapore</td><td>Singapore</td><td>27,900,000</td><td>24,792,400</td><td>12.53</td><td rowspan="10">15.05</td></tr>
<tr><td>2</td><td>Port Klang</td><td>Malaysia</td><td>7,118,714</td><td>6,300,000</td><td>13.00</td></tr>
<tr><td>3</td><td>Tanjung Pelepas</td><td>Malaysia</td><td>5,470,000</td><td>4,770,000</td><td>14.68</td></tr>
<tr><td>4</td><td>Laem Chabang</td><td>Thailand</td><td>4,848,478</td><td>4,215,817</td><td>15.01</td></tr>
<tr><td>5</td><td>JNP</td><td>India</td><td>4,060,000</td><td>3,300,000</td><td>23.03</td></tr>
<tr><td>6</td><td>Jakarta</td><td>Indonesia</td><td>3,900,000</td><td>3,347,000</td><td>16.52</td></tr>
<tr><td>7</td><td>Colombo</td><td>Sri Lanka</td><td>3,381,240</td><td>3,079,132</td><td>9.81</td></tr>
<tr><td>8</td><td>Ho Chi Minh</td><td>Vietnam</td><td>3,200,000</td><td>2,532,000</td><td>26.38</td></tr>
<tr><td>9</td><td>Manila</td><td>Philippines</td><td>2,800,000</td><td>2,638,000</td><td>6.14</td></tr>
<tr><td>10</td><td>Surabaya</td><td>Indonesia</td><td>2,109,677</td><td>1,859,737</td><td>13.44</td></tr>
<tr><td></td><td colspan="2">Total</td><td>64,788,109</td><td>56,834,086</td><td colspan="2"></td></tr>
</table>

* Ranking is based on 2007 throughputs

Data source: Cargo Systems (2009) and Port Aid (2008), modified by the authors

Aceh, located at the northern tip of Sumatra Island and the west-gate keeper of the Malacca Straits, geographically offers important shipping lanes throughout the region and to ports' hinterland of Indonesia. Strategically, with its rich resources and its position flanked by the fastest growing regions of the world's economy, China on the right side and India on the left side, and its location in one of the major markets of the world's container shipping, Aceh ports naturally has the opportunities and the capabilities to grow.

Recently, the Government of Aceh announced a plan to upgrade and redevelop several ports in Aceh with the assistance of the *United Nations for Development Programs* (UNDP) and other bodies (Aceh Government, 2008). Aceh port system comprises of eight ports and five of them face the Malacca Straits. Two of them are deepwater functioning ports (UNDP, 2008) i.e. Sabang and Lhokseumawe Port. The position of Sabang Port as a centre for trading has been reconsidered since 1993 in relation to the establishment of *Indonesia, Malaysia and Thailand's Growth Triangle* (IMT-GT). Sabang has been stated as *The Integrated Economic Development Region* (KAPET) during President Habibie and as a *Free Trade Zone* (FTZ) and a *Free Port Zone* (FPZ) by President Wahid.

Aceh, geographically, has advantages of being located at one of the world busiest shipping routes of the Malacca Straits (Figure 1). With this position, Aceh's ports provide broad accessibility to shippers in addition to its position within IMT-GT regions that have a lot of unique resources that can be used to complement the port's growth. However, despite having those values and resources, Aceh's port system is still having problems to grow as major and dynamic ports in Indonesia and in the region. At one point, as pointed out by some abovementioned authors, many ports including Aceh ports are facing problems of ill-devised and poorly implemented strategies and of unclear mechanisms of port growth in all aspects. At the same time, Aceh ports are surrounded by and are in the shadow of world huge and busy ports like the Port of Singapore, Port Klang and Port of Tanjung Pelepas (PTP) that are always enhancing their capabilities and values making it extremely difficult for other ports in the region to compete.

2. Growth Strategies for Aceh Ports

Apparently there is no single strategy can be considered as powerful enough for the growth strategy of Aceh ports. Devising and formulating various strategies is likely the best thing that the ports can strive for. Each strategy is not superior to the other in general, but appropriateness of the use of the strategy must take into account the levels of competitive environments. There are at least six strategies that Aceh ports can consider for growth (see Figure 2). In some literatures, capability or competency is categorized separately from resource-based strategy but in this paper we describe it jointly simply because capability and competency is part of the ports resources.

2.1. Resource-Based Strategy

In general, resources can be defined as any tangible (such as personnel and major items of equipment, supplies, money, data, technology, location, and facilities) or intangible entities (time, skill and knowledge, reputation, loyalty, capability and competency) that are available (legally) to a firm for performing operations and accomplishing assignments. We can simply define resources as any factors (assets) that a port can utilize as inputs in the port's operation process.

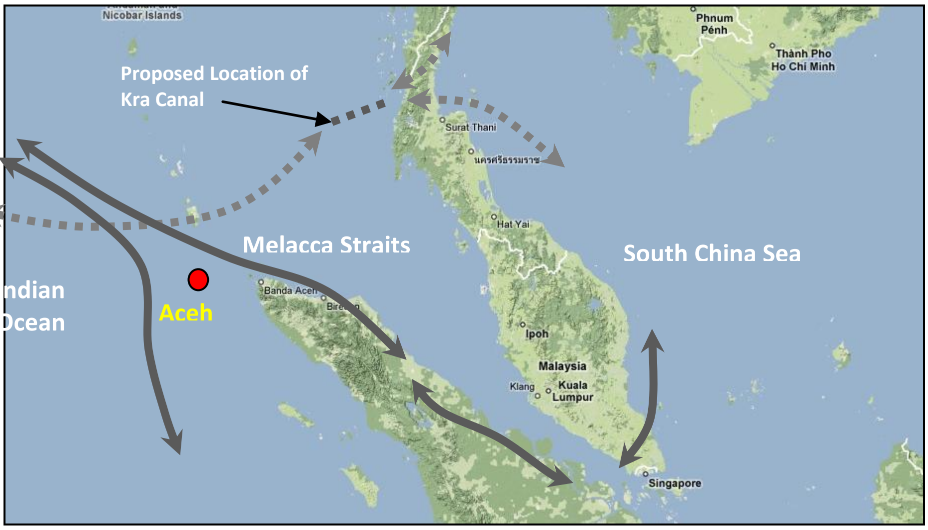

Figure 1: Strategic location of Aceh's port system
Source: Authors (modified from Google Maps: maps.google.com)

As in normal business environment, port resources can also be divided into internal resources and external resources (see Table 2). The internal resources are resources that exist within the port while the external ones are all the resources outside the port which are not the property of the port but still can be utilized by the port directly or indirectly through certain conditions such as alliances. In any port, resources play an important role in contributing to the port's growth as well as in achieving competitive advantage of a port (see figure 3). From the figure, a port that is struggling to achieve sustainable growth and competitive advantage should employ unique tangible resources combined with core and precise intangible resources. Growth, no matter how big or small, is the objective of any firm including a port and is the *sine qua non* of a port's industrial success, whereas sustainable growth and competitiveness are the strategic ambitions of any port.

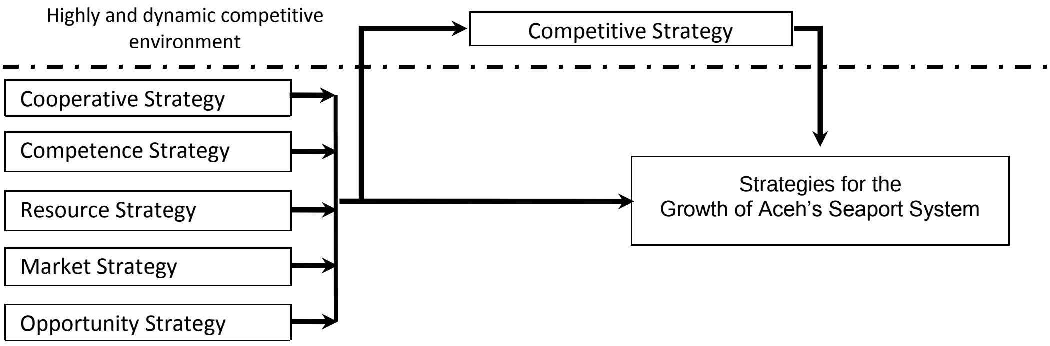

Figure 2: Concept for Growth Strategies of Aceh's Port System

Table 2: Port's resources diversification

Internal		External	
Tangible	**Intangible**	**Tangible**	**Intangible**
Such as: - Personnel	Such as: - Time	Such as: - Expertise	Such as: - customer loyalty

- equipment - infrastructure - money - Information system - technology - location - accessibility - facilities	- skill and knowledge - reputation - competency - capability	- infrastructure - technology - market - network - industrial area - environment	- external expertise - supportive policy/regulation

[Source: Subhan & Bashawir (2008)]

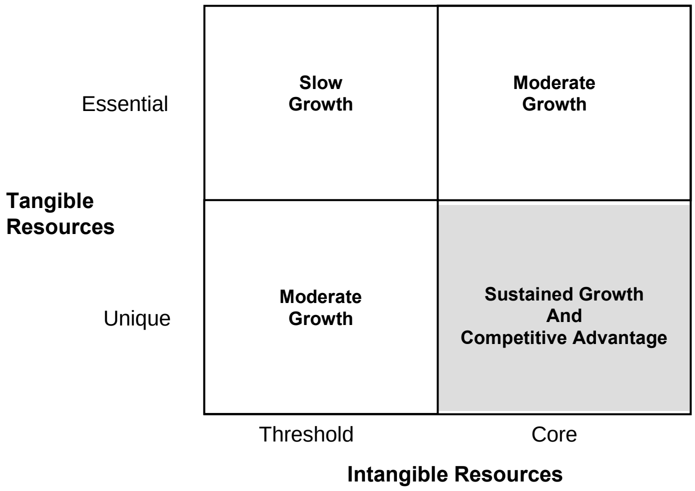

Figure 3: The Role of Tangible and Intangible Resources in relation to Growth and Competitiveness
[Source: authors]

In economics, growth is always reflected by the increase in the production of goods and services, and sometimes incomes, over time through economic activity. Penrose (1956) stated that the factors that determine the size of the increments of expansion that any industrial firm can undertake within a given period of time are factors that determine the rate of growth of the firm. For a port, growth should be defined as the increase in size, number, volume (quantity) or value, strength (quality) of productivities, services, and competitiveness *vis-à-vis* its competitors that a port can achieve within a particular time.

Common factors of ports' problems that adversely affect their growth and efficiency are the lack of resources available to them such as land availability for expansion, deep-water requirements for handling larger ships, increased port traffic, environmental constraints and local opposition to a port's development (Notteboom & Rodrigue, 2005).

2.2. Competence-Based Strategy

The ports' capability in handling the container throughputs is an important measurement employed to assess the ports' growth and performance. If we look at table 1 above, all the ports' performance is based on the throughputs handling per year. Some ports maintain their performance at 6-10 per cent increase per year while others strive to increase performance at 20-25 per cent per year.

For instance, PTP port in Malaysia started its operation in 1999 with a throughput of only 20,696 TEU that year but it has successfully increased the throughputs dramatically in 2007 to 5.5 million TEU. This achievement place the port as the third busiest port in the region. With the current infrastructure and the current plan for expansion, the port will be capable of handling 8 million TEU annually, to put containers into 29,785 TEU slots with storage capacity of 200,000 TEU. Besides that, the port is also capable to handle giant containerships currently being operated with 14 meters draft, and is able to handle future containerships whose draft are less than 19 meters. Moreover, with the dragging works, the port will be able to handle any future sized container vessels (Subhan & Bashawir, 2008).

Aceh ports should formulate a capability or competence-based strategy in accordance to this tendency. They can start with a small amount of container throughputs but with the plan to increase the capability from time to time. Skill and knowledge in enhancing the level of effectiveness and efficiency of the port performance should be enhanced to improve reputation in the market. High capability to handle port equipments such as crane, storage, pilotage, and towage or the ability to handle information system and technology is of utmost important in the ports' operation. The Port authority should also be able to connect or link the ports with logistics supply chain and intermodal transports. Concomitant with these activities, the ports should also develop customer loyalty, make use of a supportive policy and regulation by the government and exploit external expertise through strategic alliances with other potential partners. The most important thing that the Aceh port authority should remember is that all activities that are intended to increase the level of competency should be value-added, unique, inimitable, durable, and un-substitutable. Management of Aceh ports should also apply a variety of strategies[1] to improve the organizational and the operational performances including the modernization of the ports' administration and management; liberalization or de-regulation of the ports' services; commercialization; corporatization; and privatization. In this regard, Aceh can emulate Malaysia in managing the ports as aptly described by Tull & Reveley (2001) that a sound management and a competitive environment are central to port efficiency.

2.3. Market Share Strategy

The ports need to evaluate the current logistics market that exists. Understanding the market's uncertainty and evaluating low, moderate, and fast growing markets and new markets are some of the most crucial actions that the ports' authority should do as promulgated by many authors. In addition, developing a new market or entering a market with least number of rivals or serving the un-served costumers are alternative strategies that the ports can consider. The first mover normally enjoys all the advantages without much hassle (Porter, 1990).

In relation to market share strategy, Porter (1990) opined that there are three strategies that a firm or port can adopt i.e. cost leadership, differentiation, and focus. To apply this for Aceh ports, they can focus on the diversification of market such as bulk, break-bulk, non-bulk or container cargoes at the beginning stages. However, a plan for specific market should be promulgated in order to implement differentiation, cost leadership and focus in services. For example, the Aceh port system can focus on entering the container market with one deep-sea port as transhipment hub port while others can be feeder ports or distributing ports.

2.4. Opportunity Share Strategy

Opportunity comes in relation to one or more events at a time. Understanding and capturing opportunities is an important strategic activity for the ports in formulating strategies for growth. In the case of Aceh, the opportunities have been available by the growth in capacity, size, and draft of containerships, the growth of cargo market especially container market in the region, located at the world busiest container traffic of the Straits of Malacca, an un-served big hinterland of Sumatera, availability of natural deep-sea for accommodating mega containerships with high draft, and the unavailability of transhipment hub port at the western part of the straits. As such the Aceh Ports can be considered as first movers in the industry in that particular area.

It is estimated (based on Table 1) that about 100 million containers (TEU) pass through Aceh Sea annually. With this amount of container market and large number of the ships, it is a huge opportunity for Aceh ports to grow. In addition to this market, Aceh ports should also look at the unserved hinterland in Sumatera Island or even the whole of Indonesia and other parts in the region. The fact that the port of *Belawan* in North Sumatera being the only container port in Sumatera is currently facing some difficulties and limitations to grow and sustain competitiveness following the fast growing market and maritime technology and highly competitive environment in the region should provide opportunity to the Aceh ports. If the Aceh port system can

[1] The World Bank Port Reform Tool Kit, p.38

capitalize on this and formulate a sound strategy to serve the un-served hinterland of Sumatera and complement the port of Belawan, then the Aceh ports can get access to a fast growing port in the region. At the same time, cost leadership, differentiation, and focus should be taken into account in formulating this opportunity.

2.5. Competitive Strategy

In a highly competitive environment, competitive strategy plays an important role for a port to grow and sustain competitive advantage. The aim of the strategy is to compete with its rivals and sustain growth. To achieve this, ports have to create and sustain core businesses and services that are unique to the port and superior to competitors. In addition to the uniqueness, the ports have to think about durability, inimitability, and substitutability and at the same time create values to the businesses and services. These things should be tailored either to shippers and their ancillary service providers or to inland logistics service providers. As pointed out by Porter (1990), those areas that should be given great attention are cost leadership, differentiation and focus of businesses and services.

As a small ports that intent to grow, Aceh ports should not compete with more established port like the Ports of Singapore and Port Klang but form strategic alliances with them to grab opportunities, learn skills and competency, and deploy their expertise and resources to support their growth and to some extend to rise up to the competitiveness of the ports. At the same time, Aceh ports have to strengthen the infrastructures, reformulate functions and strategies, and increase investment by identifying, allocating and enhancing resources values.

2.6. Cooperative Strategy or Strategic Alliances

Resources to any firms including ports are something limited in nature. While competitiveness is continuously growing, the ports should think of how to increase competitive advantages of their ports even though their resources are limited. The ports have to add values on the resources and keep strengthening and enhancing those values continuously as described in the competitive strategy. Another effort that the ports can do is create cooperative strategy or strategic alliances.

By strategic alliances, the ports establish cooperation between the ports and other independent firms which can be other ports or logistics companies or other related service providers. In forming strategic alliances, the ports may choose to carry out one or more projects or specific activities jointly where in certain conditions allow members of the alliances to deploy their necessary skills and resources to perform the tasks. In many cases, resources provided by alliance partners from the alliances were able to strengthen their competitive position.

To grow and achieve sustainable competitive advantage, Aceh ports should form strategic alliances with several firms and service providers. Alliances with major ports in the region such as the Port of Singapore, Port Klang, and PTP sound a good strategy since they have superior capability and competency as well as resources that Aceh ports can learn and use. Another alternative is to form alliances with ports in the worlds fastest growing economies like, China and India as these two economies promise a very high growth container market for the ports. Cooperation with other multimodal transport firms, shippers, and inland logistics service providers is necessary to ensure the smooth distribution of the commodities to the ports. At the initial stage, Aceh ports should collaborate with as many parties possible and gradually reduce the alliances selectively to those parties that strategically present benefits and advantages to Aceh ports.

3. Method and Analysis

This study employs the *analytic hierarchy process* (AHP) approach in the analysis to derive the best growth strategy for Aceh port system based on quantitative data gathered from relevant parties in Aceh port industry such as government officials, port authorities and managements, experts, academicians and consultants, and port user associations. Details and procedure of analysis using the AHP is shown below.

3.1. AHP Procedure

AHP is a theory of measurement that is widely used in industries as a tool to make important decisions related to business, resource allocation, problem priority identification, performance evaluation, and many more (Song & Yeo, 2004; Vargas, 1990). AHP is based on the principle that, to make decisions, experience and knowledge of people is at least as valuable as the data they use (Vargas, 1990). In this study, AHP is used to formulate growth strategy for Aceh port system.

The data used in this study for AHP analysis was obtained through the questionnaire designed specifically for AHP purpose. An instruction to the respondents on how to answer the questions was presented in the questionnaire. Respondents were also given a brief description of the AHP method for analysis and its benefit.

Respondent of informants in this study were individuals from or representing relevant parties in Aceh port industry such as government officials, port authorities and managements, experts, academicians and consultants, and port user associations who have engaged or are involved in the formulation of port strategies in Aceh. We can divided the respondents' background into 9 different groups or factions in Aceh, they are (1) Government officials,(2) Members of local parliament, (3) Members of port authorities and specific economic development authorities, (4) Port operators, (5) Academics whose background relates to port management, (6) Architects and consultant in port planning and development, (7) Professional associations relate to port business, (8) Port users, and (9) Other institutions including international organizations whose works relate to port development in Aceh.

The analysis associated with AHP requires three steps (Song & Yeo, 2004), namely: (1) development of a hierarchical structure for analysis (Figure 4), i.e. identification of goal that wants to be achieved, development of criteria that are going to use in the analysis, and identification of several alternatives that need to be chose in the analysis based on the priority; (2) making pair-wise comparisons to yield priorities for the detailed elements of each level, i.e. for every criterion and alternative; (3) synthesising the priorities into composite measures of the decision alternatives or options.

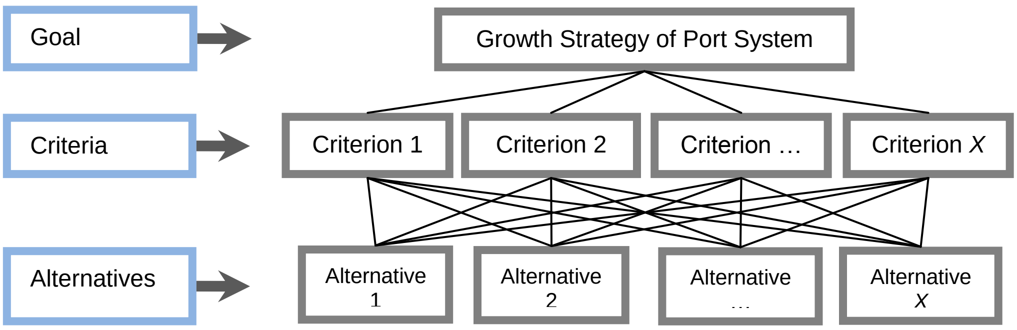

Figure 4: Hierarchy analysis structure for AHP approach

In the first step, the ultimate goal of the assessment using AHP should be clarified in which in this study the goal is to select the most appropriate strategy based on the hierarchy assessment from the six growth strategy choices or alternatives for Aceh port system, namely: resource-based strategy, competency-based strategy, market-based strategy, opportunity share strategy, competitive-based strategy, and cooperative-based strategy.

To select alternatives for the growth strategies, a set of criteria need to be identified. In this study, four criteria have been used to evaluate and to select the alternatives, namely: (1) Suitability - whether a chosen strategy is suitable with organizational capabilities, position and surrounding environment, and whether a chosen strategy is suitable with the organizational objectives and expectation and its *stakeholder*, (2) Acceptability - relates to expected results from a strategy involving profit, loss, risks, and reactions from *stakeholder*, (3) Feasibility - whether a firm has resources and competencies to implement a chosen strategy, and (4) Sustainability - how far a chosen strategy can be remained or sustained as the best strategy for that firm. Thus, the structure for

AHP analysis as shown in Figure 4 above has been transformed to as shown in Figure 5 below based on the goal, criteria, and alternatives for growth strategies for Aceh port system.

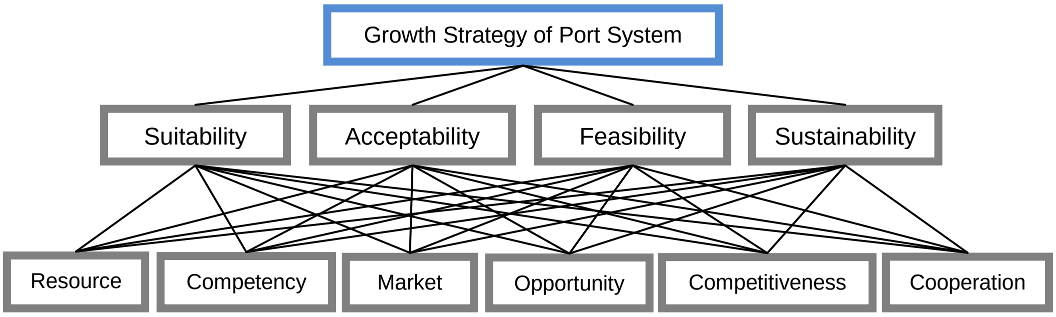

Figure 5: Hierarchy analysis structure for port growth strategy using AHP approach

Next step or in second stage after developing the hierarchical structure for AHP analysis is to make pair-wise comparisons to yield priorities by giving a weight to each criterion and alternative based on respondents' feedback or assessment. The weight (w) is presented in form of a matrix n x n (see Figure 6) where for every component, the weight is given as $a_{ij} = w_i / w_j$, where $a_{ii} = 1$ and $a_{jj} = 1$. From here, we might conclude that if we assume the value of $a_{ij} = k$, then $a_{ji} = 1/k$.

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots\cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots\cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots\cdots & \frac{w_{n1}}{w_n} \end{bmatrix}_{n \times n}$$

Figure 6: Matrix for weight calculation of the criteria

In this study, $n = 4$, and let w_1/w_1, w_2/w_2, w_3/w_3, w_4/w_4 equals to 1, therefore:

Element	Suitability	Acceptability	Feasibility	Sustainability
Suitability	*1*	w_1/w_2	w_1/w_3	w_1/w_4
Acceptability	w_2/w_1	*1*	w_2/w_3	w_2/w_4
Feasibility	w_3/w_1	w_3/w_2	*1*	w_3/w_4
Sustainability	w_4/w_1	w_4/w_2	w_4/w_3	*1*

Or it can be written as:

Element	Suitability	Acceptability	Feasibility	Sustainability
Suitability	*1*	k_{12}	k_{13}	k_{14}
Acceptability	$1/k_{12}$	*1*	k_{23}	k_{24}
Feasibility	$1/k_{13}$	$1/k_{23}$	*1*	k_{34}
Sustainability	$1/k_{14}$	$1/k_{24}$	$1/k_{34}$	*1*

Out of 31 respondents expected to respond to the questionnaire form in this study, only 25 respondents completed the form that can be used for AHP analysis. Respondents were asked to give their pair-wise comparison for every criterion as well as the alternatives by indicating relative importance in a form of 9 scales as follows: *1 = equal important; 3 = moderate important; 5 = strong important; 7 = very strong important; 9 = extreme important.* Whereas other scales or numbers i.e. 2, 4, 6, and 8 falls within the above numbers. For example, number 2, falls between numbers 1 and 3; number 4, between numbers 3 and 5; and so forth.

3.2. Criteria for Selecting Strategy

Based on data gathered in this study, evaluation matrix for pair-comparison is created and the result is shown as in Table 3.

Table 3: Evaluation matrix for pair-wise comparison for criteria element

Criteria	Suitability	Acceptability	Feasibility	Sustainability
Suitability	1	4.68	2.58	3.30
Acceptability	1.68	1	2.54	1.94
Feasibility	3.94	3.65	1	2.41
Sustainability	3.65	4.15	3.66	1
Total	10.28	13.47	9.78	8.65

From the above matrix (Table 3), we need to normalize the matrix for the criteria evaluation. The following procedure is used in transforming pair-comparison matrix into normalization matrix. Given a_{ij} is every component in the pair-comparison matrix and A_{ij} is every component in the normalization matrix, and then we can calculate:

A_{11} = (a_{11}/total weight in column 1) = (1/1+1.68+3.94+3.65) = 0.10

A_{12} = (a_{12}/total weight in column 2) = (4.68/4.68+1+3.65+4.15) = 0.35

Similar calculation performed for every component to complete the normalization process. The result (normalized matrix) is shown as in Table 4. From Table 4, we can see that *sustainability* is ranked as the most important criterion for selecting and evaluating the strategies in this study with 30 percent.

Table 4: Normalized matrix for criteria evaluation

Criteria	Suitability	Acceptability	Feasibility	Sustainability	Average	Rank
Suitability	0.10	0.35	0.26	0.38	0.27	[2]
Acceptability	0.16	0.07	0.26	0.22	0.18	[4]
Feasibility	0.38	0.27	0.10	0.28	0.26	[3]
Sustainability	0.36	0.31	0.37	0.12	0.29	[1]
Total	1.00	1.00	1.00	1.00	1.00	

The importance of *sustainability* criterion in strategy formulation is followed closely by *suitability* and *feasibility*. Meanwhile, *acceptability* criterion is situated at the last position of the most important criteria in formulating growth strategies for the port system.

3.3. Evaluation of Strategy Alternatives

Next step in AHP analysis process is to repeat the same steps and procedure for getting pair-comparison matrices and normalized matrices for all strategy alternatives (six strategies) for every criterion (four criteria). The first criterion used for the evaluation is suitability. The pair-comparison matrix for the suitability criterion is shown as in Table 5. Next, this matrix is transformed into normalized matrix as shown in Table 6.

Table 5: Evaluation matrix for pair-wise comparison for suitability criterion

Alternatives	Resource	Competency	Market	Opportunity	Competition	Cooperation
Resource	1	2.99	2.33	3.37	3.56	4.52
Competency	3.36	1	4.17	3.90	3.88	3.98
Market	3.81	2.22	1	3.37	3.64	3.33
Opportunity	2.87	2.45	2.84	1	2.51	3.42
Competitiveness	2.51	2.86	2.97	3.45	1	3.49
Cooperation	1.59	2.40	2.78	2.59	2.71	1
Total	15.14	13.91	16.10	17.69	17.30	19.74

Table 6: Normalized matrix for suitability criterion

Alternatives	Resource	Competency	Market	Opportunity	Competition	Cooperation	Average [Rank]
Resource	0.07	0.21	0.14	0.19	0.21	0.23	0.18 [2]
Competency	0.22	0.07	0.26	0.22	0.22	0.20	0.20 [1]
Market	0.25	0.16	0.06	0.19	0.21	0.17	0.17 [3]
Opportunity	0.19	0.18	0.18	0.06	0.15	0.17	0.15 [5]
Competitiveness	0.17	0.21	0.18	0.19	0.06	0.18	0.16 [4]
Cooperation	0.11	0.17	0.17	0.15	0.16	0.05	0.13 [6]
Total	1.00	1.00	1.00	1.00	1.00	1.00	

It clearly shows that according to suitability criterion, competency-based strategy is positioned as the most important strategy in the port system growth in Aceh. The strategy is perceived as 20 percent more importance than other strategies. Followed in the second and the third position is by resource-based strategy and market share strategy respectively. The last three (less importance) strategies are competitive-based strategy, opportunity share strategy, and cooperative-based strategy. However, all middle four strategies show only slightly different to one another.

Next, we evaluated strategies based on the others criteria. Normalized matrices for acceptability, feasibility, and sustainability criteria are shown as in Table 7, Table 8, and Table 9 respectively.

Table 7: Normalized matrix for acceptability criterion

Alternatives	Resource	Competency	Market	Opportunity	Competition	Cooperation	Average [Rank]
Resource	0.08	0.19	0.20	0.19	0.21	0.24	0.1846 [1]
Competency	0.23	0.07	0.23	0.18	0.17	0.20	0.1794 [2]
Market	0.19	0.17	0.06	0.19	0.20	0.20	0.1679 [3]
Opportunity	0.22	0.19	0.17	0.06	0.15	0.17	0.1600 [4]
Competitiveness	0.16	0.21	0.17	0.20	0.05	0.14	0.1557 [5]
Cooperation	0.13	0.17	0.17	0.18	0.21	0.06	0.1523 [6]
Total	1.00	1.00	1.00	1.00	1.00	1.00	

Unlike the strategy assessment based on suitability criterion as aforementioned where competency-based strategy is ranked as the most important strategy for growth for the port system, in acceptability criterion, we can see that resource-based strategy and competency-based strategy have similar importance (see Table 7 above), that is 18 percent. We can see the differences of the prioritized strategies in which the resource-based strategy is the most important strategy among others based on acceptability criterion.

Table 8: Normalized matrix for feasibility criterion

Alternatives	Resource	Competency	Market	Opportunity	Competition	Cooperation	Average [Rank]
Resource	0.11	0.27	0.23	0.27	0.24	0.24	0.2268 [1]
Competency	0.27	0.08	0.24	0.21	0.20	0.21	0.2016 [2]
Market	0.20	0.15	0.06	0.17	0.18	0.20	0.1605 [3]
Opportunity	0.12	0.18	0.17	0.06	0.17	0.16	0.1414 [4]
Competitiveness	0.15	0.17	0.16	0.14	0.05	0.14	0.1336 [6]
Cooperation	0.16	0.15	0.14	0.15	0.16	0.05	0.1360 [5]
Total	1.00	1.00	1.00	1.00	1.00	1.00	

Table 9: Normalized matrix for sustainability criterion

Alternatives	Resource	Competency	Market	Opportunity	Competition	Cooperation	Average [Rank]

Resource	0.08	0.28	0.21	0.22	0.23	0.24	0.2100 [2]
Competency	0.24	0.09	0.25	0.21	0.22	0.25	0.2110 [1]
Market	0.16	0.12	0.05	0.17	0.15	0.16	0.1361 [5]
Opportunity	0.13	0.14	0.12	0.05	0.13	0.12	0.1155 [6]
Competitiveness	0.18	0.20	0.18	0.17	0.06	0.17	0.1597 [4]
Cooperation	0.20	0.18	0.18	0.19	0.20	0.06	0.1677 [3]
Total	1.00	1.00	1.00	1.00	1.00	1.00	

The last criterion used in evaluating growth strategies for Aceh's port system is sustainability criterion. Table 9 shows that competence-based strategy is perceived as the most important strategy according to sustainability criterion in formulating strategies for growth for Aceh's seaport system. This strategy (21.10 percent) is slightly different with resource-based strategy (21.0 percent). Cooperative-based strategy (16.77 percent) is positioned as the third most important strategy based on the criterion.

4. Result

The importance of overall strategies based on their ranking needed to be analyzed before a general conclusion generated using AHP approach. To do the analysis, following procedures need to be conducted. Given:

As_ik_j = average normalized weight or score for strategy *i* based on criterion *j*

K_i = average normalized weight or score for every criterion in strategy *i*

T_i = overall score or weight for strategy *i*

Then, T*i* = Total average normalized weight or score for every strategy *i* based on criterion *j* multiplied by average normalized weight or score for every criteria in strategy *i*. Or mathematically can be written for every strategy (6 strategies) as follows:

$$T_1 = (As_1k_1*K_1) + (As_1k_2*K_2) + (As_1k_3*K_3) + (As_1k_4*K_4)$$
$$T_2 = (As_2k_1*K_1) + (As_2k_2*K_2) + (As_2k_3*K_3) + (As_2k_4*K_4)$$
$$T_3 = (As_3k_1*K_1) + (As_3k_2*K_2) + (As_3k_3*K_3) + (As_3k_4*K_4)$$
$$T_4 = (As_4k_1*K_1) + (As_4k_2*K_2) + (As_4k_3*K_3) + (As_4k_4*K_4)$$
$$T_5 = (As_5k_1*K_1) + (As_5k_2*K_2) + (As_5k_3*K_3) + (As_5k_4*K_4)$$
$$T_6 = (As_6k_1*K_1) + (As_6k_2*K_2) + (As_6k_3*K_3) + (As_6k_4*K_4)$$

Using 4-decimal calculation, we got average score for every criterion as follows:

$K_1 = 0.2726$; $K_2 = 0.1805$; $K_3 = 0.2587$; $K_4 = 0.2883$

From here, an overall evaluation normalized matrix for alternative strategy selection can be calculated as shown in Table 10. From the table, we can observe that resource-based strategy is perceived as the most important strategy among other alternative strategies. The importance of resource-based strategy is followed by competence-based strategy with very slight difference that is only 0.04 percent.

Table 10: Overall evaluation matrix for all alternative strategies

	Suitability (0.2726)	Acceptability (0.1805)	Feasibility (0.2587)	Sustainability (0.2883)	Final Score	Rank
Resource	0.1752	0.1846	0.2268	0.2100	0.2003	[1]
Competency	0.1999	0.1794	0.2016	0.2110	0.1999	[2]
Market	0.1738	0.1679	0.1605	0.1361	0.1584	[3]
Opportunity	0.1527	0.1600	0.1414	0.1155	0.1404	[6]
Competitiveness	0.1642	0.1557	0.1336	0.1597	0.1535	[4]
Cooperation	0.1340	0.1523	0.1360	0.1677	0.1475	[5]
Total	1.000	1.000	1.000	1.000	1.000	

From this table, we can conclude that strategies for growth of Aceh's port system based on their priority as follows: (1) Resource-based strategy (20.03 percent), (2) Competency-based strategy (19.99 percent), (3) Market share-based strategy (15.84 percent), (4) Competitive-based strategy (15.35 percent), (5) Cooperative-based strategy (14.75 percent), and (6) Opportunity share-based strategy (14.04 percent).

5. Conclusions

There are myriad of strategies one can formulate and apply to any industries or businesses. In port industry, however, any strategy selected hinges upon respective port authority. Literature is abounding on the selection of strategy to ensure growth sustainability of a port. In this study, resource-based strategy was found to be perceived as the most sought after strategy to achieve growth, followed by competence-based and market share-based strategies, contrary to previous research which preferred competitiveness or competitive advantage. This phenomenon is usually true in regional ports or new ports that consider resources as the main driver in port development.

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Port Reform in Taiwan: New Government Opportunities or Port Competitiveness?

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Abstract

Between 1995 and 1999, port of Kaohsiung in Taiwan was ranked as the third largest container throughput port in the world. Due to changes of business environment, Kaohsiung port's position as the world number 3rd container port was overtaken by Busan of Korea in 2000. Since then, Kaohsiung's ranking in the world container port traffic league dropped year by year to world number 12th in 2009. Taiwan government launched port reform programs to improve the deteriorating situation, including the introduction of the "liberalization and privatization" of port operations in ports of Keelung and Kaohsiung in 1998 and 1999 respectively. Nevertheless, the performance of ports in Taiwan was not improved. One decade later, the government decided to change the port governance and set out to begin operation in 2012. The previous researches pointed out that the driving forces of port reform could be one or more several reasons as the following: (1) globalization of trade; (2) new public management philosophy; (3) technological innovation (such as vessel, cargo tracking, or management information systems); and (4) new government opportunities (processes and strategies), etc.

The major purpose of this paper is to investigate the new programs for changing the governance of port management and operation systems in Taiwan. Following the introduction, section two will review various reasons and methods to conduct port reform. Section three discusses the processes and new programs to be implemented in Taiwan. Section four will conduct a survey to collect stakeholder's opinions on Taiwan's new programs. Finally, section five presents some concluding remarks.

Keywords: Port reform, Taiwan, Port privatization, Kaohsiung port

1. Introduction

Shipping is important to world economy. It is known over ninety percent of international trading goods in the world is carried by ships. Sea transport is even more important to Taiwan because it is a small island located in the western Pacific rim. Thanks to the joint efforts made by government and businessperson over the past fifty years, relatively speaking, Taiwan have well-developed shipping and port industries. In liner shipping, the three biggest container carriers based in Taipei are Evergreen Marine Corporation, YangMing Marine Transport Corporation, and Wan Hai Line. There are also many bulk carriers providing tramp services (Chiu, 2007). The total ships controlled by the Taiwanese was more than 29.8 million deadweight tons (DWT) in 2009, which accounted for 2.7 percent of the total world ship's tonnage. Taiwan ranked as the country with 11th largest controlled fleet in the world although over 86.35% was the so-called flag-of-convenience (FOC) ships (UNCTAD, 2009, p. 53).

Regarding the port industry, Taiwan currently has four international commercial ports (Keeling with Taipei and Suao subsidiary ports, Taichung, Kaohsiung, and Hualien) and two international industrial ports (Milao and Hoping). Between 1995 and 1999, port of Kaohsiung in Taiwan was ranked as the third largest container throughput port in the world. Due to changes of business environment, Kaohsiung port's position as the world number 3rd container port was overtaken by Busan of Korea in 2000. Since then, Kaohsiung's ranking in the world container port traffic league dropped year by year to world number 12th in 2009. Since 1989, Taiwan government launched port reform programs to improve the deteriorating situation, including the "liberalization and privatization" of port services. Nevertheless, the performance of ports in Taiwan was not improved. Two decades later, the government decided to change the port governance and set out to begin operation in 2012 (Table 3.1).

The major purpose of this paper is to investigate the new programs for changing the governance of port management and operation systems in Taiwan. Following the introduction, section two will review various reasons and methods to conduct port reform. Section three discusses the processes and new programs to be implemented in Taiwan. Section four will conduct a survey to collect stakeholder's opinions on Taiwan's new programs. Finally, section five presents some concluding remarks.

2. Literature review

According to Burke (2002), organizations change all the time, each and every day; but the change, for the most part, is unplanned and gradual. Planned organization change is unusual and revolutionary change is rare indeed. Interestingly, influenced by the UK government's port privatization program in the late 1980s, many countries launched port reform scheme (Tull and Reveley, 2008). The driving forces of port reform could be one or more several reasons as the following: (1) globalization of trade; (2) new public management philosophy; (3) technological innovation (such as vessel, cargo tracking, or management information systems); and (4) new government opportunities (processes and strategies) (Brooks and Cullinane, 2007, p. 5). Indeed, facing the changing market environment, modern (container) ports hoping to capture and keep important footloose clients on a sustainable basis require providing integrated (package) services characterized by a high level of reliability and flexibility, short time-to-market, as well as non-market conditions such as transparency within efficient governance structures. Moreover, containerization and intermodality revolutionized modern shipping as well as hinterland transportation so deeply that there is definitely a need to re-assess the role and functions of (container) ports (Notteboom, 2007).

Cass (1998) mentioned about the purposes to privatize ports could be: (1) to obtain open market finance on favorable terms, and (2) to promote efficiency and competition. Tull and Reveley (2008) presents some main arguments that have been used to justify privatization, including: (a) expansive and inefficient ports constrain trade, (b) the efficiency and know-how of the private sector should be introduced into ports, (c) reducing demands on the public budget, (d) reducing expenditure on port labor by removing the state from port operations, and (e) other objectives, especially in the UK, have included raising revenue and encouraging share ownership amongst the general public.

There are many ways to conduct port reform. Brooks and Cullinane (2007) once used the phrase "port reform" to mean the restructuring of the governance of ports as part of a government's devolution program. Devolution, according to Rodal and Mulder (1993), means "the transfer of functions or responsibility from the delivery of programs and services from the federal government to another entity" and privatization is the most extreme form of devolution (Brooks and Cullinane, 2007, p. 5); the other ways of devolution include "control, consultation, and partnership". Tull and Reveley (2008) indicated that the three main types of port reform are "commercialization, corporatization and privatization". Many methods can be used to conduct port privatization, such as: commercialization, liberalization, sale of assets, corporatization, concessions (BOT or leases), joint ventures, and management (or technical) contract (Cass, 1998).

The objectives of port reforms, at least, requires to achieve cost reduction (and in most cases also reduction in port charges) and service improvement. Thus, the models for port governance and management are required to respond both to new technology associated with larger ship sizes and increasing integration of international supply chain, competition for the growing transshipment trade, and broader national economic growth and reform objectives (Affleck, 2008). Facing the difficulty to assess the performance of various port governance models, Brooks and Pallisz (2008) developed a conceptual framework that can be used for a comprehensive port evaluation and adjustment of the existing governance models.

3. Port reform process in Taiwan

Ports are important to Taiwan's economy because it heavily relies on international trades and ports serve as the gateway of exporting and importing goods. Therefore, how to maintain the efficient operations and provide good services in ports has always been a vital task for the government and port operators. Since 1980s, as indicated in table 3.1, several major strategies have been taken to strengthen the competitiveness of ports in Taiwan, especially the port of Kaohsiung. The first is to provide the value-added services, for example, the export processing zone in 1980s and free trade zone beginning in 2004. The second is to attract the tranship business, for example, dedicated terminal and off-shore shipping center. The third is to restructure the organization of port, such as the liberalization and privatization of port operations (Chen, 2007).

In the 1980s, Kaohsiung served as the gateway of Taiwan's export and import trade. To promote exports, the port area set up a free export-processing zone, which parts from neighboring counties could be assembled into products in port free zone, and then re-export. It has been proved to be one of the most successful experiences to promote export businesses in the world. But the business of export processing zone has been dropped significantly when low cost labor in neighboring countries is available. The re-location of Taiwan's manufacturing industries also caused the decrease of container throughput in Kaohsiung port and made the port's world ranking continuing dropping since 2000.

To attract more transship business, port of Kaohsiung adopted the "dedicated terminal". Under that the shipping lines can lease container berths for container loading and unloading for a set period of time (e.g. 5-10 years). The major objective of this strategy is to secure the business between shipping lines and the port. In Kaohsiung, however, the vessels to be served by the dedicated terminal were limited to only those of the shipping lines that leased the berths. This restriction to the vessels of the container berths has restricted the business opportunities for more than two decades. In 1998, this restriction was lifted to allow the leasers of the container berths to handle containers of other shipping lines. However, the effect is limited. Since the 2000s, most shipping lines have already transferred their focus on other Asian ports.

Table 3.1 Important events for port reform in Taiwan

Year	Important event	Effect
1989	● Taiwan central government (Executive Yuan) announced launching "state-owned enterprises privatization" policy. ● The major purposes are to increase operational efficiency and flexibility of state-run enterprises.	● On maritime transport sector, as of 2010, two companies were privatized: Yang Ming Line (on 15 Feb. 1996) and Taiwan Navigation Corporation (on 20 June 1998).
1990	● Taiwan government filed application with GATT (later WTO) to region the Organization. ● This action represented Taiwan government to launch liberalization policy on all its industries.	● On 1 Jan. 2002, Taiwan became the 144th WTO member (Chinese Taipei).
1995	● Along with the promotion of service industry's liberalization, the central government (CEPD) commissioned a research to investigate the issues and policies of port liberalization. ● Both "liberalization and privatization" were included and discussed how to introduce to port operations.	● The reform of port labor employment launched to enhance the efficiency of cargo handling.
1998	● Due to Provincial Government to be removed from the government hierarchy by 20 Dec. 1998, port administration system needed to be changed.	● Various systems proposed, no action taken. ● Port administration directly reported to MOTC after 20 Dec. 1998.
January 1998	● Stevedore services in Keelung port was privatized. ● Port labor problem solved in Keelung port.	● Port labor is no longer employed by the Harbor Bureau. ● Dock workers are employed by the

		private stevedore companies. ● The number of stevedore companies is no longer restricted; those that meet the conditions can be set up freely to provide cargo-handling services. ● Terminal operators and consignees with more choices of stevedore service.
January 1999	● Stevedore services in Kaohsiung port was privatized. ● Port labor problem solved in Kaohsiung port.	● The same effect as happened in Keelung port.
August 2000	● New ruling DPP party took office and decided to change Port Bureau as a business entity. ● Considering to invite local govern government to organize "Port Council" to administer port planning and operations.	● No action due to no consensus between central and local government. ● Central government was also under re-organization to be completed in Jan. 2010.
2001	● MOTC proposed the so-called "four acts for maritime and port reform" to Executive Yuan (Parliament) for promoting reform of maritime administration and port operation. ● Parliament did not pass those Acts in 2002.	● No action.
February 2005	● MOTC again submitted the "Proposed Act of Harbor Bureau Establishment and Supervision" to Parliament. ● Parliament did not pass the proposed Act.	● No action.
2010	● MOTC submitted port reform acts (including Organization Act of Maritime and Port Administration and Act of the Establishment of Taiwan Port Corporation Limited) to Parliament. ● If the proposed Acts approved by Parliament, Maritime and Port Administration will be set up in 2012; port businesses will be operated by the State-run Taiwan Port Corporation.	● To be decided.

Sources: Derived and revised from various sources including Wu *et al.* (2006), Chiu and Lin (2007), Chen (2010), etc.

Since 1989, government began introducing the "privatization and liberalization" to port operations. Stevedore services in Keelung port was privatized in 1998, that was followed by Kaohsiung port in 1999. After that port labor is no longer employed by the Harbor Bureau; instead, workers are employed by the private stevedore companies. Moreover, the number of stevedoring companies is no longer restricted; those that meet the conditions can be set up freely to provide cargo-handling services, therefore providing both terminal operators and consignees with more choices of stevedoring service. In accordance with Commercial Port Law, port services are classified as the following: pilotage; towing and tug assistance; provisioning, fueling and watering; garbage collecting and ballast waste disposal; navigation aids; shore-based operational services including communications, water and electrical supplies; emergency repair facilities; anchorage, berth and berthing services; ship tally services; passenger services; stevedore services; and warehousing services, etc. As of January 2010, most services in port area have been liberalized and privatized except for the pilotage. To boost the competitive advantages of ports and attract business, the strategy of a "Free Trade Zone" was introduced in 2004. It expects to upgrade the port operations from being an Asian "transship" center to a "logistics and distribution" center and a part of global supply chain. As of June 2010, ports of Kaohsiung, Keelung, Taichung, Taipei and Suao have all been approved to establish the free trade zone.

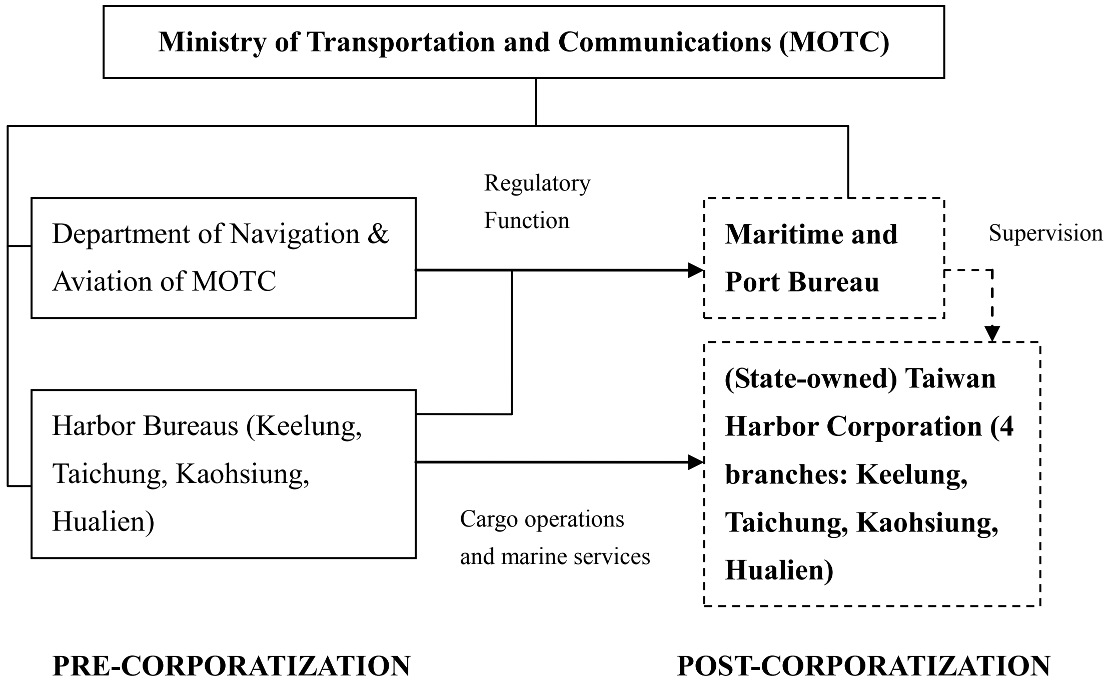

Fig. 3.1 Proposed Structural Changes to the Governance of the Ports in Taiwan

Sources: Internal documents, MOTC (2010)

Although government adopted some strategies to improve port operations, there are still some serious problems hampering the further development of port businesses, such as: (1) central government is lack of a comprehensive plan of port function, which causing unnecessary interport competition; (2) it is lack of integration and horizontal cooperation between governmental agencies, which weakening the generation of more port businesses from free trade zone project; and (3) government is lack of a clear positioning plan of its ports in the Asian market, which delaying the approving of constructing a mega container terminal in Kaohsiung port and possibly causing the loss of competitiveness, etc.

Along with the completion of central government re-organization, Ministry of Transportation and Communications (MOTC) announced to re-organize the existing Harbor Bureaus because they have been criticized being a regulator but also operating cargo and marine services which caused unfair competition with private operators and inappropriate public administration system. As represented in Fig. 3.1, the proposed changes are (1) to set up a “Maritime and Port Bureau” to be the shipping and port regulator and administer in January 2012, and (2) to establish a “State-owned Taiwan Harbor Corporation” to manage the port facilities and services in January 2012 or 2013.

4. Empirical investigation

To understand the employee’s opinions on the new initiative of organization reform to be implemented in 2012, this study designed a questionnaire to collect information (Chen, 2010). Totally, purposive sampling method was used to select 110 employees from the four international ports as shown in Table 4.1; they were requested to answer the questionnaire.

Table 4.1 Information of Respondents

Information category	Data category	No. of Respondents	Percentage (%)
Location of port	Keelung port	25	25 %

	Taichung port	35	35 %
	Kaohsiung port	30	30 %
	Hualien port	20	20 %
	Total	110	100 %
Time to work in port authority	More than 16 years	83	75 %
	6-15 years	15	14 %
	Less than 5 years	12	12 %
Working department	Port operation	36	33 %
	Port administration	32	29 %
	Personnel & Accounting	22	20 %
	Engineering	11	10 %
	Ship administration	9	9 %
Job responsibility	Chief	29	26 %
	Non-chief	81	74 %

As shown in Table 4.2, the majority opinions prefer establishing one "State-owned Port Corporation" to supervise four branches (in Kaohsiung, Taichung, Keelung and Hualien). The advantages are policy unity and resources can be jointly used. As indicated in Table 4.3, this new proposal will seemingly be supported by existing employees because they consider that the "current organization cannot cope with the needs of port business & operation" and their "benefits remain no change under the state-run corporation system".

Table 4.2 Type of State-run Port Operation Corporation

Type of organization	No. of Respondents	Percentage
A. To establish four State-run Port Operation Corporations separately (in Keelung, Taichiung, Kaohsiung and Hualien)	41	37 %
B. To establish one State-run Port Operation Corporation to supervise four branches	53	48 %
C. To establish one State-run Port Operation Holding Corporation to supervise four subsidiary companies	16	15 %
Total	110	100 %

Table 4.3 Reasons to support the port reform

Reason to support	No. of Respondents	Percentage
A. Current organization cannot cope with the needs of port business & operation	47	42.72 %
B. Maintain state-run corporation system, employee's benefits remain no change	31	28.18 %
C. Most employees consider port reform will help enhance port competitiveness	13	11.82 %
D. Most employees are old and qualified to retire for protecting their benefits	7	6.36 %
E. Economic prospective deteriorated which weakening the objection of employees	6	5.45 %
F. Others	6	5.45 %
G. The reform proposal is too good to be resisted	0	0

Still, some employees worried their benefits (e.g., salary, retirement) will be affected and have to work far away from home because of job position changes; some also concerned the future port corporation cannot be operating profitably due to it cannot own the land in port area (Table 4.4). Nevertheless, most port employees recognize that it is urgent to change the port organization from an administrative agency to corporation entity to achieve the following objectives, such as (1) to enhance port competitiveness (through internal coordination

& specialization to fight against foreign port's competition), (2) to separate the responsibility of port administration and port operation function, (3) to improve port operational efficiency, and (4) to improve the flexibility of employee's recruitment, etc (Table 4.5).

Table 4.4 Most worried matters concerning the port reform

Worried matter	No. of Respondents	Percentage
A. Influence of employee's benefits (e.g., salary, retirement)	94	85.45 %
B. Port corporation cannot own the land in port area which cause the corporation has no land asset	56	50.91 %
C. Job position changes causing employees to work far away from home	45	40.91 %
D. The new organization is redundant and cannot improve efficiency	40	36.36 %
E. Others	6	5.45 %

Table 4.5 Possible effects of the port reform

Possible effect	No. of Respondents	Percentage
A. To enhance port competitiveness (through internal coordination & specialization to fight against foreign port's competition)	64	58.18 %
B. To separate the responsibility of port administration and port operation function	58	52.73 %
C. To improve port operational efficiency	55	50.00 %
D. To improve the flexibility of employee's recruitment	55	50.00 %
E. Employees with different qualification and salary will cause conflict	38	34.55 %
F. Conflict between Port Administration and Port Corporation due to blurred responsibility	37	33.64 %
G. To improve port infrastructure and effective use of port facilities	35	31.82 %
H. Port corporation lacks of capability to operate businesses and needs help from government	30	27.27 %
I. Young person will not join port corporation due to lack of information about port reform	30	27.27 %
J. To improve the efficiency of handling the ship administration, surveying and navigation safety	2	1.81 %
K. Others	1	0.01 %

5. Concluding Remarks

The port reform process in Taiwan can be roughly divided into two stages. The first stage, from 1989 to 1999, has achieved the privatization of dockworkers in ports of Keelung and Kaohsiung as well as liberalization and privatization of many port services in international and industrial ports (such as operation of dedicated terminals, towing and tug assistance, fueling, watering, emergency repairing, Mooring & unmooring services, ship tally services, stevedore services, and warehousing services). The second stage, beginning from 2000, launched another new task (i.e. port devolution) and continued conducting privatization. The recent action is to set up a "Maritime and Port Bureau" under central government and corporatization of port authorities in 2012. The new programs have got support from existing port employees. The major reasons are: (1) most employee's benefits remain no change, (2) to enhance the port competitiveness, (3) to separate the responsibility of port administration and port operation function, and (4) to improve port operational efficiency.

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A Study on Operational Performance Evaluation of the World's Leading Container Ports

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Abstract

As the competition among the world ports has become increasingly fierce, every port is striving to increase its investments constantly and lower its operational costs in order to maintain the competitive edge and provide satisfactory services to port users. The unreasoning behaviour, however, has induced that substantial waste and inefficiency exists in container port production. Therefore, it is of great importance for the port to know whether it has fully used its existing infrastructures and that output has been maximised given the input. From this perspective, data envelopment analysis (DEA) provides a more appropriate benchmark for the container port. This study applies there models of DEA to acquire a variety of analytical results about the operational efficiency to the world' leading container ports. According to efficiency value analysis, this study first finds the reason of inefficiency. It is followed by identification of the potential areas of improvement for inefficient ports by applying slack variable method. Finally, return to scale approach is used to assess whether each port is in a state of increasing, decreasing, or constant return to scale. The results of this study can provide port managers with insights into resource allocation and optimization of the operating performance.

Keywords: Efficiency, Container port, Data envelopment analysis, production function

1. Introduction

In recent years, with rapid expansion of global business and international trade, one distinctive feature of the current container port industry is that competition among container ports is more intensive than previously (Liu, 1995; Tongzon and Heng, 2005; Yap and Lam, 2005).

Port markets used to be perceived as monopolistic due to the exclusive and immovable geographical location of the port and the unavoidable concentration of port traffic. However, the rapid development of international container and intermodal transportation has drastically changed the market structure from one of monopoly to one where fierce competition is prevalent in many parts of the world. Many container ports no longer enjoy the freedom yielded by a monopoly over the handling of cargoes from their hinterland. Instead, they have to compete for cargo with their neighbouring ports (Cullinane et al., 2006).

To maintain its competitiveness in such competitive condition, Kevin Cullinane et al. (2006) claimed container ports have to invest heavily in sophisticated equipment or in dredging channels to accommodate the most advanced and largest container ships in order to facilitate cost reductions for the container shipping industry.

It is important to note, however, that pure physical expansion is constrained by a limited supply of available land, especially for urban centre ports, and escalating environmental concerns. In addition, the excessive and inappropriate investment also can induce the phenomenon of inefficiency and wasting of resources. In this context, improving the productive efficiency of container port (Le-Griffin et al., 2006) appears to be the viable solution.

Realizing the facts, port authorities have shown strong interest in efficient port management. Thus, they are continually searching for strategies to meet growing demands by utilizing their resources reasonably. (Tongzon, 1995; Martinez-Budria et al., 1999; Coto-Millan et al., 2000; Notteboom et al., 2000; Tongzon, 2001; Cullinane, 2002; Cullinane et al., 2004).

In this context, it is essential that how to rationally utilize the existing infrastructures in order to achieve a desired result that output has been maximised given the input, as well as find the potential areas which should be improved immediately for inefficiency port.

For a container port, productivity performance makes significant contribution to the prospects of survival and competitive advantage. It is also important tool in informing port authorities and operators port planning. Traditionally, the productivity of container ports has been variously evaluated by numerous attempts at calculating and seeking to improve or optimise the operational productivity of cargo-handling at berth and in the container yard (Evers and Koppers, 1996; Ashar, 1997; Gehring and Bortfeldt, 1997; Imai et al., 1997; Kim, 1997; Kim and Bae, 1998; Kim and Kim, 1998; Kim and Kim, 1999; Robinson, 1999; Avriel et al., 2000; Wilson and Roach, 2000; Chu and Huang, 2002; Imai et al., 2002).

If container ports can conduct effective evaluation of their productivity performance to enhance the efficiency of productivity, it will provide valuable information for port managements in their attempts to establish competitive strategies for the future and to improve their resource utilization for ongoing improvements in operational efficiency.

From this perspective, data envelopment analysis model provides a more appropriate benchmark for the container port. The aim of this study is assumed to be the minimisation of the use of input(s) and maximisation of the output(s), by applying with DEA-CCR, DEA-BCC, and DEA-Super Efficiency, three models, to acquire a variety of analytical results about the productivity efficiency for the twenty-one world' leading container ports.

According to efficiency value analysis, this study first finds the reason of inefficiency. It is followed by identification of the potential areas of improvement for inefficient ports by applying slack variable method. Finally, return to scale approach is used to assess whether each port is in a state of increasing, decreasing, or constant return to scale.

The paper is structured as follows: after the introductory section of chapter 1, there will be followed by the description of three data envelopment analysis (DEA) models. In so doing, the three main approaches to applying DEA to analyse data are included in Section 2. The required input and output variables are defined and the data that has been collected is described. Estimates of the efficiency of a sample of container ports are derived in Section 3. Finally, conclusions are drawn in Section 4.

2. Research Method

2.1 Data Envelopment Analysis (DEA)

DEA can be roughly defined as a nonparametric method of measuring the efficiency of a Decision Making Unit (DMU) with multiple inputs and/or multiple outputs. This is achieved by constructing a single ‗virtual' output to a single ‗virtual' input without pre-defining a production function. The term DEA and the CCR model were first coined in Charnes et al. (1978) and were followed by a phenomenal expansion of DEA in terms of its theory, methodology and application over the last few decades. The influence of the CCR paper is reflected in the fact that by 1999 it had been cited over 700 times (Forsund and Sarafoglou, 2002).

Among the models in the context of DEA, the two DEA models, named CCR (due to Charnes et al., 1978) and BCC models (due to Banker et al., 1984) have been widely applied. The CCR model assumes constant returns to scale so that all observed production combinations can be scaled up or down proportionally. The BCC model, on the other hand, allows for variable returns to scale and is graphically represented by a piecewise linear convex frontier.

Because the CCR model gives a value of 1 for all efficient DMUs, it is unable to establish any further distinctions among the efficient DMUs. Andersen, P. and Petersen, N. C., (1993), therefore, presented Super-efficiency DEA model which removes an efficient DMU, and then estimates the production frontier again and provides a new efficiency value for the efficient DMU that had previously been removed. The new efficiency value can thus be greater than 1, and the efficiency values of inefficient DMUs do not change.

In recent years, DEA has been increasingly used to analyze port production. Compared with traditional approaches, DEA has the advantage that it can cater for multiple inputs to and outputs from the production process. This accords with the characteristics of port production, so that there exists, therefore, the capability of providing an overall summary evaluation of port performance (Kevin Cullinane et al, 2007). The DEA methodology has been applied to the evaluation of port performance in the previous literature. For example, Roll and Hayuth (1993) probably represents the first work to advocate the application of the DEA technique to the ports context. However, it remains a purely theoretical exposition, rather than a genuine application. For the period 1990–1999, Itoh (2002) conducted a DEA window analysis using panel data relating to the eight international container ports in Japan. Tongzon (2001) uses both DEA-CCR and DEA-Additive models to analyze the efficiency of four Australian and 12 other international container ports for 1996. Barros and Athanassiou (2004) apply DEA to the estimation of the relative efficiency of a sample of Portuguese and Greek seaports.

However, most previous studies have adopted two basic models of DEA (the CCR model and the BCC model) to obtain aggregate efficiency, technical efficiency and scale efficiency. In contrast, this study applies DEA-CCR, DEA-BCC, and DEA-Super Efficiency, three models, to acquire a variety of analytical results about the productivity efficiency.

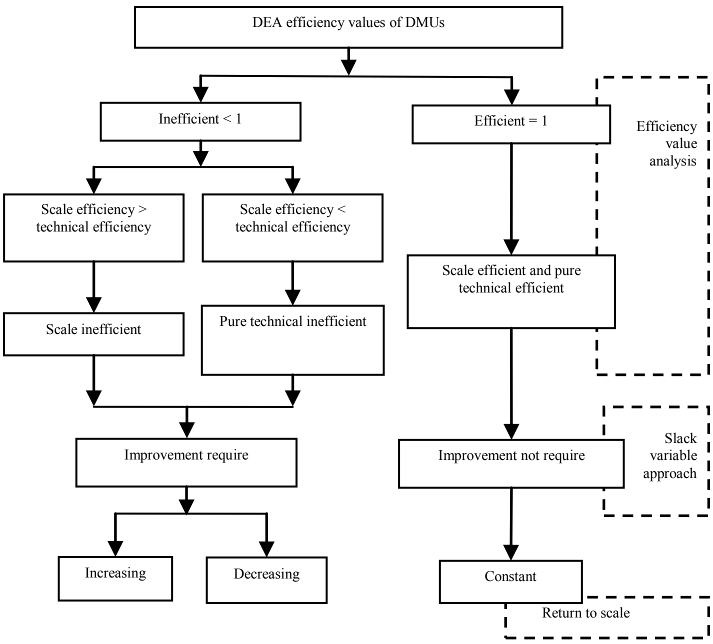

Figure 1: Flow process of DEA analyses
Source: Author(s) of the original source

In this study, the DEA model includes three types of analysis. With respect to the efficiency value analysis, when technical efficiency is less than 1, that is technically inefficient, this means that the efficiency of the inputs and output being used is not appropriate, and that it is necessary to decrease input or increase output. However, when the scale efficiency is less than 1, that is scale inefficient, it means that the operational scale is not achieving an optimal value, and that the operational scale should be enlarged or reduced (based on the return to scale). In addition, it is possible to compare the technical efficiency value with the scale efficiency value, with the smaller value of the two indicating the major cause of inefficiency. Finally, the slack variable analysis handles the utilization rate of input and output variables. It does this by assessing how to improve the operational performance of inefficient DMUs by indicating how many inputs to decrease, and/or how many outputs to increase, so as to render the inefficient DMUs efficient. This facilitates an overall understanding of which input variable is more critical for efficiency improvement (L. C. LIN, 2007). In summary, the flow process of multiple DEA analyses can be depicted as shown in figure 1.

2.4 Research Procedure

The research procedure of this study is summarized in figure 2. After the selection of container ports, the output variable for the study should be selected firstly. Drawing on the literature review, site survey & interview, and Brainstorming to eliminate the duplication factors, the initial inputs variables can be chosen.

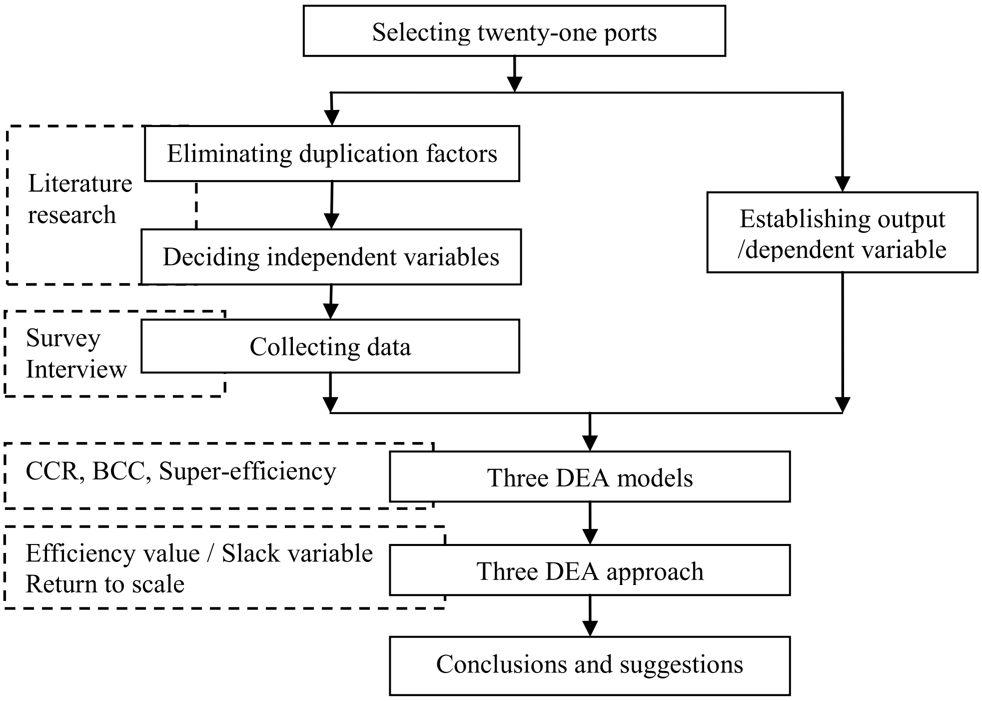

Figure 3: Research procedure
Source: Author(s) of the original source

Then, in order to provide a more comprehensive picture of research, and for the purpose of finding the operational efficiency value, an exploration composed of the CCR, BCC and Super-efficiency DEA models and three analytical approaches which include efficiency value analysis, Slack variable method and Return to scale approach have been applied. After that, the evaluation results and suggestions will be given.

3. Result Analysis

3.1 Data Collection and Definitions of variables

Because it is difficult to acquire data on international ports, most of the previous documents have focused on the evaluation of ports within a single country. For doing a typical analysis, the sample comprises the twenty-one world‘s leading container ports from the list of world top container ports published in 2008, including eight Chinese ports—Shanghai-Waigaoqiao, Shanghai-Yangshan, Hongkong, Qingdao, Tianjin, Shenzhen, Ningbo, Guangzhou; thirteen other region ports—Singapore, Rotterdam, Hamburg, Dubai, Los Angeles, NJ/NY, Tokyo, Kaohsiung, Port Klang, T/Pelepas, Antwerp, Long Beach, Busan. Thus, it has facilitated the acquisition of more reliable and timeliness, on a comprehensive scale.

Table 1: Data collection of the world's leading container ports in 2008 year

Variable / Ports	Country	Inputs					Output	Rank
		Yard area/ per berth	QC/per berth	TC/per berth	YT/per berth	Berth Length	Throughput /per berth	
Hong Kong	China	116.2	4.1	12.8	27.5	325	1010417	1
Waigaoqiao	China	342.5	4	13.5	22.8	301	975000	2
T/Pelepas	Malaysia	200	4.5	11.2	15	360	933333	3
Dubai	UAE	90.1	3.6	16.7	24.1	288	845000	4
Tianjin	China	161	4.5	12.6	26.8	377	669063	5
Shenzhen	China	150	3.3	10.8	12	306	645000	6
Singapore	Singapore	85.5	3.1	6.6	12	311	586667	7
GuangZhou	China	245	3.1	6.6	10.5	275	578947	8
Yangshan	China	1642.5	4.1	12.5	25.3	342	576923	9
Ningbo	China	200	3.7	9	16.1	340	561500	10
Qingdao	China	167	2.8	3.9	12.13	317	386363	11
Kaohsiung	Taiwan	111.5	2.8	4.3	7.5	287	372308	12
Port Klang	Malaysia	78.9	2.27	6.4	9	251	362273	13
Busan	Korea	155.5	2.9	7.2	9.3	321	347110	14
Rotterdam	NL	166.1	2.24	8	9	319	328182	15
Hamburg	Germany	116.2	2.4	12.2	14.4	280	293939	16
Los Angeles	USA	239.9	2.5	6.1	12.8	330	290741	17
Tokyo	Japan	167	2.2	13.7	13.5	311	261717	18
Antwerp	Belgium	177	2.65	16.2	3.4	353	254706	19
NJ/NY	USA	150	2.5	11.5	23.2	293	201538	20
Long Beach	USA	116.6	1.71	4.8	11.9	232	190882	21
Average		232.3	3.1	9.8	15.2	310	508172	

With respect to definitions of variables, a thorough discussion of the importance, difficulties and potential impact of variable definition can be found in (Song et al, 2003), and can be summarised as follows. The input and output variables should reflect the actual objectives and process of container port production as accurately as possible. Because the most container ports rely heavily upon sophisticated equipment and information technology, rather than being labour-intensive; and the competition among the world ports has become increasingly fierce (Kevin Cullinane et al, 2005).

Therefore, in this study, the main criterion of the choosing inputs and output is assumed to be the minimisation of the use of input(s) and maximisation of the output(s).

In order to determine the input variables/independent variables, the used factors for variables in the study are discovered through an abundant literature review, discussion with experts working in container ports for more than 20 years, and brainstorming, all factors that relevant to port operation, are to be considered such as port facilities like yard area, number of berth, water depth, length of berth, gate, rail station etc., and port equipment like Y/T, Q/C, RTGC, RMGC, reach stacker, top handler and folk lifter etc.

However, as far as the process of container port production is concerned, a container port depends crucially on the efficient use of infrastructures and facilities. On the basis of that, yard area, the quantities of quay crane, yard crane, yard tractor, berth length, and water depth have been deemed to be the most suitable factors to be incorporated into the models as input variables. Other input factors that possibly influence the efficiency estimates that may be derived from this analysis include aspects such as: berth occupancy, crane operating hours and equipment age and maintenance. However, the selection of suitable variables for this study depended on data availability, and the difficulties on acquiring data. They have not been included in this study.

With respect to output variable, container throughput is unquestionably the most important and widely accepted indicator of container port output. Almost all previous studies treat it as an output variable, because it closely relates to the need for cargo-related facilities and services and is the primary basis upon which container ports are compared, especially in assessing their relative size, investment magnitude or activity levels. Most importantly, it also forms the basis for the revenue generation of a container port or terminal (Kevin Cullinane et al, 2005). Synthesizing the former research, in this study, the port productivity indicator is defined as the per berth handling capacity by dividing annual throughput by number of berth.

3.3 Efficiency Results Derived from DEA Models

As with using the data of twenty-one world's leading container port by applying with DEA approaches, for proving the production function of container ports exhibits either constant or variable returns to scale, the DEA-CCR and DEA-BCC models were chosen from among several DEA models to analyse port production. In addition, for ordering the efficiency ports, the DEA-Super-efficiency was adopted.

The efficiency analytical results for container port are summarized in table 1, and the following observations can be made. The column and row totals represent, respectively, the efficiency value of each port and the condition of return to scale in 2008 year.

Table 2: Efficiency under three DEA Models

Model / Ports	Efficiency			Reasons of inefficiency		Return to scale
	Score					
	CCR efficiency	Super efficiency	Rank	BCC efficiency	Scale efficiency	
Hong Kong	1.000	1.242	1	1.000	1.000	Constant
T/Pelepas	1.000	1.209	2	1.000	1.000	Constant
Antwerp	1.000	1.204	3	1.000	1.000	Constant
Qingdao	0.925	1.115	4	1.000	0.925	Increasing
Singapore	1.000	1.099	5	1.000	1.000	Constant
Dubai	1.000	1.079	6	1.000	1.000	Constant
Waigaoqiao	1.000	1.079	6	1.000	1.000	Constant
Guangzhou	1.000	1.017	8	1.000	1.000	Constant
Kaohsiung	0.977	0.977	9	1.000	0.977	Increasing
Shenzhen	0.654	0.925	10	0.754	0.868	Increasing
Port Klang	0.785	0.785	11	1.000	0.785	Increasing
Ningbo	0.736	0.736	12	0.812	0.907	Increasing
Rotterdam	0.672	0.672	13	0.992	0.678	Increasing
Tianjin	1.000	0.654	14	1.000	1.000	Constant
Busan	0.599	0.599	15	0.863	0.694	Increasing
Yangshan	0.584	0.584	16	0.777	0.752	Increasing
Los Angeles	0.561	0.561	17	0.847	0.662	Increasing
Hamburg	0.508	0.508	18	0.866	0.587	Increasing
Long Beach	0.489	0.489	19	1.000	0.489	Increasing
Tokyo	0.486	0.486	20	0.877	0.554	Increasing
NJ/NY	0.327	0.327	21	0.795	0.412	Increasing
Average	0.776	0.826		0.933	0.823	

It is clear from table 2 that, the DEA-CCR model yields lower average efficiency estimates than the DEA-BCC model, with respective average values of 0.776 and 0.826, where an index value of 1.00 equates to perfect (or maximum) efficiency. The Super-efficiency model was utilized to reinforce the discriminatory power of the CCR model. Hong Kong has the best performance among these twenty-one ports. T/Pelepas and Antwerp port ranked as the second and third best in this model, respectively. The scores are more than 1.200, with these efficiency values far exceeding that of other ports.

By using of efficiency value analysis, slack variable approach, and return to scale method, the analytical results can be summarized as:

Firstly, the aggregate efficiency value acquired from the CCR model of Shanghai-Waigaoqiao, Hong Kong, Tianjin, Guangzhou, Singapore, Dubai, T/Pelepas, and Antwerp are all equal to 1. The efficiency values of other ports in the years were less than 1, which indicated that they were relatively inefficient ports. The ‗pure technical efficiency value' obtained from the BCC model represented the efficiency in terms of the usage of input resources. If a port had an efficiency value equal to 1 in the CCR model, the value of its pure technical efficiency would also be equal to 1. However, if the efficiency value on the CCR model was less than 1, a comparison could be made between the pure technical efficiency value and the scale efficiency value, thus allowing a judgement to be made about whether the inefficiency was caused by an inefficient application of input resources or an inappropriate production scale. All of the pure technical efficiency values of Shanghai-Waigaoqiao, Hong Kong, Tianjin, Qingdao, Guangzhou, Singapore, Dubai, Kaohsiung, Port Klang, T/Pelepas, Antwerp, and Long Beach are equal to 1. The technical efficiency values of other ports are less than 1, thus indicating that they would need to improve their usage of resources. Among these, New York/New Jersey port had the least pure technical efficiency value.

Secondly, according to the results of return to scale, Shanghai-Waigaoqiao, Hong Kong, Tianjin, Guangzhou, Singapore, Dubai, T/Pelepas, and Antwerp were relatively efficient ports and had constant return to scale. In addition, apart from constant return to scale, Shanghai-Yangshan, Qingdao, Shenzhen, Ningbo, Rotterdam, Hamburg, Los Angeles, NJ/NY, Tokyo, Kaohsiung, Port Klang, Long Beach, and Busan were in a state of increasing return to scale in 2008.

Table 4: Slack variable analysis results

Variable / Ports	Country	Inputs					Rank
		Yard area/ per berth	QC/per berth	TC/per berth	YT/per berth	Berth Length	
Hong Kong	China						1
Waigaoqiao	China						2
T/Pelepas	Malaysia						3
Dubai	UAE						4
Tianjin	China	13.69	0	0	1.33	0	5
Shenzhen	China	0	0	2.16	0	39.65	6
Singapore	Singapore						7
Guangzhou	China						8
Yangshan	China	877.97	0	0	0	10.29	9
Ningbo	China	60.34	0	0	0	3.09	10
Qingdao	China						11
Kaohsiung	Taiwan	0	0.73	0	0	89.5	12
Port Klang	Malaysia	0	0	0.76	0	37.72	13
Busan	Korea	17.39	0.05	0	0	55.54	14
Rotterdam	NL	26.8	0	1.24	0	96.06	15
Hamburg	Germany	0	0	2.38	0	47.05	16
Los Angeles	Malaysia	95.63	0	0	0.51	53.71	17
Tokyo	Japan	16.13	0	3.17	0	68.79	18
Antwerp	Belgium						19
NJ/NY	USA	25.89	0	1.21	2.1	31.02	20
Long Beach	USA	33.52	0	0	0.96	41.58	21

Finally, the slack variable analysis showed, in table 3, that Shanghai-Waigaoqiao, Hong Kong, Tianjin, Guangzhou, Singapore, Dubai, T/Pelepas, and Antwerp had been relatively efficient; their ratios of input variables to output variable were appropriate, and they were capable of applying their input resources effectively to achieve enhanced efficiency. In contrast, Shanghai-Yangshan，Qingdao, Shenzhen, Ningbo, Rotterdam, Hamburg, Los Angeles, NJ/NY, Tokyo, Kaohsiung, Port Klang, Long Beach, and Busan were relatively inefficient as a result of inappropriate application of input resources; however, in these cases, an inappropriate production scale was the cause of the inefficiency. The results indicated that Shanghai-Yangshan, Tianjin, Ningbo, Rotterdam, Los Angeles, NJ/NY, Tokyo, Long Beach, Busan ports should have adjusted their area of container yard. Kaohsiung and Busan should have adjusted their number of quay crane. Shenzhen, Rotterdam, Hamburg, Los Angeles, NJ/NY and Long Beach ports should have adjusted their number of yard crane. Tianjin, Los Angeles, NJ/NY and Long Beach ports should have adjusted their number of yard tractor. In addition, Shanghai-Yangshan, Shenzhen, Ningbo, Rotterdam, Hamburg, Los Angeles, NJ/NY, Tokyo, Kaohsiung, Port Klang, Long Beach and Busan should have adjusted their berth length.

4. Conclusions

For the container ports in the competitive circumstances, efficiency is an important concept and concerned with how to use limited resources more economically for any sort of production. As a benchmarking approach to study efficiency, DEA enables a port to evaluate its performance from each other in DMUs. By doing this, the possible waste of resources and the industry best practice can be identified. By using a range of DEA models, this study has evaluated the twenty-one leading container ports of the world, and in the process has acquired varied and complementary conclusion from the different models. The study has making efficiency value analysis, and has established a return to scale to compare the technical efficiency value with the scale efficiency value, with the lesser of the two indicating the major cause of inefficiency for each port. Moreover, using slack variable analysis, the study has provided useful information that indicates how relatively inefficient container port can improve their efficiency.

Empirical results reveal that substantial waste exists in the production process of the container ports in the twenty-one world‘s leading container ports. For instance, the average efficiency of container ports using the DEA-CCR model amounts to 0.776. This indicates that, on average, the ports under study can dramatically increase the level of their outputs while using the same inputs.

Empirical results also reveal that the ports under the study were found to exhibit a mix of increasing and constant returns to scale at current levels of output. This indicates that, the scales of leading container ports are not saturated. Such information is particularly useful for port managers or policy makers to decide on the scale of production.

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The Impacts of Ownership Structure and Competition on Port Capacity Investments and Pricing: An Economic Analysis

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Abstract

Contemporary economic development ensures that port performance has become pivotal within the logistical supply chain. While considerable studies have discussed the interdependence of port ownership, inter-port competition, capacity investment and port pricing, few analytical models have been developed, thus preventing researchers from drawing an overall picture of the port industry, or deriving general results of port operation. Hence, this paper proposes an integrated economic model with which the effects of the attributes stated above can be analyzed jointly. Our results indicate that capacity investments and congestion level are influenced by ownership forms, the presence of inter-port competition and possible externalities (spillover effects) due to port operation. This study allows us to investigate port behaviors systematically, rather than focusing on a single port decision, with different objective functions being specified so as to analyze possible strategic differences between public and private sectors, as well as different levels of governments. It also provides fresh insight to the ongoing debates of private participation in the ownership and operation of transport infrastructure, as well as the possible impacts of continuing governmental involvement.

1. Introduction

Contemporary economic development has opened up the consumer market to various regions around the world. To ensure that such products can sustain global competitiveness, the speed of cargo movement must be smooth and efficient. This is likely to exert considerable challenges, as efficiency in international transportation requires the integration of several functions along the supply chain so as to provide quality services at reasonable prices. Indeed, being transportation hubs, the performance of ports, as critical nodal points (Cowen, 2010), has become increasingly pivotal in complementing the activities of different stakeholders within the logistical supply chain (cf. Heaver, 2002; Sanchez et al., 2003; Notteboom and Rodrigue, 2005). On the other hand, with increasing ship sizes, mergers and acquisitions between shipping lines and the restructuring of the shipping networks, recent developments in global shipping have led to few port calls, thus intensifying port competition and the increasingly importance of transshipment traffic in deciding the competitive positions of ports around the world (Ng, 2009).

Hence, in many places around the world, being an important attribute in affecting service quality and thus port performance (cf. Chang et al., 2008; Ng, 2006), port congestion becomes a pressing issue to address. Congestion would deteriorate port service quality with longer average process time. In turn, this would increase the economic costs of ship operation. As a consequence, the overall costs of the marine operation would increase. Generally speaking, to address port congestion problem, there are two main approaches. One direct approach is to invest more capacity, for instance, berths, cranes and other port infrastructures. In such case, *ceteris paribus*, increasing port capacity would enhance service quality, and thereby theoretically attract more traffic to the port. The downside of such strategy, however, is that port capacity investments may be very costly, especially given the industry‟s capital intensive nature (Baird, 2000; Haralambides, 2002; Slack and Fremont, 2004). The second approach is to levy higher service charges with the aim to reduce the port service demands. If a port has substantial market power, such a strategy may be profitable. Nevertheless, if there is sufficient competition, such a strategy may not be a wise option. The pressure for more capacity but simultaneously lower service charges poses a significant dilemma to port decision-makers where real world experience indicates that, especially in regions where multiple ports compete with each other, ports have often invested too much capacity and but charged too low prices. An illustrative example can be found in the East Mediterranean where the rapid growth in port capacity of Limassol and Damietta led to fierce competition between them, with prices being set so low that neither of them is able to even cover respective operation costs (World Bank, 2007). Another illustrative example can be found among Chinese container ports, where excess capacity was estimated to reach a total of 35 million TEUs in 2010 – three times more than the actual growth between 2000 and 2008 (AXS-Alphaliner, 2009). In 2009, the berth utilization rates of Tianjin, Xiamen and Fuzhou were only 55, 42 and 27 percent, respectively, with 2, 10 and 2 new berths already under construction within respective ports (World Cargo News, 2010), while at the same time, the total container capacity in Dalian in 2010 was forecasted to be 100 percent of the total demand in 2008 (AXS-Alphaliner, 2009). Hence, port congestion may be solved but non-socially optimal excessive capacity investments may exist.

Another complicating factor is changes in ownership structure. Throughout past decades, various management reforms, including the transport sector, had been adopted so as to adjust to changing circumstances since the 1980s. Within the port sector, many such illustrative examples can be found, where a distinguished feature of such reforms is the advocacy of establishing various reform models, often based on the seductive belief of the time where capitalist economies would be better governed through the decentralization of socio-economic decisions (cf. Harrison, 2010). Through devolution and the transfer of assets and operations responsibilities to private enterprises, public-private partnership and concessionary agreements (Theys et al., 2010), ports around the world gradually move away from direct public management to autonomous, but more complex, entities, with mixed forms of ownership and/or management models being established, with the landlord port model being one of the most popular options (cf. Wang et al., 2004; Brooks and Cullinane, 2007). Although reform objectives vary, they usually share common goals: to enable the organization to evolve so as fit in a changed environment that is shared by the sector at a global scale. Being well-documented in previous works (Heaver, 1995; Wang et al., 2004; Brooks and Cullinane, 2007; Cullinane and Song, 2007; Ng and Pallis, 2010), the core objectives are similar, e.g., higher technical efficiency, economic benefits through competition, lowering bureaucracy, reducing public investments, etc. In other words, such evolutionary process mainly aims to lower transaction costs (Hall, 1986).

However, it is general knowledge that the objectives of private firms can be substantially different from those of a public, or government controlled, enterprise (Vining and Boardman, 2008). Indeed, there is no shortage of research works indicating that ports are often treated as strategic assets (cf. Ng, 2002) and, being part of the city-regional system, in many cases, their evolutionary process often cannot escape the existing political administrative boundaries (cf. McLeod and Jones, 2007). In the past decades, real world experiences within port management reform suggest that even after reforms, quite often, governments (central and/or local) may control some or even majority shares of ports, so that they can maintain certain degree of influence on port operation and strategic development, with the establishment of joint ventures between foreign and local, state-owned enterprises operating container terminals within Chinese ports being illustrate examples (Ng, 2002; Wang et al., 2004). Even within the public sector, as pointed out by Ng and Pallis (2010), the objectives between governments from different levels may not be entirely consistent: local authorities may be more concerned with the benefits to the local economies, while national authorities may focus on coordinating the planning and policies of several ports, thus ensuring that the total welfare can be maximized at the national (or regional) level. Hence, in understanding port reform (including changes in ownership and operating structure) nowadays, as warned by Harrison (2010), one should be aware of the complicated process behind leading to its final outcome, including performance.

Based on such background, in this paper, we propose an integrated economic model with which the effects of port ownership and inter-port competition on its capacity investment and pricing can be analyzed simultaneously. There is little doubt that port capacity and pricing are important attributes in deciding port"s service quality, as various research works have suggested (see, for instance, Chang et al., 2008; Ng, 2006;

Tongzon, 2009). In particular, by defining a composite objectives function, our model can conveniently analyze the cases where ports have mixed ownership, i.e., government and private firms may control varying shares of ports. The inclusion of mixed ownership is extremely important because port management reform rarely involves complete devolution and/or privatization (cf. World Bank, 2007; Ng and Pallis, 2010). Instead, the public sector usually redefines new governance structure through various means (Theys et al., 2010). Moreover, with different definition of social welfare, our model provides a new dimension in analyzing the different strategies adopted by local and central governments. Apart from a significant research gap yet to be filled concerning the inter-relationship between port ownership and performance (see section 2), a major contribution of this study is that it focuses on explaining *how* and *why* ownership structure affects the performance of ports, rather than simply endorsing the notion that ownership *does* affect performance. In particular, our modeling results suggest that: (1) the absence of inter-port competition, profit-maximizing private investors would investment less capacity than local or central governments, who care about regional economic benefits and the well-being of port users. However, private investors also charge higher prices which reduce traffic volume. In an overall, we argue that port ownership would have little significant or systematic influence over congestion level; (2) inter-port competition plays an important role in the determination of port capacity, pricing and resultant traffic volume and congestion level. In particular, when the spillover effect of port operation to the local economy is moderate while inter-port competition is significant, private investors would invest too much capacity than social optimal level. In such cases, local governments would commit even more capacity. This reduces congestion level but lead to excess capacity (i.e., wastage of valuable resources). These results, together with other findings, can significantly contribute to the ongoing debates of the structure of private participation in the ownership and operation of transport infrastructure – to what extent, under what circumstances, as well as the relation between public and private sectors. In a nutshell, the outcomes of this study are highly relevant in enhancing our understandings on the strategies of economic actors on the evolution and development of port planning and management.

The remaining of the paper is structured as follows. Section 2 provides the literature review, followed by the establishment of the economic model in section 3, where a benchmark monopoly port case will be analyzed. Section 4 extends the analysis to cases with inter-port competition. Finally, the conclusions are provided in Section 5.

2. Literature Review

The potential advantages of devolution and private participation in the operation and management of transport and logistics facilities were widely recognized by researchers (see, for instance, Boardman and Vining, 1989; Estrin and Perontin, 1991; Vickers and Yarrow, 1989; Yarrow, 1986). Throughout the past decades, one had witnessed the implementation of various types of port reforms which had been comprehensively documented in existing literature (see, for instance, Brooks and Cullinane, 2007; Wang et al., 2004; Ng, 2002). Port reform often involves the participation of the private sector with the objective of reducing bureaucracy and enhancing efficiency (Beresford et al., 2004; World Bank, 2007). Given this trend, for the last two decades, the impacts of organizational structures and management systems on port efficiency had gradually become a topic which had interested transport economists. In this respect, a problem existed where considerable works investigating the effects of ownership, competition and policies on capacity and pricing were either descriptive in nature or *ad hoc* case studies (see, for instance, Cullinane and Song, 2001; De Langen and Pallis, 2006; Everett, 2007 and 2008; Goss and Stevens, 2001; Haralambides, 2002; Vining and Boardman, 2008), thus difficult to apply them directly to predict the net effects of the above variables, especially given the rather complex and inter-dependent nature of ownership and competition on capacity investment and pricing as mentioned in the introductory section.

A number of quantitative studies investigating the issue did exist though. A pioneer study can be dated back to the 1990s, when Liu (1992) undertook performance analysis on British seaports operated by different types of enterprises. An important contribution of his works was that, instead of a clear-cut distinction between public and private ownerships, Liu also identified the influence of mixed ownership which could pose significant implications on port performance. Later, Cullinane et al. (2002), by applying a stochastic frontier model, attempted to assess the influences of various types of ownership on Asian container terminals, and concluded that devolution and privatization were closely associated with performance. Based on the British experience, Baird (2000) argued otherwise, however, where the sale of port assets, including the transfer of operation rights and/or regulatory functions, to the private sector did not necessarily improve performance, or even counter-productive in some cases. He further explained that, due to the specific nature of ports nowadays (long term payback and capital intensive nature), an almost total dependence on the private sector to provide both port infrastructure and superstructure would result in significantly delayed investments on crucial operational facilities and equipments, which were obviously contrary to the original objective of port privatization. Thus, full port privatization would impede the improvement in performance although, to some extent, private sector participation could also increase the efficiency level, implying that the extent of private sector intervention in the port sector would have an inverted U-shaped effect on port operational efficiency. In this regard, Tongzon and Heng (2005), based on the stochastic frontier approach, provided some evidences that the impacts of privatization on port performance followed an inverted U-shaped curve. They conclusions were supported by Cheon et al. (2010) who argued that port performance enhancement did come from the ownership reform and asset management practices, though rejecting any roles of devolution and corporatization. Gonzalez and Trujillo (2008) disagreed, however, claiming that port performance changed little after management restructuring.

Within the same period, other researchers had applied a positivist approach investigating the relation between governmental influence and performance. For example, Oum and Yu (1994) studied the effects of government intervention, notably subsidies, on the performance of railways located within OECD countries. Results indicated that dependence on subsidies had negative correlations with performance, of which similar correlations also applied to managerial autonomy. Although they called for improved subsidizing policies, findings were far from comprehensive as they did not consider the effects of the differences in operating and market environments. A similar work on ports was undertaken by Barros (2003) focusing on the impacts of government‟s "incentive regulation" (in terms of subsidizing policies) on the performance of Portuguese seaports, with the drive for greater technical efficiency being part of the government‟s plan preparing for privatization within the sector. Results were rather mixed, however, leading him to conclude that public policies did not necessarily lead to better performance. A recent study was undertaken by Ng and Gujar (2009) investigating government policies, efficiency and competitiveness on Indian dry ports, arguing that governments were often keen to maintain certain degree of existence (and thus influence) on transport facilities. Finally, Bassan (2007) went even further and proposed an evaluation tool for port operation and capacity analysis, although the failure to take institutional factors (including ownership and policies) into account (other than merely mentioning their potential influences) had limited its empirical applicability.

Generally speaking, the works illustrated above provided interesting insight on the possible relation between different organizational (including ownership) structures and managerial systems and performance. However, these works shared common, but important, shortcomings, notably the concentration on technical methodologies in addressing the topic. Hence, in most cases, they addressed whether ownership *did* affect performance but did not proceed further investigating *how* and *why*, i.e., the possible reasons behind such phenomenon. Such defect can be well-illustrated by the following article‟s conclusion investigating the performance determinants of container terminals:

> *"…berth utilization – a proxy of productivity analysis on this analysis – is considered the most vital contributor to overall port performance, and would be under the control of the port authority subject to a port's administrative and organizational structures. In the case of a tool or service port…the degree of terminal productivity is determined solely by the port authority. However, in a landlord port…terminal productivity relies on the private terminal operator…"*
> (Song and Han, 2004)

Under such cases, how would port authorities and private terminal operators affect performance, and why? Moreover, how could their works help decision-makers to make appropriate decisions related to devolution and/or private participation in port ownership and operation? The dynamics, including the process behind the establishment of the scene was clearly found lacking, causing the failure of such works in reflecting the complete picture. Indeed, the reform outcomes of different ports, even after the implementation of generic solutions, can be fundamentally different due to the existence of diversified political systems within different regions (Ng and Pallis, 2010). Thus, existing works only addressed half of the issue: to what extent variances in ownership and competitive structures had caused variances in performance. The other half – the roles that the dynamics behind, as well as to what extent port ownership and operation should be shared between public and private sectors, as well as governments of different levels – had been continuously overlooked. Such ignorance explains why, at least partially, despite the availability of considerable works, a generally accepted conclusion on the issue - the inter-relationship between private participation and performance - still cannot be reached (Liu, 1992 and 1995; Cullinane et al., 2002; Song and Cullinane, 2001; Tongzon and Heng, 2005). Unsurprisingly, the lack of consensus ensured that the stated works were mainly *ad hoc* in nature and did not clearly address how and why inter-port competition had affected port performance, including capacity investments and pricing, as Kent and Ashar (2001) had clearly illustrated. These shortcomings have limited the potential contributions of these stated works, implying that a significant research gap has yet to be filled. Hence, this study aims to fill in this gap through investigating the effects of port ownership and inter-port competition on port"s strategies of capacity investment and pricing, and resulting service level and social welfare effects. Below we will construct the economic model.

3. The Economic Model

We consider one single port facing linear inverse demand function which is specified as

(1) $$\rho = a - bQ$$

where ρ is the full price paid by port users (e.g. ship liners) while Q is the port output. The full price ρ comprises two parts: port due/service charge P plus extra cost related to congestion at the port. Port delay function D increases in port traffic Q but decreases in port capacity K, and so is specified as

(2) $$D = \frac{\alpha Q}{K} \text{ and } K \le Q$$

Congestion parameter α is a constant exogenously determined by port production technology and operation efficiency. A larger α implies longer congestion delay for any given capacity and traffic volume. The requirement $K \le Q$ implies that the port output can not exceed its designed capacity. Basso and Zhang (2008) reviewed the usage of such a delay function in recent studies. They propose that one should solve the equilibrium outputs first with such delay function, and then ensure the solution satisfy the capacity constraint (i.e. the solutions are interior solutions). We shall adopt a similar approach in our paper. Let congestion cost measured in monetary value to be $T = \mu D$, the demand function can be rewritten as

(3) $$P = a - bQ - \mu D$$

Denote the capital cost as r and the constant marginal cost of port operation as c, the profit of the port is simply

(4) $$\pi = (P - c)Q - rK$$

To model the complex ownership forms in the port industry, we consider a port which is partially privatized. The private port operator owns a share of s in the port and its objective is to maximize port profit π. The government owns the remaining (1-s) share of the port and aims to maximize social welfare. An economics text-book approach to define social welfare is to add up port profit π to the consumer surplus of port users. With such an approach, the interests of all parties involved will be included.

However, such an approach may not be relevant for major seaports serving as international gateways. In this case, the demand for a port is a derived demand of international trade, which of involves end users (i.e. producers, importers and exporters, freight forwarders etc.) beyond municipal/national boundaries. For example, Rotterdam is the largest seaport in the world, yet less than 5% of the cargos handled in the port are destined for The Netherlands, and even few cargos are destined for the city itself (Port of Rotterdam, 2010). The same pattern holds for the Port of New York/New Jersey, Port of Shanghai and Singapore etc. In addition, since many ports are owned by local/municipal governments instead of federal/central governments, it is not clear to what extent those port authorities or local governments will take account into the welfare of im-/exporters, or the shipping companies who are not local residents. The consumer surplus defined by the port demand function, which captures the welfare of the port users, may not be of great importance to local government or port authorities.

Port operations often bring positive externalities or spillover effects to local economies: increased traffic volume often leads to increased employment, and contributes to the growth of related industries such as supply-chain management, warehousing, logistics services and to some extent local manufacturing industries. As a result, port authorities and governments routinely use traffic volume as a key index of port performances. Such spillover effects have been well recognized in practice, yet they have rarely been explicitly modeled in quantitative economic analysis.

With such complexities in port operation, it is unclear on what exactly the best specification of a port operator‟s objective function is. As a matter of fact, it is not for sure whether one single type of port objective function can sufficiently reflect the objectives of the large number of ports operating within extremely diversified environments. To ensure that our analytical conclusions are robust to alternative specifications, and more importantly, to analyze the implications of different types of government involvements, we decide to model and compare the analytical results with following two specifications of a government‟s objective function:

For a "local government" who cares the economic benefits to the port area only, its objective function is to maximize "Local Benefit" *LB* as specified in (5), which only include port profit and the spill over effects to local economy. h (h>0) is the spill over benefits derived per unit cargo handled

(5) $$LB = \pi + hQ$$

For a "central government" who also cares about the well-being of port users, its objective function is to maximize social welfare *SW*, which is the sum of port profit, consumer surplus and spill over effects:

(6) $$SW = [(P-c)Q - rK] + [\int_0^Q \rho(x)dx - \rho(Q)Q] + hQ$$

It should be noted that the terms "local government" and "central government" are mainly used as references. In practice, a local government may also cares about users‟ interests in order to maintain long-term cooperative relationships. On the other hand, a central government does not have to always fully appreciate port users‟ well-being, especially foreign companies who do not have a major local presence. As shown in the following sections, such alternative specifications will only make a difference when there is substantial inter-port competition.

Clearly, a private port operator‟s objective is not entirely consistent with that of a government. The eventual port strategy may be best described as a compromise between the private investor and the government involved. Therefore, we define a partially privatized port‟s objective as a composite function of profit maximization and local benefit/welfare maximization, weighted by the port ownership shares controlled by the private operator and the government respectively. Below we present the models for the cases of local government and central government involvements separately.

3.1. Partnership between private investor and local government

In this section we consider the partnership between a private investor and a local government, where the private investor controls a share of s ($0 \le s \le 1$) of the port. The port‟s objective function is thus specified as in (7), where condition $\pi \ge 0$ reflects the requirements of budget balance (thus that the port is free from government subsidy) usually imposed by the government, and of course non-negative profit condition which is essential for private port operator to participate:

(7) $$Max_{P,K}\Pi = (1-s)[(P-c+h)Q - rK] + s[(P-c)Q - rK]$$
$$s.t. \quad Q \le K \text{ and } (P-c)Q - rK \ge 0$$

Clearly, the objective function Π is simply the weighed average of port profit and spill-over effects to the local economy. The port maximizes this composite / weighted objective function by choosing the appropriate port service charge *P* and the port capacity *K*. The corresponding first order conditions (FOCs) are derived as

(8.1) $$\frac{\partial \Pi}{\partial P} = Q + (P-c)\frac{\partial Q}{\partial P} + (1-s)h\frac{\partial Q}{\partial P} = 0$$

(8.2) $$\frac{\partial \Pi}{\partial K} = (P-c)\frac{\partial Q}{\partial K} - r + (1-s)h\frac{\partial Q}{\partial K} = 0$$

By demand function (3), it is straightforward to show that

(9) $$\frac{\partial Q}{\partial P} = -\frac{1}{b+\mu\dfrac{\partial D}{\partial Q}} \quad \text{and} \quad \frac{\partial Q}{\partial K} = -\frac{\mu\dfrac{\partial D}{\partial K}}{b+\mu\dfrac{\partial D}{\partial Q}}$$

With equation (2), (3), (8) and (9), it can be further derived that the optimal capacity and price charged by the port, and the corresponding traffic volumes are

(10.1) $$P = \frac{1}{2}[a + c - (1-s)h]$$

(10.2) $$K = \frac{\sqrt{\alpha\mu}}{2b\sqrt{r}}[a - c + (1-s)h - 2\sqrt{r\alpha\mu}]$$

(10.3) $$Q = \frac{1}{2b}[a - c + (1-s)h - 2\sqrt{r\alpha\mu}]$$

The constraints in (7) requires that

(11.1) $$r \le \alpha\mu$$

(11.2) $$a - c - (1+s)h \ge 2\sqrt{r\alpha\mu}$$

where (11.1) ensure the port earns non-negative profit, while (11.2) ensures that the output is smaller than port capacity invested. These two conditions ensure (10.1)-(10.3) are interior solution. In addition, it can be shown that

(12) $$\frac{\partial K}{\partial s} < 0, \quad \frac{\partial P}{\partial s} > 0, \quad \frac{\partial Q}{\partial s} < 0, \quad \frac{\partial D}{\partial s} = 0, \quad \frac{\partial K}{\partial h} > 0$$

The interpretation is straightforward: as the private investor controls a larger share of the port, less capacity will be invested (i.e., $\partial K/\partial s < 0$). Meanwhile, the port will charge a higher price which reduces port traffic volume (i.e., $\partial P/\partial s > 0$ and $\partial Q/\partial s < 0$). As a result, port ownership does not have any systematic impacts over the congestion level at the port ($\partial D/\partial s = 0$)

3.2. Partnership between private investor and central government

In the case of partnership between a private investor and a central government, the port"s objective function is specified as in (13). Compared to the case of partnership with a local government, the difference is that port users" consumer surplus is also included.

$$(13) \qquad Max_{P,K}\Pi = (1-s)[\int_0^Q \rho(x)dx - \rho(Q)Q + (P-c+h)Q - rK] + s[(P-c)Q - rK]$$
$$s.t. \quad Q \le K \text{ and } (P-c)Q - rK \ge 0$$

With the specifications in (1)-(3), the first order conditions for (13) can be derived as in (14.1)-(14.3), while capacity constraint and non-negative profit constraints in (13) requires that $r \le \mu\alpha$ and $s(a-c-2\sqrt{\mu\alpha r}) \ge (1-s)h$.

$$(14.1) \qquad Q = \frac{1}{(1+s)b}[a-c+(1-s)h-2\sqrt{\mu\alpha r}]$$

$$(14.2) \qquad K = \frac{\sqrt{\mu\alpha}}{(1+s)b\sqrt{r}}[a-c+(1-s)h-2\sqrt{\mu\alpha r}]$$

$$(14.3) \qquad P = \frac{1}{1+s}[sa+c-(1-s)h+(1-s)\sqrt{\mu\alpha r}]$$

With the same proportion of private partnership *s*, compared to the case of local government, the involvement of a central government leads to larger capacity investment and lower service charge. As a result, traffic volume is higher. As a result, the congestion level (i.e. *D*) will be the same as in the case of local government. In addition, it can be shown that

$$(15) \qquad \frac{\partial K}{\partial s} < 0, \quad \frac{\partial P}{\partial s} > 0, \quad \frac{\partial Q}{\partial s} < 0, \quad \frac{\partial D}{\partial s} = 0, \quad \frac{\partial K}{\partial h} > 0$$

The results are similar to the case of local government: As the private investor controls a larger share, port charge will be increased while capacity investment will be reduced. This leads to reduced traffic volume, but congestion level will not be affected.

4. The Case With Inter-Port Competition

In the last section, we only considered the case of a monopoly port. In practice, many ports around the world face some competitive pressure, either from nearby ports with overlapping hinterlands, or major hub ports serving significant transshipments. In some ports, terminals are separately owned by different terminal operators. Such inter-terminal competition may also be approximated with inter-port competition modeled in our study, if terminal operators have similar autonomy in deciding price and capacity investment. Clearly, the presence of inter-port competition may affect ports" operation and competition strategy. To investigate such potential effects, we consider a case when there are *N* ports competing with horizontally differentiated services. Such differentiation may arise either from the different services provided by port operators, or simply the fact that these ports have overlapping but not identical hinterlands. As a result, even if the ports offer homogenous services, some consumers may prefer to use the nearest ports to others. The demand function faced by port *i* is specified as

$$(16) \qquad P_i = a - bq_i - \gamma\sum_{j\ne i} q_j - \frac{\mu\alpha q_i}{K_i}$$

where P_i, q_i, K_i are the price, output and capacity of port *i*. The parameter γ ($0 \le \gamma \le b$) measures the degree of product differentiation among the ports. When $\gamma = 0$, the ports provide totally differentiated services thus that they are not competing with each other. This is essentially the same case studied in section 3. When $\gamma = b$, the ports provide homogenous services to each others and the market becomes perfectly competitive when *N* is large.

This demand function corresponds to a representative consumer maximizing the following utility function, where *M* is the numeraire good (money):

$$(17) \qquad U = a\sum_{i=1}^{N} q_i - \frac{1}{2}[\sum_{i=1}^{N}(b + \frac{\mu\alpha}{K_i})q_i^2 + \gamma\sum_{i\neq j} q_i q_j] + M$$

The ports are assumed to have identical costs of capital *r* and marginal cost *c*, and in all ports private operators own a share of *s* of the port. Such port symmetry implies that at equilibrium the outputs at all ports are the same. Consequently, consumer surplus is $CS = U - \sum_{i=1}^{N} P_i q_i$, while profits of all the ports, or producer surplus, are $PS = \sum_{i=1}^{N}(P_i - c)q_i - r\sum_{i=1}^{N} K_i$, and the total spill over effects in all the ports is obtained by summing up across all ports. The total welfare is therefore specified as

$$(18) \qquad SW = a\sum_{i=1}^{N} q_i - \frac{1}{2}[\sum_{i=1}^{N}(b + \frac{\mu\alpha}{K_i})q_i^2 + \gamma\sum_{i\neq j} q_i q_j] + [\sum_{i=1}^{N}(h - c)q_i - r\sum_{i=1}^{N} K_i]$$

While the total social welfare of all the ports can be clearly defined as in (18), the specification of each port‟s objective function is not straightforward as there is no port specific consumer surplus. The surplus of the users of a port, say port *i*, is dependent on the traffic volumes served by other ports (i.e., q_j ‟s for all $j \neq i$) as well as the degree of product differentiation among the ports (i.e., γ). More importantly, each port‟s objective function is dependent on the market structure, and it can be quite complicated when a central government is involved. A central government prefer to coordinate the capacity and pricing decisions of all the ports in order to maximize overall social welfare. However, it is unclear how this can be done if multiple private investors are involved. Consider a case when private company A has shares in two ports in a region, while another private company B has interests in the remaining three ports. The central government wishes to coordinate capacity investment and pricing for all ports. However, private company A and B aim to maximize each individual port‟s profit and therefore don‟t always prefer cooperation to competition. Without additional assumptions, it is unclear how each port‟s objective shall be specified for such complex market structure and port ownership forms. Therefore we choose to consider following three special cases:

Case I: all ports are fully privatized and there is no government involved at all. This implies that $s = 1$. There are *N* private investors competing with each other in an oligopoly port market;

Case II: all ports are partially privatized where *N* private investors and *N* local government each controls proportions of *s* and 1-*s* shares in these ports respectively.

Case III: all ports are owned by a central government thus that $s = 0$. There is neither privatization nor inter-port competition. The central government coordinates the pricing and capacity investments in all ports to maximize overall social welfare:

While these cases do not cover all possible market structures, they present increasing government involvement and port coordination from Case I to Case III. This allows us to evaluate the effects of inter-port competition, port coordination and privatization by comparing modeling results across these cases.

4.1. Case I – Oligopoly fully privatized ports

As described above, in this case all ports are fully privatized and there is no government involvement at all. The *N* oligopoly ports compete with each other by setting its own capacity K_i and port service charges P_i. The profit maximization problem of port *i* can be specified as:

(19) $$Max_{P_i,K_i} \Pi_i = (P_i - c)q_i - rK_i \;\; s.t. \;\; q_i \le K_i$$

leading to following first order conditions:

(20.1) $$\frac{\partial \Pi_i}{\partial P_i} = q_i + (P_i - c)\frac{\partial q_i}{\partial P_i} = 0$$

(20.2) $$\frac{\partial \Pi_i}{\partial K_i} = (P_i - c)\frac{\partial q_i}{\partial K_i} - r = 0$$

With inverse demand function defined as in (16) and the condition of symmetry so that $q_i = q_j$ at equilibrium the oligopoly competition can be solved as follows:

(21.1) $$q_i = \frac{a - c - 2\sqrt{\mu\alpha r}}{2b + \gamma(N-1)}$$

(21.2) $$P_i = \frac{a+c}{2} - \frac{\gamma(N-1)(a - c - 2\sqrt{\mu\alpha r})}{4b + 2\gamma(N-1)}$$

(21.3) $$K_i = \frac{\sqrt{\mu\alpha}(a - c - 2\sqrt{\mu\alpha r})}{\sqrt{r}[2b + \gamma(N-1)]}$$

Capacity constraint in (19) requires that $r \le \alpha\mu$, thus that the solution is an interior solution.

4.2. Case II – Partially privatized ports with local government partnership

In this case ports are partially privatized. In each port, a local government controls (1-*s*) of port interests, and aims to maximize local benefit which is the sum of port profit and spill-over effects. The objective function of port *i* is specified as in (22), thus that each port maximizes its respective composite / weighted objective function by choosing the appropriate port service charge P_i and port capacity K_i, where capacity constraints and non-negative profit requirements apply as usual:

(22) $$Max_{P_i,K_i} \Pi_i = (1-s)[(P_i - c + h)q_i - rK_i] + s[(P_i - c)q_i - rK_i]$$
$$s.t. \;\; q_i \le K_i \text{ and } (P_i - c)q_i - rK_i \ge 0$$

The first order conditions of (22) imply that

(23.1) $$\frac{\partial \Pi}{\partial P_i} = q_i + (P_i - c)\frac{\partial q_i}{\partial P_i} + (1-s)h\frac{\partial q_i}{\partial P_i} = 0$$

(23.2) $$\frac{\partial \Pi}{\partial K_i} = (P_i - c)\frac{\partial q_i}{\partial K_i} - r + (1-s)h\frac{\partial q_i}{\partial K_i} = 0$$

Imposing symmetry condition $q_i = q_j$, it can be shown that at equilibrium

(24.1) $$q_i = \frac{a - c + (1-s)h - 2\sqrt{\mu\alpha r}}{2b + \gamma(N-1)}$$

(24.2) $$P_i = \frac{1}{2}[a + c - (1-s)h] - \frac{\gamma(N-1)[a - c + (1-s)h - 2\sqrt{\mu\alpha r}]}{4b + 2\gamma(N-1)}$$

(24.3) $$K_i = \frac{\sqrt{\mu\alpha}[a - c + (1-s)h - 2\sqrt{\mu\alpha r}]}{\sqrt{r}[2b + \gamma(N-1)]}$$

Port capacity constraint implies that $r \le \mu\alpha$. The results in (24.1)-(24.3) imply that

(25) $$\frac{\partial K_i}{\partial s} < 0, \quad \frac{\partial\left(\sum_i K_i\right)}{\partial N} > 0, \quad \frac{\partial P_i}{\partial s} > 0, \quad \frac{\partial q_i}{\partial s} < 0, \quad \frac{\partial D_i}{\partial s} = \frac{\partial D}{\partial N} = \frac{\partial D}{\partial \gamma} = 0,$$

Some of the results are similar to the monopoly port case: for each port, as the private investor controls a larger share of interests, capacity investment will decrease while service charge will increase. This leads to reduced traffic volume. In addition, when there is increased number of ports, the total capacity of all ports will increase. However, congestion delay at each port is not affected by port ownership, port service differentiation or inter-port competition (as measured by the number of competing ports, *N*).

4.3. Case III - Coordinated ports controlled by a central government

In this case, all ports are owned and controlled by a central government thus that $s = 0$. There is neither privatization nor inter-port competition. The central government coordinates pricing and capacity investments in all ports to maximize overall social welfare. The central government‟s objective function is specified as in (26), where $\vec{P} = (P_1,..., P_N)$ is the price vector of the ports while $\vec{K} = (K_1,..., K_N)$ is the capacity vector.

(26) $$Max_{\vec{P},\vec{K}} SW = a\sum_{i=1}^{N} q_i - \frac{1}{2}[\sum_{i=1}^{N}(b + \frac{\mu\alpha}{K_i})q_i^2 + \gamma\sum_{i \ne j} q_i q_j] + [\sum_{i=1}^{N}(h - c)q_i - r\sum_{i=1}^{N} K_i]$$
$$s.t. \quad q_i \le K_i \text{ for any } i$$

This leads to following vectors of first order conditions

(27.1) $$\frac{\partial SW}{\partial P_i} = \sum_{j=1}^{N}(P_j + h - c)\frac{\partial q_j}{\partial P_i} = 0, \qquad i = 1,2\ldots N$$

(27.2) $$\frac{\partial SW}{\partial K_i} = \sum_{j=1}^{N}(P_j + h - c)\frac{\partial q_j}{\partial K_i} = r - \frac{\mu\alpha q_i^2}{2K_i^2}, \qquad i = 1,2\ldots N$$

Note all ports are symmetric thus that $P_1 = P_2 = ... = P_N$. By (27.1) we have

(28) $$(P_i + h - c)\sum_{j=1}^{N}\frac{\partial q_j}{\partial P_i} = 0 \qquad i = 1,2,\ldots N$$

This implies that either $P_i = c - h$ or $\sum_{j=1}^{N} \frac{\partial q_j}{\partial P_i} = 0$. Below we show that $\sum_{j=1}^{N} \frac{\partial q_j}{\partial P_i} = 0$ is not possible so that $P_i = c - h$ must hold. Note by (16) we have $P_i = a - bq_i - \gamma \sum_{j \neq i} q_j$ for port *i* and $P_l = a - bq_l - \gamma \sum_{j \neq l} q_j$ for another port *l* ($l \neq i$). Differentiating the two equations with respect to P_i leads to

(29.1) $$(b + \frac{\mu\alpha}{K_i}) \frac{\partial q_i}{\partial P_i} + \gamma \sum_{j \neq i} \frac{\partial q_i}{\partial P_i} = -1$$

(29.2) $$(b + \frac{\mu\alpha}{K_l}) \frac{\partial q_l}{\partial P_i} + \gamma \sum_{j \neq i} \frac{\partial q_j}{\partial P_i} = 0$$

If $\sum_{j=1}^{N} \frac{\partial q_j}{\partial P_i} = 0$, it follows from (29.2) that $(b + \frac{\mu\alpha}{K_l} - \gamma) \frac{\partial q_l}{\partial P_i} = 0$, or $\frac{\partial q_l}{\partial P_i} = 0$ since $b \geq \gamma$ and the cost of delay is positive. As *l* is arbitrarily chosen, this implies that $\frac{\partial q_1}{\partial P_i} = \frac{\partial q_2}{\partial P_i} = ... = \frac{\partial q_N}{\partial P_i} = 0$, which contradicts to (29.1). Therefore, we must have

(30) $$P_i = c - h$$

Such result is a variant of the well-known principle of public utility pricing: to maximize social welfare, price should be set at marginal cost *c*. In (30) the price is marked down by *h* to incorporate the positive externality of port operation to the economy. With (30), (27.1), (27.2) and the symmetry condition, it can be solved that at equilibrium

(31.1) $$q_i = \frac{a + h - c - \sqrt{2\mu\alpha r}}{b + (N-1)\gamma} \qquad i = 1,2,\ldots N$$

(31.2) $$K_i = \frac{\sqrt{\mu\alpha}(a + h - c - \sqrt{2\mu\alpha r}}{\sqrt{2r}[b + (N-1)\gamma]} \qquad i = 1,2,\ldots N$$

4.4. Equilibrium results comparison of the three cases

For ease of reference, superscript is used in this section to denote the outcomes in the three cases as defined above. It can be found that when the positive spill-over effect *h* is very large thus that $sh > (\sqrt{2} - 1)(a - c) - \sqrt{2\mu\alpha r}$, we always have $K^I < K^{II} < K^{III}$. That is, a fully privatized port will invest the least capacity. The involvement of local governments leads to larger capacity, which is still insufficient for overall welfare maximization. The intuition is clear: if there is significant spillover effect of port operation, a central government will fully take into account of such positive externality by coordinating larger capacities and outputs.

When the positive spill-over effect is moderate and inter-port competition is not very aggressive, in the sense that $sh \leq (\sqrt{2} - 1)(a - c) - \sqrt{2\mu\alpha r}$ and the number of competing ports $N < \frac{[(2 - \sqrt{2})(a - c) + (2 - \sqrt{2}(1 - s))h]b}{[(\sqrt{2} - 1)(a - c) + (\sqrt{2}(1 - s) - 1)h - \sqrt{2\mu\alpha r}]\gamma} + 1$, we still have $K^I < K^{II} < K^{III}$. That is, when the competition is not too sharp, private investors or local governments will still under-invest than the social optimal level.

When the positive spill-over effect is moderate and inter-port competition is very sharp with a large number of ports competing in the market, in the sense that $sh \le (\sqrt{2}-1)(a-c)-\sqrt{2\mu\alpha r}$ and $N > \frac{[(2-\sqrt{2})(a-c)+2h]b}{[(\sqrt{2}-1)(a-c)-h-\sqrt{2\mu\alpha r}]\gamma}+1$ in our model, we have $K^{III} < K^{I} < K^{II}$. That is, privatized ports will over-invest than social optimal when there is significant competitive pressure. Interestingly, capacity waste is worst in the case with local government involvement. Since local governments care both (local) port profit and (local) spill over effects, under competitive pressure they tend to over-invest in port capacity.

While port capacity investment can be influenced by many factors as discussed above, when port pricing is taken into account, the condition $D^{I} = D^{II} < D^{III}$ always hold. That is, fully privatized ports will have the same congestion level as in the case of partially privatized ports involving local governments. A central government however would achieve higher congestion level. This is different from the case of monopoly port as inter-port competition promotes larger capacity investment. However, competition effect is absent if all ports are controlled by a central government.

5. Conclusions

Contemporary economic development ensures that port performance has become pivotal within the logistical supply chain. While many qualitative studies have discussed the inter-dependence of port ownership (including mixed ownership), inter-port competition, capacity investment and port pricing, few analytical models have been developed thus that all these factors can be analyzed simultaneously. This prevents researchers to draw an overall picture of the port industry, or to derive some general results of port operation. This paper proposes an integrated economic model with which the effects of these factors can be analyzed jointly. Our analytical results suggest that capacity investments and congestion level can indeed be influenced by factors such as ownership forms, presence of inter-port competition and possible port operation externalities. The result highlights include: (1) *ceteris paribus*, private investors would commit less capacity than governments who care more about regional economic benefits and the well-being of port users. However, given their profit maximization (or at least cost coverage) nature, private investors would charge higher prices which would likely reduce traffic volume. Under such balancing mechanism, in the absence of inter-port competition, port ownership would have no systematic influence over congestion level; moreover, (2) inter-port competition plays important roles in the determination of port capacity and pricing. As a result, congestion level will also be affected. In particular, when the spillover effect of port operation is moderate while inter-port competition is significant, private investors would invest excessive capacity than the social optimal level. Local governments would commit even more capacity. This would reduce congestion level but lead to excess capacity, and ultimately wastage of valuable resources.

Our model has provided evidence to support the proposition that port capacity and congestion can be influenced by many attributes including ownership structure, spillover effects, inter-port competition and (the continuance) of public influence. This probably explains why diversified port management structures have been observed in different regions around the world. Our study supports the standpoint of Ng and Pallis (2010) where the influence of institutions cannot be neglected in understanding diversified port reform process. Our study also serves as an ideal complement to other qualitative works (see section 2) and offers fresh insight to the topic, and indicates that it is important for port decision-makers to conduct detailed empirical investigation on the factors we modeled when actual policy/business decisions are to be made. Perhaps more importantly, our model offers some convincing empirical evidence counter-arguing the logic of unrestricted private participation in ownership and operation of large scale public infrastructures like ports (cf. Harrison, 2010). Surely, devolution and privatization can bring some positive effects. Nevertheless, as warned by Vining and Boardman (2008), it is not necessarily a cure-all strategy for port decision-makers.

Some simplifications have been made in our model due to modeling tractability. First, it is assumed that the efficiency levels of public and private ports are the same. If private ports are more efficient than public ports, then our model would predict less congestion when private share holding in a port increases. Secondly, it is assumed that the capital costs are the same for both state and private investors. In reality, state investors or governments usually are rated as low risk borrowers. As a result, their capital costs are usually lower than private investors. In such a case, capacity investment will increase as state investors have greater interests in the ports. If these two factors are explicitly considered, the actual port investment decision will deviate from our conclusion depending on the magnitudes of these two factors. The influences of these two factors are predictable thus that they should have limited impacts to the conclusions obtained in our study. However, the influences of alternative congestion functions are less clear. As Basso and Zhang (2008) pointed out, instead of imposing capacity constraints, one may introduce a more convex delay function so that congestion increases dramatically when traffic volume approaches capacity limit[1]. Future studies testing alternative delay functions will be valuable.

Despite such limitations, by modeling partial privatization (mixed ownership) and composite port objective functions, we have proposed a good framework to analyze a range of ownership options within one consistent model. Methodologically, we also offer an integrated model with which the effects of ownership, inter-port competition and positive externality/spillover effects can be analyzed jointly. In addition, ports are modeled as making decisions on both pricing and capacity. This allows us to systematically study port behaviors rather than focus on a single port decision only. Indeed, the framework we proposed is very general in that many factors have been explicitly considered. Different objective functions have been specified in order to analyze possible strategic differences between local and central governments. Such a new approach has not been widely used in the port literature. Last but not least, this study offers some fresh insight to the ongoing debates of private participation in the ownership and operation of transport infrastructure, as well as the implications of continual government involvements. Further studies incorporating empirical elements in the future would be of great value.

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[1] For example, one alternative delay function is $D = \frac{Q}{Q(K-Q)}$, thus that D approaches infinity when output Q approaches capacity K.

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Service Quality Gap between the Expectations of Shippers and Carriers in Asian Dry Bulk Shipping

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Abstract

Bulk shipping is a highly competitive market that is subject to volatile freight rates caused by imbalance between demand and supply as well as changes in input costs. As such companies constantly face challenges of being competitive in the market and making profit. This highlights shipping companies" need to maintain a high level of customer satisfaction and service quality. On the other hand, the service quality expectations of shippers are beyond the terms and conditions of the charter party that often cannot specify the intangible elements of service quality. Although, the concept of service quality is not new in dry bulk shipping, it is often not well understood. This paper seeks to evaluate the gap between the service quality expectations of shippers and shipping companies as a way to gain insights into shipping companies" competitive advantage. In particular, the paper extends previous research on service quality to dry bulk shipping companies in Asia. A survey of both shippers and carriers in Asia covering various factors of shipping services is conducted, data obtained are analyzed to investigate the contribution of these factors to service quality, and the implications for shipping service quality management are discussed. The results of data analysis reveal that gaps between the service quality expectations of shippers and carriers exist, but with varying levels of significance.

Keywords: service quality, dry bulk shipping, SERVQUAL, competitiveness, Asia.

1. Introduction

The shipping industry is global and highly competitive; ships can travel between ports around the world and shipping companies, especially in the dry bulk sector compete freely on the global market. As such, shipping companies are under constant pressure to maintain competitiveness. Broadly speaking, the competitiveness of a shipping company is influenced by country-specific factors and company-specific factors. The former can be the country"s trade with the rest of the world, financial market development, shipping policies, development of the shipping industry in the past, access to sea, shipbuilding capacity and the technology and economic development (Nguyen, 2009, 2010). The latter can be the company"s scale economies, marketing strategies, management skills and experience, and financial resources (Stopford 1997). As country-specific factors are fundamentally external to shipping companies, they are less controllable. In practice, operational efficiency among other factors is critical to the survival of shipping companies and companies find novel ways to improve its competitiveness. The following factors often attract most attention from companies as they try to improve their market competitiveness:

1. The cost-effectiveness/leadership through employing large ships and seafarers from third world countries,

2. The ability to respond to changes in the market through effective management of fleet tonnage,
3. The service quality and service differentiation.

In particular, companies may face a trade-off between the first and the third factors. Cost effectiveness/leadership may have a negative impact on service quality while improving service quality could result in higher costs. For example, to reduce costs, shipping companies have consistently reduced manning both at sea and in the company‟s offices but this leads to more workload for individual employees, giving them less time to accomplish their jobs and devote to customer issues, both of which negatively affect service quality. Regarding the second factor above, if for example the company‟s tonnage supply is rather sluggish due to it normally taking a year or more to build a ship, therefore any sudden and rapid surge in the demand cannot be catered to in the short run. Likewise a slump in demand often results in an excess supply of tonnage lowering the freight rate and causing losses. Thus, carriers are increasingly more concerned about service quality and differentiation in order to secure their competitive advantage.

Another factor is that the important aspects of shipping services are governed by a mutually agreed charter party between the shipper and the carrier. The terms and conditions of the contract of carriage are laid out in the charter party. The charter party has historically favoured the owners, which leaves the charterers dissatisfied with the services provided, even though the services provided are as per the contract. The charter party does not and cannot specify the tangibility, reliability, responsiveness, competence, communication, security and customer knowledge standards of the service which are of as much importance to the service as the transportation itself. It can also be seen from the financial perspective that carriers are providing their service quality levels according to the freight rate.

However, the shipper‟s expectations of service quality may differ from the carrier‟s perception of the shipper‟s expectations. Similarly the shipper‟s perception may differ from the carrier‟s perception of service. Therefore, it is of paramount importance that carriers understand shippers‟ perceptions and expectations of service quality to gain sustainable competitive advantage. Hence, the gap between shippers‟ and carriers‟ expectations and perceptions of service quality needs to be analyzed and subsequent action should be taken to minimise such a gap. As customer demands are continually changing; the service quality gap needs to be continuously monitored and services should be tailored to the needs of the customer.

This study analyses the gap between the perceptions and expectations of service quality in shipping. Although the concept of service quality is not new to shipping, it has not always been well understood and effectively applied. This paper extends previous research on service quality to dry bulk shipping in Asia and investigates the contribution of the key factors to service quality as a means for carriers to manage the third factor mentioned above, in relation to service quality and service differentiation. To achieve the research objective, the quantitative primary data for the study are collected through an online survey and then used to evaluate the gap between the service quality expectations of shippers and carriers. A survey questionnaire is developed by adapting the well known service quality framework, SERVQUAL developed by Parasuraman, Zeithaml and Berry (1988, 1992, 1995) to the dry bulk shipping sector in Asia.

The body of the paper is divided into five sections. The next section presents a review of the literature on service quality in shipping. Sections three and four explain the data collection and analytical methods, and the main findings and implications respectively. The last section is the conclusion.

2. Service quality in shipping

It is of paramount importance for service providers to manage service quality. One way to achieve this goal is for service providers to learn about customer expectations of the service quality as it forms a basis for the monitoring and managing of service quality. In other words, the evaluation of the gap between the customer‟s and service suppliers‟ expectations is the first and critical step in assessing service quality. It has already been noted that there is insufficient research on service quality expectations, especially in dry bulk shipping. This study seeks to address this deficiency in the literature by examining the gap between the shippers‟ and carriers‟ perceptions and expectations of dry bulk shipping.

In dry bulk shipping, the scope and terms of service are subject to negotiation and agreement between shippers and carriers through fixture notes, charter parties, and contracts of employment. However, the expectation of service is not well communicated and the carrier perceives the expectation standards based on past experiences and market research. This section explains how the Parasuraman, Zeithaml and Berry (1993) conceptual framework can be applied to shipping.

In order to examine the issues across the stakeholder groups, it is necessary to establish the importance of the various attributes identified by Parasuraman, Zeithaml and Berry (1988, 1992, 1995). Moreover, due to the trade-off between service quality and cost, it is important to establish if dry bulk shippers are ready to pay a premium for better service quality, and whether it is important to assess the value-added services that the shipper expects the carrier to perform.

To achieve the above mentioned objectives, first, it is important to assess if the fulfillment of the contract of carriage is considered by the stakeholders as good service quality. In dry bulk shipping, the contract of carriage documents the scope of services. However, due to the heterogeneity, inseparability, perishability and intangibility (HIPI) characteristics of service, the freight contracts may not be able to document the service quality requirements of shippers.

Second, due to intense competition in the dry bulk shipping industry, many carriers make use of quality aspects of service in order to differentiate their service and gain an edge over their competitors. Analysis of websites of many dry bulk carriers and operators reveals that carriers/operators tend to place much emphasis on service quality and advertise their services as high quality, reliable and tailored to meet customers" needs. Interestingly, many dry bulk owners/operators claim they provide value-added services and emphasize their intention to be a strategic partner of cargo interests (shippers). Dry bulk shipping companies have been seen increasingly applying for ISO quality certifications to convince customers that they are highly qualified service providers. Therefore, it is important to know if the shippers consider the carriers" ISO certification when selecting carriers for transportation of their commodities.

Third, due to the economic recession of the past couple of years and the nature of some dry bulk trades, dry bulk cargoes are sold while the cargoes are being shipped. For example, iron ore is often transported by traders and sold to their customers while the cargo is en route. This requires that the bills of lading be switched, to reflect the name of the correct consignee or receiver, since the bill of lading is a document of title. Due to lack of time, bills of lading do not reach the discharge port in time and therefore, cannot be presented to the ship master for the delivery of the cargo. Shippers and consignees regularly request carriers to discharge the cargo without the presentation of the original bill of lading and give the carriers a “letter of indemnity” for non-presentation of the original bill of lading. This puts the risk of wrong discharge on the carriers. Thus, it is important to assess if shippers and consignees consider this to be a critical element of service as carriers have the right to hold the cargo until the original bill of lading is presented.

Parasuraman, Zeithaml and Berry (1985) suggest that the quality that a consumer perceives in service is a function of the magnitude and direction of the gap between the consumer"s expectation and perception of service. The expectation of service depends on customers" personal needs, past experience and word of mouth communication. Parasuraman, Zeithaml and Berry (1990) have shown that the first and most critical step in delivering service of a high quality is to know the expectations of customers. The questionnaire for this study is designed based on the comprehensive works of Parasuraman, Zeithaml and Berry (1985, 1988, 1990, 1991, 1993) on service quality.

Parasuraman, Zeithaml and Berry"s (1985, 1988, 1990, 1991, 1993) extended model of service quality (SERVQUAL), is based on the definition of the five distinctive gaps between customers" expectations and their perception of service as highlighted in Figure 1. The SERVQUAL questionnaire helps service providers to better understand the service expectations and perceptions of their customers and measures service quality along five dimensions, including:

- tangibility,
- reliability,

- responsiveness,
- assurance, and
- empathy.

Zikmund (2003) highlights the importance of questionnaire relevancy and accuracy to ensure that the information obtained is requisite to solving the business problem. However, as noted by Pantouvakis, Chlomoudis and Dimas (2008), although SERVQUAL is a useful instrument for the measurement of shipping service quality, special attention needs to be paid to its adaptation to specific industries due to the problems associated with its dimensionality. As discussed in Section 3, the SERVQUAL questionnaire for this study has been adapted to the dry bulk industry to measure the expectation scores.

3. Data collection and analytical methods

This study measures the gap between the expectations of the stakeholders in dry bulk shipping along the five dimensions mentioned above, namely tangibles, reliability, responsiveness, assurance and empathy. To achieve the objective of studying the SERVQUAL expectation gap in dry bulk shipping, this study uses an online survey as a tool to collect data. In particular, the questionnaire utilised in this study uses a five-point Likert scale to rate the expectations of the respondents and measures service quality along five dimensions of service quality. The questionnaire identifies three stakeholder groups targeted in the study:

- Stakeholder group one: Dry bulk shippers and consignees
- Stakeholder group two: Dry bulk carriers and operators
- Stakeholder group three: Brokers

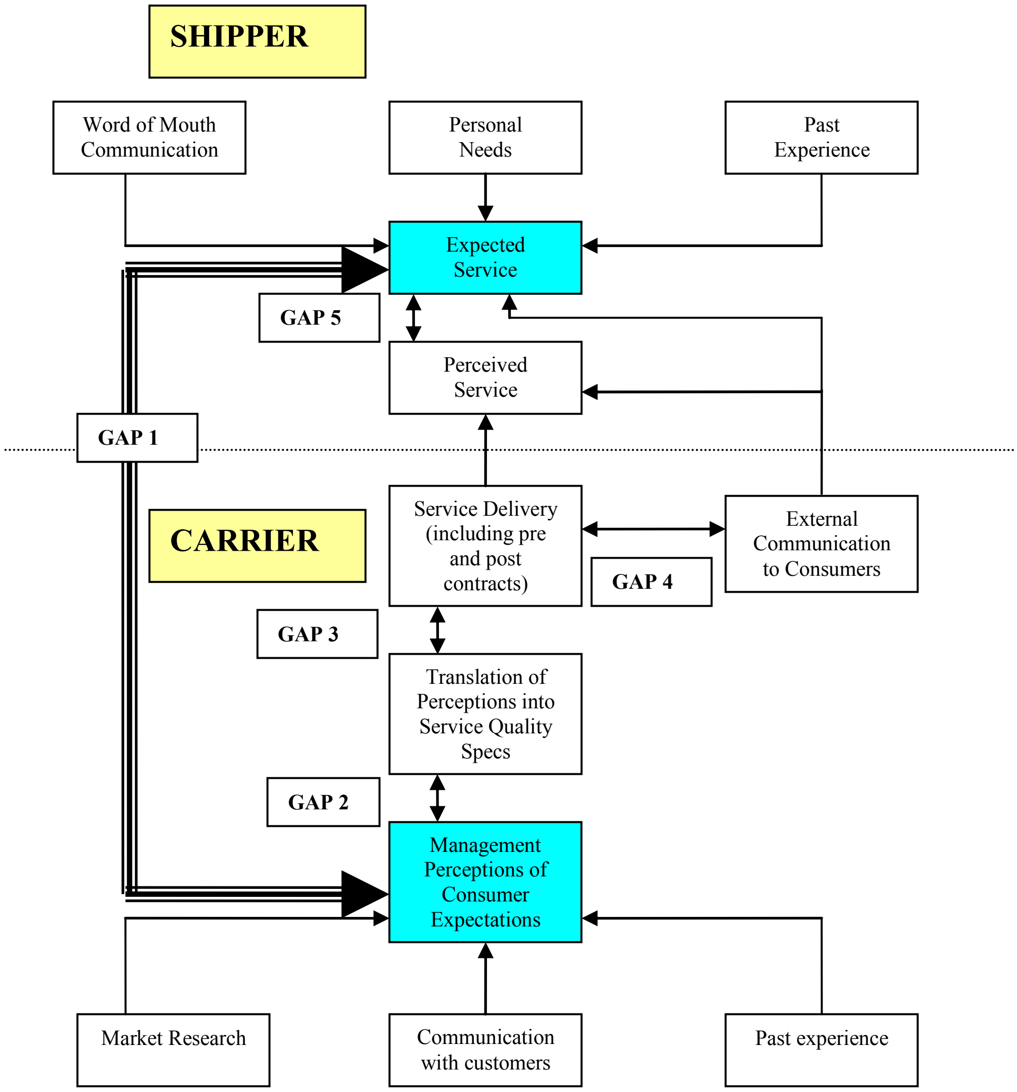
Simple random sampling is one of the most common probability sampling methods, in which each member of the population has the same probability of being selected. Lobo (2002), in a similar vein, elaborates on the above discussion and suggests that it is imperative that the target population is correctly identified at the beginning of the sampling process to sufficiently recognize the data sources.

The sample set is drawn from the list of dry bulk shippers provided by the „Coal Spot website" and the list of carriers provided by the Lloyds MIU database. Additionally, the directory of the Singapore Shipping Association, Hong Kong Shipping Association and recommended industry contacts are also used to assist adequate participation.

All 180 companies included in the above contact lists were invited to participate in the study and include:

- Stakeholder group one: 59 dry bulk shippers and consignees
- Stakeholder group two: 68 dry bulk carriers and operators
- Stakeholder group three: 53 brokers.

Figure 1: Service quality expectation gap



Source: Adapted from Parasuraman, Zeithaml and Berry (1993)

The distribution of stakeholders targeted indicates that the sampling covers a good mix of all the three groups. The survey administration included a series of telephone calls to known industry contacts and reminder emails to all others. Furthermore, in line with the Human Research Ethics rules, an information sheet was also sent to participants explaining the purpose and benefits of the study, the reason for invitation and any risk of participation. In addition, the following questions were addressed in the invitation letter:

1. What is the purpose of this study?
2. Why have I been invited to participate in this study?
3. What does this study involve?
4. Are there any possible benefits from participation in this study?
5. Are there any possible risks from participation in this study?
6. What if I have questions about this research?

The survey questionnaire used in this study is developed based on Parasuraman, Zeithaml and Berry‟s (1988, 1992, 1995) approach adapted to the dry bulk shipping industry. In particular, the following issues/questions were covered in survey:

1. Is there a service quality expectation gap existing between shippers and carriers?
2. Should carriers provide more value-added services in addition to freight services?
3. Should there be a premium for carriers delivering high quality service?

4. Does the fulfillment of the contract of carriage constitute good service quality?
5. Are carriers‟ ISO certificates important when a shipper selects a carrier for freight service?

A total of 27 responses were received of which 11 respondents each were from stakeholder group one and two. Only 5 responses were received from stakeholder group three.

Percentage responses for each of the attitude responses of each of the attitudes (strongly disagree, disagree, neutral, agree, strongly agree) were calculated, and the means and standard deviations of the expectation scores of all the attributes computed. The difference between the expectations of the stakeholder groups was analyzed using relevant statistical tests to evaluate the gap between carriers‟ and shippers‟ expectations. The larger the gap on the attribute, the greater would be the effort required by the carrier to bridge the gap. Conversely, no gap or positive gap would indicate that the carriers outperform on the attribute and completely understand the customers‟ requirements.

Following Zikmund (2003) and others, this study applied the t-test of the means of two populations with unequal variances. In particular, the following hypotheses are tested:

- *Null hypothesis*: The means of the feedback (service quality expectation) of the two stakeholder groups are equal.
- *Alternative hypothesis*: The mean of the feedback of the stakeholder group one is higher than that of stakeholder group two.

The test statistic and the degrees of freedom respectively are specified as follows:

$$t = \frac{\overline{X_1 - X_2}}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{[(S_1^2/n_1) + (S_2^2/n_2)]^2}{\frac{(S_1^2/n_1)^2}{n_1 - 1} + \frac{(S_2^2/n_2)^2}{n_2 - 1}}$$

where:

$\overline{X}_1$ = mean of group 1
$\overline{X}_2$ = mean of group 2
S_1^2 = variance of group 1
S_2^2 = variance of group 2
n_1 = sample size of group 1
n_2 = sample size of group 2

4. Main findings and implications

The scores of the five dimensions of SERVQUAL were computed by summing up the mean score of all the questions for each dimension and dividing the total by the number of questions in that particular dimension. The analysis of the five dimensions of SERVQUAL revealed that the shippers considered reliability as the most important dimension of service quality while carriers considered responsiveness and assurance as the most important dimension. It is, however, interesting to note that respondents from stakeholder group 1 considered tangibility as the least important of the five dimensions.

Table 1: Scores of five dimensions of SERVQUAL

Dimensions of Service Quality	*Stakeholder group 2*	*Stakeholder group 1*	*Difference*

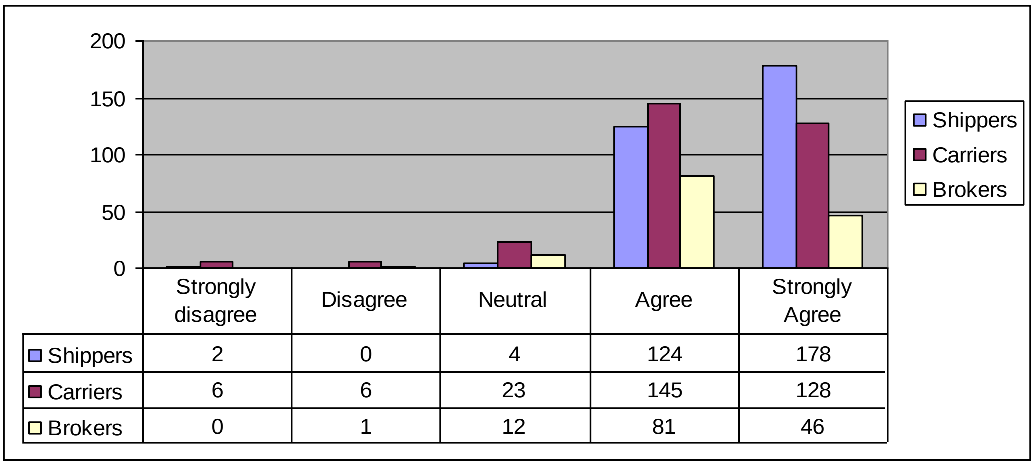
Tangibility	4.01	4.44	0.43
Reliability	4.38	4.76	0.38
Responsiveness	4.42	4.51	0.09
Assurance	4.42	4.62	0.20
Empathy	4.11	4.45	0.35

As shown in Table 1, the maximum gap between stakeholders 1 and 2 concerns the tangibility of service. Generally this large gap between the two groups suggests that carriers will need to put greater efforts to meet shippers‟ expectations on tangible attributes.

The analysis of the importance of attitudes reveals that stakeholder group 1 considers reliability as the most important aspect of service quality. All the 11 respondents from group 1 strongly agreed that reliability is an important dimension of service quality.

Of the 28 questions in Part 1, the gap between the means of the responses of the carriers and shippers was negative for 27 questions suggesting that shippers‟ expectations are greater than carriers‟ expectations. The t-test of the two samples assuming unequal variances of only 10 out of the 28 questions showed that this service quality gap is statistically significant. Figure 2 summarizes the responses from *all* respondents to the survey questionnaire. The mean and variance of the carriers‟ responses are 4.25 and 0.67 respectively, while those of the shippers are 4.54 and 0.39 respectively.

Figure 2: Pooled Data



To overcome the small sample size issue, responses to many questions were pooled to obtain much larger data set, which was then used for the t-test comparing the *overall* expectation of the two groups. Table 2 highlights that the corresponding t-statistic with 572 degrees of freedom is -4.88 and p-value is 0.0007, which strongly indicate at the 1% significance level that shippers have higher expectations of service quality than the carriers. This finding is extremely critical as it highlights that overall the dry bulk shippers‟ expectations of service quality are greater than the carriers' expectations.

Table 2: T-Test using pooled data

Two-Sample t-Tests assuming Unequal Variances

	Carriers	Shippers
Mean	4.253247	4.538961
Variance	0.671814	0.386099
Observations	308	308
Hypothesized Mean Difference	0	
Df	572	
t Stat	-4.87509	
P(T<=t) one-tail	7.05E-07	

t Critical one-tail	1.647522	
P(T<=t) two-tail	1.41E-06	
t Critical two-tail	1.96412	

Results of the survey on the carriers' management of expectation on service quality

Table 3 summarizes the respondents" answers to Part B, Question 1 of the questionnaire (see Appendix 1). 81% of the respondents agreed that there is a premium on freight for carriers delivering high quality service. 91% of the respondents from stakeholders group 1 believe there is a premium on freight for delivering high service quality compared to only 64% and 80% of the respondents from stakeholder group 2 and 3 respectively.

Table 3: Stakeholders' responses

	Yes	No
Stakeholder group 1	91%	9%
Stakeholder group 2	64%	36%
Stakeholder group 3	80%	20%

Respondents suggested that the following value-added services should be provided by a high quality carrier:

1. Terminal storage arrangements, pre-carriage, on-carriage.
2. Shipment tracking.
3. Transparency in dealings and information exchange with charterers/shippers - some quality carriers already do that, but many others do not.
4. Access to some web based program to the charterer/shipper where they can monitor vessel movement under the contract.
5. Guaranteed delivery dates/on time delivery.
6. Reliability and punctuality.

The respondents suggested pre-carriage, on-carriage and terminal storage arrangements as value-added services implying door–to-door carriage requirement. Interestingly, this entails inter-modal operations, which itself would not be the core competence of the dry bulk carriers and operators and hence, the carriers may be reluctant to provide such a service.

Shipment tracking is another suggestion made by stakeholders as a value-added service. In order to reduce inventory costs and have an agile supply chain, shipment tracking is rather important for shippers. Shipment tracking together with on-schedule delivery is imperative for the shippers to plan their operations. Shipment tracking would involve additional costs to the carriers and cost benefit analysis of the same would be required by the carriers before a decision can be made to provide real-time shipment tracking facilities.

Table 4 summarizes the respondents" answers to part B, question 3 of the questionnaire (see Appendix 1). 42% of the respondents agreed that carriers that demand higher freight rates often provide better service quality. Only 36% of respondents from stakeholder group 1 consider the carriers demanding higher freight rates as the ones providing better service quality, whereas respondents from stakeholder group 2 and 3 who consider the carriers demanding higher freight rates as better service providers are 45% and 40% respectively.

Table 4: Stakeholders' responses

	Yes	No
Stakeholder group 1	36%	64%
Stakeholder group 2	45%	55%
Stakeholder group 3	40%	60%

Table 5 summarizes the respondents" answers to part B, question 4 of the questionnaire (see Appendix 1). Only 27% of the shippers considered the fulfillment of the terms of contract of carriage as a good service quality. Interestingly, 82% of respondents from stakeholder group 2 consider fulfillment of the terms of contract of carriage as a good service quality. This essentially means that dry bulk shippers expect more from the shipping service than mere fulfillment of the terms and conditions of the contract.

Table 5: Stakeholders' responses

	Yes	No
Stakeholder group 1	27%	73%
Stakeholder group 2	82%	18%
Stakeholder group 3	60%	40%

Table 6 summarizes the respondents‟ reply to whether carrier‟s ISO certification is considered when fixing business. 58% of the respondents agreed that a carrier‟s ISO certification is considered when fixing business. Interestingly, only 27% of the respondents from stakeholder group 1 consider a carrier‟s ISO certification, whereas 73% of the respondents from stakeholder group 2 consider that it is important to have ISO certification for fixing business.

Table 6: Stakeholders' responses

	Yes	No
Stakeholder group 1	27%	73%
Stakeholder group 2	73%	27%
Stakeholder group 3	80%	20%

Table 7 summarizes the respondents‟ responses to carrier‟s flexibility in documentation. 73% of the respondents consider a carrier‟s flexibility in documentation such as accepting Letter of indemnity (LOI) without bank guarantee to release cargo without presentation of documents such as Original bill of lading (OBL), switching OBL‟s as a critical aspect of service quality. 82% of the respondents from stakeholder group 1 considered a carrier‟s flexibility in documentation a critical aspect of service quality, whereas only 64% of the respondents from stakeholder group 2 considered the same.

Table 7: Stakeholders' responses

	Yes	No
Stakeholder group 1	82%	18%
Stakeholder group 2	64%	36%
Stakeholder group 3	80%	20%

Table 8 summarizes that 62% of the respondents suggest that shippers provide guidelines regarding the service quality expectations to the carriers. 64% of the respondents each from stakeholder group 1 and 2 indicated that the guidelines are provided by the shippers.

Table 8: Stakeholders' responses

	Yes	No
Stakeholder group 1	64%	36%
Stakeholder group 2	64%	36%
Stakeholder group 3	60%	40%

5. Conclusion

Dry bulk shipping is a unique industry which is lacking significant research on the gap between shippers and carriers‟ service quality expectation. This study is the first step in the analysis of service quality in Asian dry bulk shipping. The result of data analysis indicates a significant gap between the service quality expectations of shippers and carriers. Of the 28 questions asked in the questionnaire, 24 questions had answers indicating that shippers‟ expectations of service quality are higher than those of the carriers. This is further confirmed by t-tests. Only one question concerning the carriers‟ employees‟ timely response to customers‟ requests and complaints had a positive gap suggesting that the carriers‟ expectations of service quality are higher than those of the shippers on this aspect. On the other hand, the two groups‟ expectations are the same for the three questions that concerned expectations on ship maintenance, cargo handling equipment and the carriers‟ ability to keep to schedules.

In order to assess the overall gap between the service quality expectations of the two groups, the study applied the t-test of the pooled data. The result of the test strongly indicates a significant overall gap existing between the expectations of shippers and carriers. Thus, this overall conclusion implies that the carriers can improve service quality and thereby gain competitiveness in the market by aligning their service quality with customers‟ expectations.

The findings indicate that 91% of the shippers in the sample believe there is a premium to be gained for carriers to provide better service quality. Interestingly, only 64% of the carriers believe that shippers would be willing to pay a premium for better service quality. Thus, the results of the data analysis for dry bulk shipping are consistent with Deming‟s (1982) service improvement model, which suggests that service quality improvement leads to greater profitability, decreased costs and increased market share. Moreover, in dry bulk shipping, service quality that is aligned with shippers‟ expectation of service would result in improved productivity, less delay, increased market share and increased profits. However, the results of the data analysis also found that only 36% of shippers agree that carriers demanding higher freight rates provide better service quality.

It has also been found that dry bulk shippers consider intangible elements of service to be more important than tangible elements. Shippers expect their carriers to do more than just fulfill the terms and conditions of the contract of carriage. In particular, 82% of the dry bulk carriers believed that fulfillment of the terms and conditions of the contract of carriage constitute good service quality, while only 27% of the surveyed shippers considered the same. Therefore it can be concluded that shippers expect more to service than mere fulfillment of the terms of the contract of carriage.

The analysis of the dimensions of service quality revealed that shippers consider carriers‟ reliability as the most important factor of service quality. Interestingly, stakeholders 1 and 2 consider tangibility as the least important factor. This seems to be consistent with the argument that intangible elements of service are rather important while tangible elements, though important, are not considered to be utmost priority. This result is in line with Mehta, Lobo and Mehta‟s (1997) findings that service quality is not entirely governed by tangible factors.

The analysis of service quality dimensions in dry bulk shipping also reveals that the largest gap between shippers‟ and carriers‟ expectations of service quality pertains to the tangibility and reliability dimensions. Although shippers have a relatively low expectation of the tangibility dimension of service quality, the expectations of carriers is even lower. Increased efforts from carriers to improve on the tangible factors of service quality would be required to narrow the service quality gap.

The study has found that 82% of the surveyed shippers expect the carriers to be flexible in documentation and consider it a critical aspect of service quality whereas only 64% carriers consider the same. This gap in the shippers‟ and carriers‟ views may be due to the fact that carriers are concerned about the risks associated with flexibility in documentation. In addition, it has also been found that dry bulk shippers expect high quality carriers to provide value-added services in addition to transportation services. Shippers expect carriers to provide vessel monitoring services so that they can track their shipments and monitor the vessel schedules closely. It has been suggested that carriers need also offer terminal storage, pre-carriage and on-carriage services. These are not core competencies of dry bulk carriers but could be provided through a strategic partnership with inland logistic service providers or third party logistics providers.

A gap between carriers and shippers‟ service quality expectations found by the study suggests that dry bulk carriers‟ service is not up to their customers‟ expectations. Even though carriers can provide services as per the terms and conditions of the charter party, this does not necessarily mean that the service performed is up to the satisfaction of the shippers/charterers. The importance of the intangible elements of service cannot be over emphasized. While bulk shipping is often considered as extremely competitive, making efforts to reduce the expectation gap may improve service quality and customers satisfaction that will improve customers‟ loyalty and the company‟s competitiveness.

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Appendix

"Questionnaire On Service Quality Gap Between Shippers And Carriers In Dry Bulk Shipping"

Service Quality Gap between Expectations of Shippers and

PART A: Expectations of service quality

Please tick only one of the choices for each question. The questions are designed to measure the stakeholders' expectations of service quality.

i. Tangible factors of high service quality in shipping

*** 1. The tangible factors are critical to service quality.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 2. Ships and cargo handling equipments meet safety standards and operational requirements for carrying the shipment.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 3. The ships of quality carriers are well maintained.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

*** 4. Quality carriers ensure that their ships' cargo holds are maintained to the highest / requisite standards suitable for carriage of the charterer's cargo.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 5. The employees of quality carriers demonstrate their knowledge, skills and diligence at work and when handling customers.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 6. Materials associated with the marketing aspects of service (such as website, pamphlets or statements) are visually appealing.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 7. The standards & modes of communication, and customer & operational reporting (24 X 7) are of high standard and latest technology.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

Reliability

*** 1. Reliability is a critical factor in service quality.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 2. Quality carriers are committed to keeping their promise and schedule.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 3. Quality carriers are serious about addressing customers' concerns and needs.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 4. Quality carriers are committed to providing service quality to customers' satisfaction.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

*** 5. Quality carriers insist on error free documentation.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

Responsiveness

* 1. Responsiveness is a critical factor to service quality.

- Strongly disagree
- Disagree
- Neutral/Unaware
- Agree
- Strongly agree

* 2. High quality carriers always advise shippers/consignees of the ships' operational schedule and keep to the timeline.

- Strongly disagree
- Disagree
- Neutral/Unaware
- Agree
- Strongly agree

* 3. Quality carrier's employees respond to customers' requests and complaints in a timely manner.

- Strongly disagree
- Disagree
- Neutral/Unaware
- Agree
- Strongly agree

* 4. Quality carrier's employees are always willing to help customers.

- Strongly disagree
- Disagree
- Neutral/Unaware
- Agree
- Strongly agree

Service Quality Gap between Expectations of Shippers and

Assurance

* 1. Quality assurance is a critical factor to service quality.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* 2. Quality carriers ensure secure financial transactions.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* 3. The competence and diligence of the ship officers and shore-based staff instills confidence in customers.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* 4. The employees of quality carrier's are consistently reassuring and courteous with customers.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

* 5. The employees of quality carrier's have sufficient and relevant knowledge base to handle customers' requests and questions.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

Empathy

* **1. Empathy is a critical factor to service quality.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* **2. Quality carriers give individual attention to their customers.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* **3. Quality carriers have convenient operating hours and attend to customers' needs at any time.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

* **4. Quality carriers' employees give personal attention to customers.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

*** 5. Quality carriers understand and care about customers' best interests.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

*** 6. Employees of quality carriers try to understand and address the specific needs of individual customers.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral/Unaware
- ◯ Agree
- ◯ Strongly agree

Service Quality Gap between Expectations of Shippers and

PART B

* 1. Do you believe that there is a premium on freight to be had for carriers delivering high quality service?

- ◯ Yes
- ◯ No

2. Please suggest value added services that, in your view, a high quality carrier should provide.

* 3. Do you believe that carriers that demand higher freight rates often provide better service quality?

- ◯ Yes
- ◯ No

* 4. Does the fulfillment of the terms of the contract of carriage constitute good service quality?

- ◯ Yes
- ◯ No

* 5. Is carrier's ISO certification considered when fixing business?

- ◯ Yes
- ◯ No

* 6. Do you consider carrier's flexibility in documentation such as accepting LOI's without bank guarantee to release cargo without presentation of OBL, switching B/L's etc as a critical aspect of service quality?

- ◯ Yes
- ◯ No

Service Quality Gap between Expectations of Shippers and

* 7. Do shippers provide any guidelines regarding service quality expectations to the carriers?

- ◯ Yes
- ◯ No

8. Please provide your remarks, if any.

Scale Diseconomies and Efficiencies of Liner Shipping

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Abstract

In the context of liner shipping, carrying capacity can be seen as a key resource to strive for better firm performance. The liner shipping market nowadays has entered a phase in which liner shipping companies (LSCs) reap economies of scale. The concept of economies of scale has led the industry to grow by enlarging its capacity and firms allocate more ships to offer shipping services in the worldwide market. However, the results of enlarged capacity may be uncertain. By examining empirical data (from 1997 to 2008), this paper investigates the relationship between capacity and firm performance in the liner shipping industry and attempts to use an S-curve to describe their relationship. The findings suggest that the S-curve is robust. Furthermore, this study attempts to provide theoretical basis for shipping lines to determine the optimal carrying capacity.

Keywords: liner shipping, diseconomies of scale, S-curve, capacity, revenue

1. Introduction

From the perspective of the industrial organisation paradigm, Porter (1981) proposed that "*the industry structure determines the conduct of firms whose joint conduct then determined the collective performance of the firms in the marketplace*". This implies a strong tie between market structure, conduct and performance (SCP). According to Coase (1937), SCP can be defined as "*the observable structure characteristics of a market determine the behavior of firms within the market, and that the behavior of firms within a market, given structural characteristics, determines measurable aspects of market performance.*" In the context of liner shipping economic and political conditions shape its market structure. Koch (1974) defined market structure as "*the strategic elements of the environment of a firm that influence, and are influenced by, the conduct and performance of the firms in the market in which it operates*". Market structure can be investigated through such variables as economies of scale, entry barriers, industry concentration, and product differentiation (Lun et al., 2009). The market structure of the liner shipping industry affects firms' conduct in their business operations (Pepall et al., 2005). Market conduct involves the actual behaviours of firms in a market and how the firms respond to the conditions imposed by the market structure and how they interact with rivals. One of the most significant aspects of market conduct is pricing policy and capacity management. The performance of LSCs depends on their conduct when making such decisions as pricing and capacity level. The shipping market fluctuates from time to time. In some situations, LSCs confront intense price competition and under-utilisation of fleet capacity which results in low average profits. When there is a shortage of supply of shipping capacity, LSCs may charge a higher freight rate which results in high average profit (Lun et al., 2010a).

The liner shipping industry has, in recent years, gained increased attention from the government, trade associations and global traders (Notteboom and Rodrigue, 2008). Song et al. (2005) pointed out that there are two contemporary issues that need to be explored in the liner shipping area. One argument is that the LSCs face intense competition in the globalised liner shipping market. The second point raised is over-capacity of the LSCs. The overcapacity leads to lower freight rates. As a result, the liner shipping is currently characterised by low profit margin. The level of capacity utilisation depends on the growth of containerised cargo, the speed with which existing operators introduce new and larger vessels into liner shipping service, and the level of exits of operators from the market. On the track of liner shipping research, pervious works are mainly restricted to ship operations such as optimal speed and ship scheduling (e.g., Christiansen et al., 2004). Various mathematical programming models and optimisation techniques have been heavily developed that provided operating solutions by using deterministic models or stochastic models. However, recent studies in liner shipping management are rather limited. This paper attempts to fill the research gap by investigating the relationship between capacity and market share in liner shipping as well as determining a functional specification of this relationship. In this study, we attempt to present structural characteristics of the liner shipping industry by investigating internal and external factors as the basic parameters of the S-curve and testing it using the empirical data from 1997 to 2008. We further attempt to determine the shape of the S-curve so as to disclose the transition from scale economies to scale diseconomies.

2. Literature Review

It is well recognised that perceived growth and scale operations determine the performance of firms. The organisational growth stimulates economies of scale and expansion of firm size is closely related with prestige. To remain competitive, many firms intend to strive for growth in the dynamic operating environment (Lun et al., 2010b). LSCs nowadays enlarge their firm size to demonstrate their ability to confront traditional and new challenges. For instance, large sized operations induce an operational mechanism to facilitate cost efficiency over a high production volume (Dobrev and Carroll, 2003). Large firms are able to gain a better position to deter new competitors from entering into the market (Porter, 1999). Operating on a large scale prompts geographical expansion and encourages the globalisation of business (Lun et al., 2010b). LSCs extend their geographical coverage to attract sufficient cargo volume that allows them to reap economies of scale in vessel operations so as to diminish the unit cost of container handling (Midoro and Pitto, 2000). The enhancement of capability in the liner shipping context can create a potential source of competitive advantages (Lai, 2004). Apart from scale operations, many LSCs have taken initiatives to broaden and widen the range of services to enable them to exceed shippers' expectations (Yang et al., 2009). To exploit the business opportunities, LSCs offer comprehensive shipping services such as increasing the service frequency and the number of ports of call. Indeed, many LSCs enlarge their service scope to extend vertically by providing a wide range of related services include developing various logistics related services and expanding container terminal operations internationally (Lun and Browne, 2009).

Originating from the strategic management literature, a firm gathers organisational resources and uses its resources in an optimal pattern. Capacity can be seen as one of the key resources in the context of liner shipping (Yang et al., 2009). Based on Day (1994, p.38), it is proposed that capabilities are "*complex bundles of skills and accumulated knowledge, exercised through organizational processes, which enable firms to coordinate activities and make use of their assets.*" Makadok (2001) emphasised that the process of production is found to be scale optimal and fosters increasing economic returns. Economies of scale in the use of resources constitute a substantial competitive advantage of firms to gain survival and prosperity (Winter, 2000). In the context of liner shipping operations, low rates of return on capital and low freight rates have stimulated the LSCs to enlarge their capacity to spread fixed unit costs and increase profit (Fusillo, 2006; Yang et al., 2009). Based on that, the world's mega LSCs tend to increase their carrying capacity which has intensified the characteristic of concentration of operations in the overall liner shipping industry. Since 1995, the trends of merger and acquisition have spanned across shipping firms (Yang et al., 2009). Large LSCs swallow small LSCs with the aim to solidify their competitive position against other rivals (Fusillo, 2006). Examples include the takeover of CP Ships by Hapag-Lloyd in 2005 (now one of the top five LSCs in the world), the takeover of P&O Nedlloyd by Maersk in 2005, and the merging of CMA CGM and Delmas in 2006. These consolidations have created an extraordinary scale of consolidation in the liner shipping industry (Slack et al., 2002; Yang et al., 2009; Yip and Lun, 2009). From this perspective, returns on investment are determined by firm size.

3. Methodology

The analysis is divided into two steps. In the first step, the S-curve is used as the theoretical basis for production frontier analysis. The S-curve is an approximation of an unknown frontier function and the accuracy of the S-curve is verified by observed data. The S-curve will therefore be used to test for the presence of both economies and diseconomies of scale in the liner shipping market. In the second step, the macroeconomic data of the liner market are considered to determine the shape of the S-curve. We wish to explain the shape of the S-curve in view of the macro market conditions. We believe that insights can be achieved from a parametric model, which allows statistical testing and can be used to explain the diseconomies of scale.

The first step is to estimate the parameters of the S-curve for each year. The S-curve concept is employed here with the presence of the diseconomy of scale. When the capacity q is initially introduced into the production, the revenue r is low because operators of small capacity are competing for market share. As the operator acquires more capacity, the revenue r will increase until it reaches the maximum revenue r_∞. Without loss of generality, we assume that the relationship between capacity and revenue would be described by an S-curve. The standard equation for the S-curve can be defined as:

$$r(q) = \frac{r_\infty}{1 + a\exp(-bq)} + r_0 \qquad (1)$$

where *r* is the revenue, *q* is the capacity, r_∞ is the saturation value or the upper limit at infinity, *a* the shape parameter, and *b* the scale parameter.

$$\ln\left(\frac{r_\infty}{r - r_0} - 1\right) = \ln a - bq \qquad (2)$$

The shape parameter *a* indicates the position of curve initialization. A small value *a* means that the change from scale economies into scale diseconomies occurs at a small value of capacity *q*. Therefore, the problem of scale diseconomies will be observed at a small value of *q*. A large value *a* delays the occurrence of scale diseconomies along the capacity *q*. The scale parameter *b* indicates the growth rate of the curve. A small value *b* means that the change rate of scale economies into scale diseconomies is slow. Therefore, if *b* is small, the interface between scale economies and diseconomies spreads over a large range of capacity *q*. A large value *b* shows a flat S-curve. In the second step, we attempt to estimate the S-curve versus macro market data. Instead of remaining static, the liner market is dynamic over time. The liner market can be quantified by four primary components: (1) demand, (2) supply, (3) operating cost, and (4) profit. To investigate the hypothesis, the model specification is expressed as:

Parameters of S-curve = f (*Demand, Supply, Operating cost, Profit*) (3)

where *Demand* = seaborne trade; *Supply* = new delivery, new order, and scrapping; *Operating cost* = bunker price, and seamen wages; *Profit* = freight rate. The parametric model (3) allows for statistical testing and can be used to explain diseconomies of scale.

4. Data and Discussion

In this study, we mainly evaluate and measure the efficiency of LSCs. We consider the internal and external factors in examining the determinants of efficiency in the liner shipping industry. It is preferable to use empirical data to evaluate firm performance (Cho et al., 2008). To study the internal factor, the data of total revenue and total capacity of the top 20 ocean carriers from 1997 to 2008 were collated from Containerisation

International. Containerisation International is highly recognised within the maritime sector as a source of invaluable insight and statistics on the container market over the last 40 years (source: Containerisation International).

To examine the external factor of liner market, the data of seaborne trade, new delivery of container vessels, new order of container vessels, scrapping of container vessels, bunker price, seamen wages and freight rate from 1997 to 2008 were collected from the Review of Maritime Transport, Clarkson Research Studies, International Labour Organization (ILO) and Drewry, respectively. Since 1968, the Review of Maritime Transport has been one of UNCTAD's flagship publications. It highlights the worldwide evolution of shipping, ports and major transportation pertaining to liquid bulk, dry bulk and containers. The Clarkson Research Studies offers research, statistical and financial services to ship brokers and the maritime industry. The team of experienced researchers and analysts at Clarkson Research maintains comprehensive databases of the world's bulk, container and general cargo fleets comprising 30,000 vessels on a daily basis (source: www.clarksons.com). The ILO publishes research related to the changing nature of work and employment which brings insight and direction to policy makers. The ILO maintains integrity, independence and high professional standards and gathers, disseminates, analyses, and processes statistical data to the public. In doing so, the ILO is able to provide timely labour statistics and accurate economic analysis, facilitating increased awareness of common problems, explaining actions and mobilising interest (source: www.ilo.org). Drewry Shipping Consultants Limited offers a full range of economic, commercial and technical consulting and publishing services to the international maritime industry. Manned by a research team of dedicated, highly skilled and experienced analysts it has established comprehensive databases over three decades (source: www.drewry.co.uk).

Accordingly, we believe that these five sources provide relevant and objective data to measure our study variables, including individual liners in terms of total revenue and total capacity, seaborne trade, freight rate, bunker price, seamen wages, new delivery, new order, and scrapping. Our research uses several quantitative analytical tools to empirically test the efficiency of liner operators. We illustrate internal and external factors as the basic parameters of the S-curve to determine the optimal carrying capacity of shipping lines. The S-curve is widely used to describe actual costs, planned spending and the budgeted cost of work performed. The S-curve is helpful in conducting a risk analysis of shipping finances by showing the altered spending rates needed to attain profitability (Cioffi, 2005). To predict firm performance, the external variables of the liner market are considered into regression analysis.

4.1 The S-curve

When exhibited as a function of time, costs of projects or accumulated efforts are usually presented as an S-curve (Cioffi, 2005). In this study, there are two main factors for consideration, capacity and revenue, in exploring the tendency of liner shipping operations from the S-curve effect. To test the relationship between capacity and revenue, we use twelve years of data, from 1997 to 2008, gathered from Containerisation International. The empirical data of total capacity and total revenue of the top 20 liner operators are collected to plot an envelope graph. The recent consolidation among LSCs generates the S-curve effect. Between 1997 and 2008 the bigger LSCs captured a larger market share by enlarging capacity. The concentration ratio (CR4) increased significantly from 15.5% in 1997 to 32.8% in 2008 (Yip and Lun, 2009). Between 1997 and 2008, LSCs enlarged their tonnage to capture more market share. It is noticeable that the return of liner operators is in accordance with market share. Thus, accordingly, the market players have engaged in a strategy of acquisition or expansion over the past few years.

Our findings confirm that capacity and revenue are not linear correlated. In that case, we apply an S-curve to characterise the relationship between capacity and revenue each year from 1997 to 2008. Cioffi (2005) noted that the name of the S-curve stems from "*the S-like shape of curve (i.e., flatter at the beginning and end, steeper in the middle)*". In general, the S-curve is a form of the learning curve, which supposes that performance improvement eventually reaches a plateau (Ngwenyama et al., 2007). The S-curve is typically applied in economic production that scale economies exhibit below optimum scale and scale diseconomies above optimum scale (Coelli et al., 2005). The S-curve describes the frontier of each capacity level that generates the maximum revenue. On one hand, LSCs are on the frontier when they are efficient. On the other hand, LSCs are beneath the frontier when they are inefficient. Yip and Lun (2009) demonstrated that LSCs that occupy a capacity share between 4% and 9% are capable of attaining 8% to 20% of revenue share in the liner market. According to the 2008 data, it shows that the optimal firm size in liner shipping is between 4% and 6% of the size of capacity share. LSCs enjoy increasing returns of scale occurring at the capacity share below 4%, whereas decreasing returns of scale existing at the capacity share beyond 5%. It follows that LSCs increase revenue without expanding their capacity under the efficient frontier. The S-curve analysis is summarised in Table 1.

Table 1: Results of S-Curve analysis

Year	*Shape Parameter* *ln a*	*Scale Parameter* *ln b*	*R-squared*
1997	5.121	4.772	0.930
1998	4.540	4.738	0.852
1999	5.330	5.058	0.856
2000	6.875	5.260	0.782
2001	6.627	5.281	0.701
2002	9.383	5.588	0.800
2003	5.476	4.961	0.884
2004	2.472	4.459	0.711
2005	2.758	3.978	0.965
2006	3.142	4.025	0.925
2007	3.950	4.382	0.929
2008	2.814	3.642	0.902

4.2 The regression model

The key findings are produced by regression analysis. To provide an understanding on how S-curve and market factors are associated, we carry out a parametric analysis to assess the relationships of these study factors (Lun and Quaddus, 2009). Market factors (i.e., seaborne trade, freight rate and scrapping) are tested with S-curve parameters. The results are reported in Table 2, while only significant variables are included.

Table 2: Results of regression analysis

		Dependent variables	
		Shape Parameter ln *a*	*Scale Parameter* ln *b*
	Independent variables		
Demand	ln Seaborne Trade	90.91 (3.842) **	29.63 (4.623) ***
	ln Container Throughput	−70.43 (−3.659) **	−25.49 (−5.085) ***
Supply	ln Fleet Capacity	-	-
	ln Delivery	−9.24 (−7.262) ***	−2.24 (−5.918) ***
	ln New Order	-	-
	ln Scrap	-	0.17 (3.547) **
Operating Cost	ln Bunker Price	19.62 (5.299) ***	5.62 (5.093) ***
	ln Seamen Wages	86.53 (3.047) **	38.47 (5.618) ***
Profit	ln Freight Rate	−34.13 (−5.559) ***	-
	Constant	−455.8 (−1.84)	−283.67 (−5.183) ***
	R-squared	0.971	0.960
	Adjusted R-squared	0.928	0.900
	F-statistic	22.35 ***	15.93 ***
	Akaike Info. Criterion	1.906	−0.501

Year: 1997-2007
*** (**, *) Significant at the 0.01 (0.05, 0.10) level (2-tailed)

For large values of shape parameter *a* and scale parameter *b*, the scale diseconomies are found at a large value of capacity q. The results in Table 2 show that when the operating costs increase (i.e., bunker cost and seamen wages), both parameters a and b will increase, and therefore the scale diseconomies will be found at a larger capacity q. It is common that a high setup industry has a higher value of scale economies, for example, power plants, container terminals, etc.

The shape parameter a depends on the freight rate. Given that the supply, demand and cost are unchanged, the increase of freight rate leads to a more profitable operation. Relatively, the portion of cost reduces, and the effect of freight rate is opposite to operating cost. The sign of freight rate is therefore assumed. On the other hand, Table 2 shows that more supply of liner shipping (i.e., delivery) will introduce the scale economies at a smaller capacity q, because both parameters a and b will decrease accordingly. It is well known that more supply implies more intensive competition and a higher potential of oversupply. The effect of scrapping is to reduce the supply, and so the scale parameter b increases if supply is reduced by scrapping. Thus, the diseconomies of scale may be observed at a smaller capacity, if more supply is available.

It is surprising that the existing fleet does not have significant impact on the S-curve statistically. A possible reason is that the delivery has reflected the effect of the fleet increase. It is implicit that *Current fleet = Previous fleet + Delivery – Scrap*. The signs of demand variables might raise some doubts at first glance, where the sign of seaborne trade is positive but container throughput negative. Actually the opposite signs represent the competing effects of scale economies and diseconomies. The increase of seaborne trade leads to higher values of both shape parameter a and scale parameter b. Expanding seaborne trade will encourage scale economies. The increase of container throughput implies a higher degree of coordination problems and scale diseconomies are the result.

5. Conclusions

In this paper, we consider a two-step approach that allows not only for frontier analysis of scale economies, but also a parametric analysis of the parameters of the frontier function. The S-curve is used to describe the frontier function and the fitness is confirmed with high values of R-squared statistic. Unlike other functions, the S-curve assumes the presence of scale economies and diseconomies. We further test the shape and scale parameters of the S-curve with market data. It is found that the shape parameter depends on the demand for liner shipping and the scale parameter depends on the cost of liner shipping.

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China's Oil Import Forecast and its Impact on Tanker Fleet Composition

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Abstract

China is embracing a booming economy and is attempting to further develop transportation infrastructures. As one of strategic resources, crude oil is playing and surely will play an important role in the rise of China. Due to the limitations of domestic resources and production capacities, there is huge amount of oil needs to be imported to fill the gap between domestic oil production and consumption. In order to maintain oil reservation in a safe manner, the strategic oil reserves plan is proposed for China. However, existing tanker fleet faces problems of unreasonable fleet composition, limited ship size and insufficient capacity. Therefore, an appropriate fleet composition for China"s tanker fleet is in urgent need, which includes approaches to adapt to new changes of waterway and tactics to maintain high competence global wise.

Based on above mentioned facts, this paper aimed at forecasting the import demand by sea in 10 years, which is a polished version of forecast comparing with other forecasts given by different literatures with crude oil focus, and analysing its impact on tanker fleet composition by identifying the risk factors.

The paper took uncertainties into consideration, which is a good start for the proposal of China"s tanker fleet composition.

Keywords: tanker, fleet composition, crude oil, forecast, uncertainties

1. Introduction

As an important type of energy enabling development of national economy, crude oil is one of the basic resources of modern industry and modern civilization. Crude oil, as one of strategic resources, has intertwined closely with national strategies, global politics, international relationships and national competence. In addition, as part of emerging economies, China is embracing a booming economy as well as advancing development of infrastructure in the coming decades. As a result, crude oil is playing and surely will play an important role to China.

According to International Energy Agency (IEA) 2005, China"s total oil demand would increase from 6.4 million barrels per day (mb/d) in 2004 to over 13 mb/d in 2030, which implies that a large proportion of China"s oil demand will have to be met by imports. Therefore, the country"s net oil imports would rise from 2.3 mb/d in 2004 to 4.5 mb/d in 2010 and 10.5 mb/d in 2030, respectively.(Chang Huiqing,2007) Under this circumstance, crude oil transportation is of great importance. However, China faces with several problems. There are risks for safety of oil transportation. In case of war, diplomatic events or other irresistible emergency situations, China might have to face the challenge of being in lack of oil shortly after emergency happens. There were researches on the analysis of oil consumption; however, most of the study ignored the risk factors and uncertainties. Former study made predictions with less focus on the specific situation of China‟s oil import.

F. Gerard Adams and Yochanan Shachmurove (2008) build an econometric model of the Chinese energy economy based on idea of energy balance. Hun-cun Tung (2008) examines China‟s future energy trend by analyzing how the energy demand in China has changed and how it will change by looking at several domestic factors. Miranda-da-Cruz (2007) applies the UNIDO approach to energy supply and demand trend at the country level and he uses China and its industrial development as a case study. Wang Hui (2006) analyze the situation of domestic petroleum production and consumption with predictions on the basis of the analysis of main factors. Hou Jianwei (2006) and Hu Xianghong (2006) analyze the status of China's petroleum foreign trade in the international petroleum market through analyzing oil resources in the world and the present situation of the international petroleum trade.

As all discussed above, a forecast on the import demand of China‟s crude oil under uncertainties is in urgent need, which is the foundation of further research on the composition of China‟s tanker fleet. In the „national energy security report‟ (Ni Jianming, 2005) and „Global energy market report‟ (China Institute of Contemporary International Relations Research Center of Economic Security, 2005), risks in China‟s oil import are identified, which includes economic operation risks, transportation risks and risks due to insufficient oil strategic reserves.

2. Identification of uncertain factors

Based on the reality of China, there are several factors which affect the crude oil import demand. The identification of uncertain factors is shown as follows:

1. The relative price of crude oil.

Crude oil price is an important factor which influences oil imports. Economic theories suggest that when the price rises, demand should fall, holding other factors constant. But in empirical studies, energy demand is considered to be inelastic with respect to price, especially in the short-run.(Dahl and Sterner, 1991; Bernstein and Griffin, 2005)Even if the price is high, people still continue using cars in everyday life, which means there is still constant demand for oil.

Zhao and Wu (2007) believe that the relative price between inputs and outputs would be more important than the price of international energy in absolute terms. Furthermore, if the prices of industrial products and energy products change by the same proportion, the quantity of energy demand may not change. As a result, it is important to examine the price of oil in relative terms (i.e., the ratio of crude oil price to industrial product price index) is important.

2. Domestic Oil Output

Due to the limitation of resources, the domestic crude oil output is relatively fixed. The preliminary evaluation of petroleum geology resources in China is 106.8 billion tons. According to the study on different types of basins, final oil recoverable amount is between 14 billion and 16 billion tons. Fig 1 represents the distribution of oil resources in China, while Fig 2 indicates the distribution of undiscovered oil resources in China.

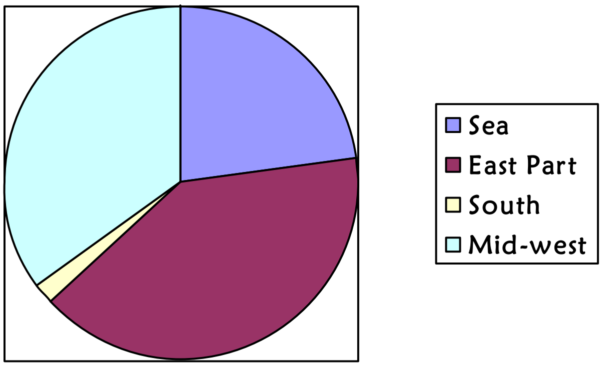

Figure 1: The distribution of oil resources in China
Source: Source: www.infobank.com

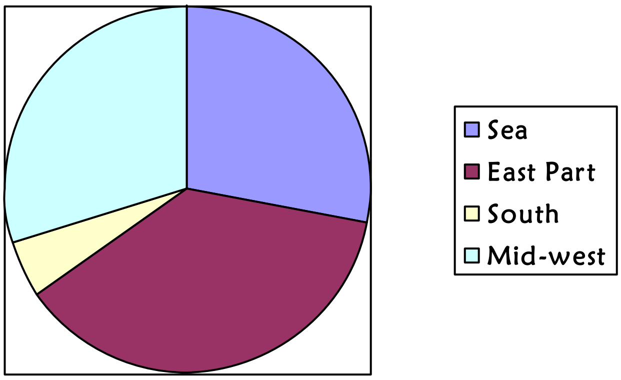

Figure 2: The distribution of undiscovered oil resources in China
Source: www.infobank.com

Although there are still some undiscovered oil resources in China, and the total oil production in main regions in China is rising slightly year by year, the trend is more and more crude oil need to be imported due to the resource limitation and exploration capability limitation. Table 1 shows the change of oil production in main regions in China from 1984 to 2004.

Table 1: Change of oil production in main regions in China from 1984 to 2004

Area	Output/y (10^4t)				Average increment/y(10^4t)			1988-2004 annual growth rate (%)
	1984	1988	1994	2004	1984-1994	1994-2004	1988-2004	
National	11450	13650	14577	17355	312.7	277.8	231.6	1.51
Northeast	5547.8	5892.8	6056.6	5244.4	508.8	-81.2	-40.5	-0.72
North China	4806.6	6362.7	5896.4	5212.1	1089.8	-68.4	-71.9	-1.24
Yangze river and Huai river	380.7	432.9	393.8	446.8	13.1	5.3	0.9	0.2
East	10729.1	12688.4	12346.8	10903.3	1617.7	-144.4	-111.6	-0.94
Northwest	691.3	902.5	1567.2	3986.9	875.9	242	192.8	9.73
Water Area	32	46.8	634.4	2443.9	602.4	181	149.8	28.8
5 Basins	10984.5	13080.6	13258.8	14750.4	2274.3	149.2	104.4	

Source: Hu Xianyue (2005)

3. Industrial output

Strong economic growth is taking place in China, and continues to boost China‟s total energy consumption. In stead of choosing GDP as the main factors influence crude oil import demand, we think industrial production is chosen for the reasons shown as follows:

- China is now in the process of industrialization, lots of infrastructures are under construction. As a result, the industrial sector with high energy intensity will be one of the major crude oil users in China.(Chang Huiqing,2002)
- Crude oil is imported largely as an industrial production input.

4. Total Traffic Volume

With the improvement of people‟s living standard in China, there is a rapid expansion of transport sector, which will surely lead to large demand for oil products, thus increases the import demand for crude oil.

Private cars are common in cities in China, and the number of private cars increased from 2.5 million units in 1995 to 14.8 million units in 2004 according to National Bureau of Statistics in 2005.Table 2 shows the number of civil vehicles and civil aircrafts from 1990 to 2007.

Table 2:Number of Civil Vehicles and civil aircrafts(1990-2007)

10,000 units

Year	1990	1995	2000	2004	2005	2006	2007
Total vehicles	551.36	1040	1608.91	2693.71	3159.66	3697.35	4358.36
Passenger vehicles	162.19	417.90	853.73	1735.91	2132.46	2619.57	3195.99
Trunks	368.48	585.43	716.32	893.00	955.55	986.30	1054.06
Civil Aircrafts	503	852	982	1245	1386	1614	1813

Source: Xianyue Hu (2005)

We can see from Table 4 that the number of vehicles in 2007 is nearly 8 times of that in 1990.

5. Change of contracts and incidents

The change of contracts and incidents affect the import demand directly.In order to keep national energy safety, the National Strategic Oil Safety and Reserves Plan is imperative. It can guarantee the crude oil demand with the growing economy and avoid the bad effects caused by blocked transportation channel, for example, the war, emergencies and trade barriers. Furthermore, the plan can control domestic oil prices. Import more oil when the global oil price is low, import less or stop importing when the price is high.

With the wider use of natural gas, we should take the percentage of oil consumption in the whole energy consumption into consideration. The percentage of oil consumption drops with the use of new energy resources, which will lead to a drop of the demand of crude oil transportation.

The government adopts various methods to implement National Strategic Oil Safety and Reserves Plan, which have direct effects on the crude oil import demand by sea. For example, oil trade diversification is raised, which contains diversified import sources, import mode and transportation mode diversification, as well as diversified supply channels.

Table 3 indicates the traffic volume and percentage of different transportation mode in crude oil import transport.

Table 3: Traffic Volume and different transportation mode

Transportation mode	2002		2003		2004	
	Traffic Volume	Percentage (%)	Traffic Volume	Percentage (%)	Traffic Volume	Percentage (%)

	(million tons)		(million tons)		(million tons)	
Tanker	64.5	93%	83.81	92%	110.43	90%
Rail	3.47	5%	5.47	6%	7.95	7%
Other modes	1.43	2%	2.82	2%	3.32	3%
Total	69.4	100%	91.1	100%	122.7	100%

Source: www.infobank.com

From Table 3 we can see the traffic volume is rising year by year. Although the diversification of transportation mode is proposed, Tanker still is the main mode for crude oil import transport. However, there is an increased proportion for other modes.

Furthermore, China doesn‟t focus on fixed export countries. By 2004, the import sources had expanded to more than 20 countries. Table 4 shows the import quantities from different export areas from 1998 to 2004.

Table 4:Import sources from 1998 to 2004

Million tons

Import Sources	1998	1999	2000	2001	2002	2003	2004
Saudi Arabia	1.81	2.50	5.73	8.78	11.39	15.17	17.24
Iran	3.62	3.94	7	10.85	10.63	12.39	11.24
Oman	5.79	5.02	15.66	8.14	8.04	9.28	16.35
Yemen	4.04	4.13	3.61	2.29	2.26	6.70	4.91
Middle East subtotal	16.67	16.90	37.65	33.86	34.39	46.37	55.79
Angola	1.11	2.88	8.64	3.80	5.71	10.10	16.12
Sudan		0.27	3.31	4.97	6.43	6.26	5.77
Other countries	1.09	4.11	5.00	4.77	3.67	5.82	9.36
Africa Area Subtotal	2.19	7.25	16.95	13.55	15.80	22.18	35.21
Vietnam	0.87	1.51	3.16	3.36	3.54	3.51	5.35
Indonesia	3.42	3.95	4.64	2.65	3.24	3.33	3.43
Other countries	1.19	1.37	2.81	2.68	5.07	6.41	5.39
Southeast Area Subtotal	5.47	6.83	10.61	8.68	11.85	13.85	14.16
Russia	0.14	0.57	1.48	1.77	3.03	5.25	10.77
Kazakhstan	0.41	0.49	0.72	0.65	1.00	1.20	1.29
Other Countries	3.34	4.57	2.85	1.31	3.34	2.27	5.29
Europe and Western Hemisphere	3.00	5.63	5.05	4.17	7.37	8.73	17.36
Total	27.32	36.61	70.27	60.26	69.41	91.13	122.72

Source: China petroleum import and export situation analysis in 2003)
China petroleum import and export situation analysis in 2004)

3. China’s Oil import forecast

3.1. Model setting

Based on the identification of uncertain factors, this paper uses multiple linear regression model to forecast import demand. We collected related data from 1993 to 2007 from market reports of Clarkson and information on the website of National Bureau of Statistics of China.The results are shown as follows:

$$Y = -92220.94119 + 4.95691233 x_1 - 1636.090774 x_2 + 0.09040121924 x_3 + 9.986177352 x_4 \quad (1)$$

Y: crude oil import demands
X1: Domestic oil output
X2: Percentage of oil consumption
X3:Domestic Industry Output

X4:Motor Vehicle holdings

Dependent Variable: Y
Method: Least Squares
Date: 02/04/10 Time: 15:18
Sample: 1993 2007
Included observations: 15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-92220.94	119714.4	-0.770341	0.4589
X1	4.956912	6.793638	0.729640	0.4824
X2	-1636.091	2305.014	-0.709797	0.4940
X3	0.090401	0.091543	0.987523	0.3467
X4	9.986177	2.439078	4.094243	0.0022

R-squared	0.982229	Mean dependent var	70539.53
Adjusted R-squared	0.975121	S.D. dependent var	56870.72
S.E. of regression	8970.244	Akaike info criterion	21.30241
Sum squared resid	8.05E+08	Schwarz criterion	21.53843
Log likelihood	-154.7681	F-statistic	138.1815
Durbin-Watson stat	1.958837	Prob(F-statistic)	0.000000

We also took the urban population proportion into the model as one of the independent variable in previous trial. However, it is found that there would be so little affection to the results when removing the factor that in the adjusted model this variable has been removed.

3.2 Result Analysis

By using smoothing method, we can get the relative data for x1, x2, x3, and x4 in 2020 separately. This paper chose two ways to deal with the results.

1. Inserting the data into the regression equation. The forecast result through the model shows that there is 473,761,300 tons of crude oil imported in 2020.
2. Using the smoothed data to form another regression equation, and we can have the result shown as 371,882,900 tons.

Wang Hui(2006) used Regression Analyzing Method, Time-series Methods and Combined Forecasting Method for Foundation Settlement to forecast domestic oil consumption. The results are shown in Table 5. Furthermore, the author compares the prediction results with that forecasted by peer institutions abroad, which are shown in Table 6.

Table 5: Import Demand Prediction by Wang Hui

100 Million tons

	2010	2015	2020
Domestic production	1.91	1.99	2.01
Consumption	3.57	4.45	5.64
Import demand	1.66	2.25	3.33

Source: Wang Hui(2006)

Table 6: Prediction Results by International Institutions

100 Million Tons

Institutions	2010	2020

International Energy Agency (IEA)	1.99	3.71
Energy Information Administration (EIA)	1.84	3.61
Organization of Petroleum Exporting Countries (OPEC)	1.51	2.3

Source: Wang Hui(2006)

We can see that the forecasting result indicates higher import quantities compared to Wang Hui‟s (2005) study. The reason is considered as that there is a totting-up of ascending trend of the independent variable, as the long forecasting period. As a result, a polished version of forecast was given by listing three levels of "risk-averseness coefficient", according to different market environment. That is a revision of the forecast results by modelling. The results are shown in Table 7.

Table 7: Forecast results under different risk levels

Risk-averseness coefficient	Forecast results (100,000,000 tons)
0.8 (market slump)	2.975
1	3.719
1.2(positive assumption of the market	4.463

We can see from the result that it is very close to the prediction of IEA.

4. Impact on tanker fleet composition

4.1 Global Crude Oil Transport

Fig 3 represents the rising tide of tanker order book by size. From Fig 7 we can have the conclusion that no matter from the perspective of existing fleet scale or order form, VLCC of over 200 thousand DWT consist the main hull form of fleet, which indicates the tendency of large scale tankers.

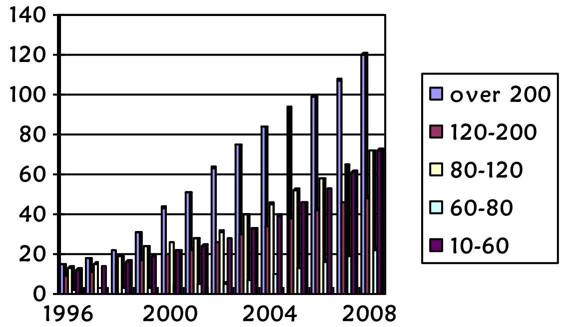

Figure 3: Tanker order book by size
Source: Clarkson

According to the rules, with the use of double hull tanker, tanker fleet will embrace a rapid growth to younger ships; old single hull tanker will accelerate in retirement. The situation of oversupply in global oil transport market will remain unchanged. Supply and demand balance ration decreased from 10% in 2002 to 4.5% in 2004, and 4.3% in 2005.Due to the decrease of ship breaking and the expansion of ship building capacity, new-built tanker supply increased from 3.8% in 2005 to 7.2% in 2007, resulted in a expand of supply and demand balance ratio to 9.4% in 2007. As a result, world oil transport market competition will be more intense, which is indicated in Fig 4, Fig 5 and Fig 6.

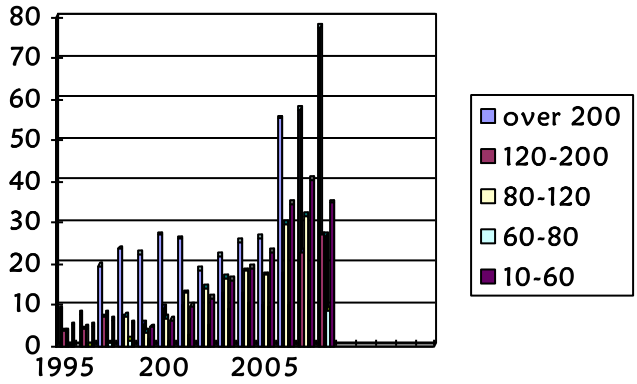

Figure 4: Double-Hull tanker Fleet by size
Source: Clarkson

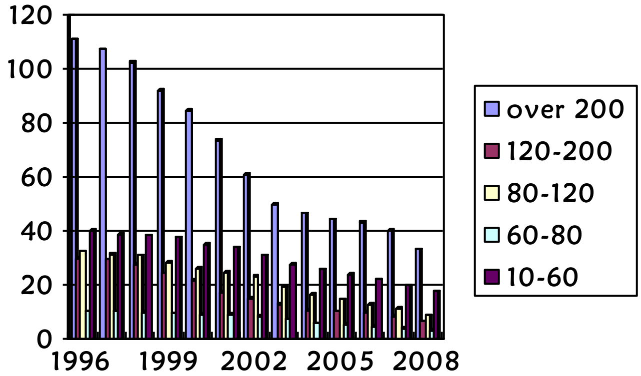

Figure 5: Non-Double Hull tanker Fleet by size
Source: Clarkson

Fig6: Supply and Demand Balance
Source: Hu Xianyue (2005)

4.2 Current Situations of Tanker Companies in China

In China, companies which run business of ocean oil trade are mainly China Merchants Group affiliated Hong Kong Ming Wah Shipping Corporation (Ming Wah), China Shipping Development Limited Corporation affiliated tanker company (CS Tanker), Dalian Ocean Shipping Company (DOSCO), Nanjing Tanker Corporation, HOSCO Group and SINOTRANS Limited Corporation.

The main types, sizes and fleet scale are shown in Table 7.

Table 7: Summary of China Trans-ocean Tanker

Tanker Company	VLCC	SUESMAX	AFRAMAX	PANAMAX
Ming Wah	8	1	7	-
CS Tanker	2	-	6	8
DOSCO	3	4	-	7
SINOTRANS	3	-	-	-
HOSCO	6	-	-	-
OTHERS	4	-	-	-

4.3 Challenges and Opportunities of Tanker Companies in China

China tanker companies face with several problems when developing. The oil transportation structure is not so perfect, with 90% of imported oil is transported by foreign oil companies. In other words, domestic tanker fleet faces problems of unreasonable ship structure, limited ship size and tonnage. Furthermore, there are little corporations among tanker companies, which results low competitive strength in the global market.

Although there are a lot to be improved, tanker companies have already taken actions. Booking orders of New-built tankers and second-hand tankers increase sharply, which greatly expand the scale of China‟s tanker fleet. Strategic agreements are signed with petrochemical companies positively, followed with an internal system reform in tanker companies in order to improve the level of management. On one side, these are the embodiment of great attention to the crude oil transportation; On the other side, we see the huge profit in oil transport operation and potential develop space in crude oil transport market in China.

Thus, how to avoid redundant construction while most tanker companies tend to order more and more VLCC, how to develop our own tanker fleet to better meet the huge potential demand, how to set up sustainable strategies for new ship deployment, hooker elimination and chartering in order to adapt to market dynamics with uncertainty factors and maintain high competence, seems to have great significance to the development of China tanker companies as well as the entire crude oil transport industry in China. If all these are solved, we will embrace great opportunities and a booming economy in China.

5. Conclusions and outlook

This paper considered the uncertainties of China‟s crude oil import. Data were collected from 1993 to 2007 from market reports of Clarkson and information on the website of National Bureau of Statistics of China.

With the forecast result of in 2020, which is very close to the prediction of IEA, a polished version of forecast was given by listing three levels of "risk-averseness coefficient", according to different market environment. Which means when there is a market slump such as the financial crisis, we took the coefficient as 0.8, while when there is a positive assumption of the market or positive incentive system, and we took the coefficient as 1.2. The real situation of China‟s crude oil transportation was fully considered, both from the demand market and the supply market. Moreover, there are analysis on the National Strategic Oil Safety and Reserves Plan.

For further research, which based on the achievements above, appropriate tanker fleet planning is a vital issue with which China has to deal. This planning problem can be divided into different aspects as follows：1) how to avoid redundant acquisition on equipments whilst most tanker companies tend to order more and more Very Large Crude oil Carriers (VLCC) , 2) how to organize national tanker fleet to better meet potential demand, 3) how to dispatch and reposition tankers in order to obtain competence in operational level, 4) how to set up sustainable strategies for deploying new tankers and arranging charter parties in order to adapt to market dynamics taking into account uncertainties .

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Factors Influencing the Quay Efficiency of Container Terminals - The Case of Major Ports in NE Asia

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Abstract

Through the support of one container shipping company, this study was able to collect operational data and to identify the factors affecting the quay efficiency of major terminal operators in North East Asia. In the first stage of the research on terminal operator in Kaohsiung, "the total number of container moves" was found to be statistically significant in influencing quay efficiency. When the research scope was expanded to other ports in North East Asia, this rule was found to have been followed by every terminal. However, remarkable differences were found in comparing the quay efficiency among the different terminal operators in the region. To come up with a comprehensive analysis, operational data and information on terminal facilities, as well as the business environment of the major terminal operators in North East Asia were collected. Major factors influencing the quay efficiency have been identified and the findings could help terminal operators to improve their quay efficiency.

Keywords: Container terminal, Quay efficiency, Terminal planning, NE Asia

1. Introduction

In the study of analyzing the factors influencing the quay transfer operation efficiency (called "quay efficiency" hereafter) of terminal operators in Kaohsiung Port, a significant relationship has been found between the "total container moves" and "quay efficiency." To determine whether this significant relationship could be found in other ports, the research scope has been expanded to include major ports in North East Asia. Not surprisingly, a significant relationship between the factor "total container moves" and "quay efficiency" with high reliability has been determined. However, there are remarkable differences in "quay efficiency" achieved among terminal operators; in other words, beside the "total container moves", there are other critical factors influencing "quay efficiency" that have not been found.

To identify the factors resulting in the huge differences in "quay efficiency" on a regional basis, a survey of relevant studies has been conducted, all possible factors have been collected for consideration. The top-down concept has been implementing in this study, all of the possible factors have been tested by Statistical Software (SPSS) to find out their relationship with "quay efficiency." The research findings of this study reveal that there are six critical factors influencing "quay efficiency." The most influential is "the linear-quay length," followed by "quay-crane density," and then by "operating years" of the terminal operator. The "container mix" has also been identified as the major item, within the compositions of "container mix", the factors influencing "quay efficiency" have been identified are "the number of both 40-ft and 20-ft empty containers discharged" and "the number of 40-ft full container loaded."

Based on the coefficients of the regression model, a formula can be drawn to estimate how "quay efficiency" can be achieved. This study is the first empirical one examines the factors influencing "quay efficiency", the research findings can help terminal operators in reviewing their operational planning and management procedures comprehensively and as a consequence, to improve their "quay efficiency."

2. Literature Review on Quay Efficiency

2.1 Academic and Industry Perspective

There are significant differences among researchers in their definition of efficiency or productivity to measure the performance of ports and container terminals. In research using Data Envelopment Analysis (DEA) to quantify the relationship between port throughput and input resources, "terminal efficiency" has been used by several research to measure the effectiveness of port productivity or throughput. Likewise, studies related to container-terminal operation efficiency have also been defined in various ways. For example, the most commonly used indicators are "quay crane efficiency," "terminal efficiency," "ship working rate," and "crane efficiency." Furthermore, a number of researchers have examined above issues from the perspectives of both operation and management perspectives (Tally (1998); Cordeau et al. (2005); Chu (2005); Dragovic (2006); Park and Kim (2008); Hansen et al. (2010) and Meisel and Bierwirth (2006, 2009)). They studied the factors influencing quay crane productivity from the operational and planning viewpoints. "Crane productivity" has been defined as "***the efficiency of total quay cranes serving a vessel***." Research studies closely related to quay efficiency have been conducted by Tongzon (1995, 2001, 2005) and Meisel (2009), Tongzon (2001) defined "ship working rate" as "***the number of containers moved per working hour per ship***." Meisel (2009) defined "crane productivity" as "***the efficiency of total quay cranes serving a vessel***." Table 1 shows the summary of definitions of the efficiency items on quay efficiency found in the literature review.

Table 1: Summary of the definitions of efficiency items

Researcher	*Efficiency Item*	*Definition*
Tongzon	Terminal efficiency	Annual throughput of the terminal
	Crane efficiency	Number of lifts per crane hour
Tongzon	Ship working rate	The number of containers moved per working hour per ship
Tongzon	Terminal efficiency	How quickly containers are Handled
Cullinane	Terminal efficiency	Annual container throughput
Park	Gross berth productivity	Annual throughput per berth
Hung	Operating efficiency	Annual container throughput
Cheon	Port efficiency	Annual container throughput
Meisel	Crane Productivity	The efficiency of total quay cranes serving a vessel

Source: Compiled by author

Unlike the varied definitions of items on efficiency or productivity in academic research, performance indicators in measuring "quay efficiency" by the terminal operators are unified worldwide. From the operational perspective, there are two indicators used to measure the efficiency of container loaded and unloaded in the quay transfer operation: "crane efficiency" and "quay efficiency". "Crane efficiency" is measured by the number of container moves per crane per ship working hour. "Quay efficiency," on the other hand, is calculated by dividing the "total number of moves of container loaded and unloaded in the quay transfer operation" by "the total ship working hour." The difference between these two indicators is that the "quay efficiency" measures the overall operational efficiency of the terminal operator, the "crane efficiency" measures the average operational efficiency of quay crane only. For example, the terminal operator may declare its crane efficiency to be 30 moves per hour, but during the ship operation, only three cranes are deployed. As a result, "quay efficiency" becomes 90 moves per ship hour. However, for high productivity terminals in North East Asia, terminal operators may assign seven or more cranes for the quay operation. Although the average crane efficiency may be as low as 20 moves per hour, its overall quay efficiency can be as high as 140 moves per ship hour. From the viewpoint of container shipping lines, the major benefit in using "quay efficiency" is to ensure the quality of service provided by the terminal operator.

Although there are arguments between shipping lines and terminal operators regarding which indicator should be used to measure the service quality, China has already established a national standard to measure the "quay efficiency." In 2005, the China Ports and Harbor Association established the national standard to evaluate both "quay efficiency" and "crane efficiency." The standards have been followed by all Chinese ports since then. When a terminal operator breaks the record of either crane efficiency or quay efficiency, the terminal operator should report to the association by submitting all evidence and reports for authentication. "Quay efficiency" has been used as the major indicator by Chinese container terminal operators to measure the service quality. The performance of "quay efficiency" has also been used as the major indicator to compete for the title of the "most efficient terminal". Table 2 shows the outstanding records of Chinese terminal operators in 2008.

As a conclusion of above analysis, this study uses “quay efficiency” as the indicator to measure the efficiency of containers loaded and unloaded in quay operation.

Table 2 Best quay efficiency achieved by Chinese terminal operators in 2008

Terminal Operator	Quay Crane Efficiency (moves/hour)	Quay efficiency (moves/hour)	Year
Yantian (YICT)	65	545	2008
Qingdao (QQCT)	95	486	2008
Tianjin (TCT)	79	387	2008
Shanghai (SHSICT)	123	850	2008
Dalian (DCT)	77	n.a.	2008
Ningbo (NBCT)	72	348	2008

Source: China Ports & Harbors Association, http://www.portcontainer.cn/

2.2 Factors Influencing Quay Efficiency

As mentioned in section 2.1, most papers examining “port efficiency” or “terminal efficiency” measure the links between annual container throughput and port facilities. Some of the factors considered include “total quay length,” “the number of quay cranes,” “the number of transtainers (yard cranes),” and “terminal size,” among others.

Aside from port facilities, there are also other factors influencing “quay efficiency.” From the operational perspective, Tongzon (1995) found that “container mix” could influence “crane efficiency.” Furthermore, Tongzon (2005) and Turner (2004) proposed that “vessel size” and “the number of container exchange” should be the factors to be considered. From the management viewpoint, Sachish (1996), Cheon (2009), and Cullinane (2006) considered “technological level” as a factor affecting quay efficiency, while Cheon (2009) and Cullinane (2006) regarded the impact of “new facility” to affect quay efficiency as well. The summary of the factors examined by previous research are shown in Table 3.

Table 3 Summary of factors influencing terminal efficiency

	Tongzon	Sachish	Turner	Hung	Cheon	Cullinane
Terminal size	*	*	*	*		*
Quay length	*	*	*	*		*
Number of quay cranes	*		*	*		*
Number of yard cranes						*
New facility					*	*
Vessel size and boxes exchanged	*		*			
Container mix	*					
Number of workers		*				*
Technological levels		*			*	*
Management quality		*				
Work Practice	*				*	
Labor	*					*
Port reform					*	

3. Container Moves and Quay Efficiency

In the beginning of this study, analysis was focused on the operational data collected from one terminal operator in Kaohsiung Port. Two items of operational information were specifically collected:

1. Total number of containers loaded and unloaded for each quay operation recorded at the container terminal in Kaohsiung during 2007;
2. Working hours for the ship operation;

The **net** “quay efficiency” for each ship call could be obtained by dividing the total container moves by the working hours. The relationship between “total moves” and “quay efficiency” is illustrated in Figure 1. It is significant that the higher the number of total container moves is taken, the higher the quay efficiency to be achieved. The operational information was further analyzed using the SPSS statistics software, by which a significant relationship was found. The relationship between the total container moves and quay efficiency can then be presented as a logarithmic curve with high reliability, as illustrated in Figure 2.

Based on the findings in Kaohsiung Port, another question arises: Can this relationship be found in the quay efficiency of other ports? Therefore, the research scope was expanded to accommodate major ports in North East Asia adopting the same methodology. To expand the study to a regional scope, operational data of seven major container ports in North East Asia based on the world ranking of throughput in 2007 and the availability of operational data were collected for analysis. The terminal operators of these ports called by the sample shipping line are listed in Table 4.

A strong relationship between "total container moves" and "quay efficiency" was found in the operational data collected from these ports. Using SPSS, the logarithmic curves with high reliability were drawn, as shown in Figure 3. Regression results of these curves are shown in Table 5. It is surprising to find that there are remarkable differences on the "quay efficiency" achieved among terminal operators in major ports of North East Asia. The "quay efficiency" achieved in both Qingdao and Yantian ranked the highest, while both Hong Kong and Ningbo ranked second. It is unexpected to discover that Hong Kong ranked behind both Qingdao and Yantian, as the terminal operator in Hong Kong, that is, the Hong Kong International Terminal (HIT), has enjoyed the reputation of being the most efficient and technologically advanced terminal for over three decades. It is also surprising to see the huge difference between the major Chinese ports and Kaohsiung and Busan, although both Kaohsiung and Busan have been ranked top three and four container ports, respectively, for decades. These remarkable differences among terminal operators led to the identification of the factors influencing "quay efficiency" in North East Asia.

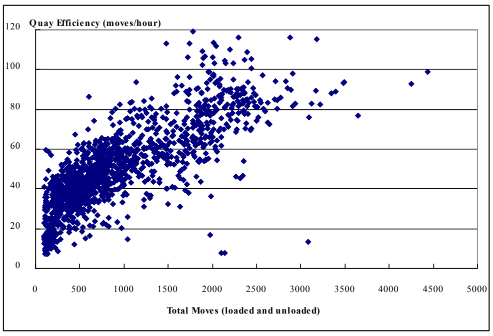

Figure 1 Relationship between Quay Efficiency and Container Moves in Kaohsiung Port
Source: Operational data from shipping line

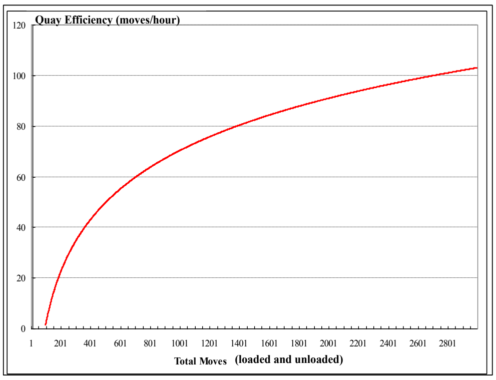

Figure 2 Regression Curve of Kaohsiung Port[1]

1

Equation	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	0.591	1404.732	1	971	0.000	-135.537	29.792

Table 4 Major container ports in NE Asia[2]

World Ranking (2007)	Port	Container Terminal Examined
2	Shanghai	Shanghai East Container Terminal
3	Hong Kong	Hong Kong International Terminal
4	Shenzhen	Yantian International Container Terminal
5	Busan	Busan East Container Terminal
8	Kaohsiung	Evergreen Terminal
10	Qingdao	Qianwan Container Terminal
11	Ningbo	Beilun Container Terminal

Source: Yearbook of Containerisation International (2008)

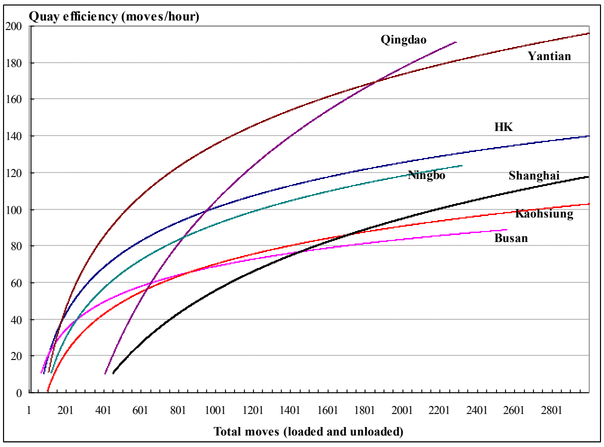

Figure 3 Regression Curves of the Major Ports in North East Asia

Table 5 Summary of regression result of the major ports

Port	*Equation*	*R Square*	*F*	*df1*	*df2*	*Sig.*	*Constant*	*b1*
Hong Kong	Logarithmic	0.784	3632.756	1.00	1000	0.00	-77.731	24.957
Busan	Logarithmic	0.787	942.8299	1.00	255	0.00	-77.676	21.230
Kaohsiung	Logarithmic	0.591	1404.732	1.00	971	0.00	-135.537	29.792
Shanghai	Logarithmic	0.841	1590.891	1.00	300	0.00	-335.783	56.638
Yantian	Logarithmic	0.804	1188.273	1.00	288	0.00	-237.192	53.909
Ningbo	Logarithmic	0.568	294.979	1.00	224	0.00	-170.413	37.986
Qingdao	Logarithmic	0.610	100.186	1.00	64	0.00	-619.206	104.806

4. Research Findings

4.1 Factors influencing quay efficiency

The "total number of container moves" has been identified to be the major factor influencing quay efficiency on a terminal basis. To determine the other factors influencing "quay efficiency" on the regional basis, the items of the data collected have been expanded based on the conclusion of the literature review. As the objective of this study is to identify the factors influencing "quay efficiency" on the regional basis, only the factors that may influence the "quay efficiency" have been collected. The items of the data collected for analysis include three categories: "terminal facilities," "container mix," and "business environment."

In practice, some Chinese ports have been found to deploy a higher number of quay cranes in the terminal to serve the "mother vessel". Therefore, to measure the possible number of quay cranes that could be assigned to quay operation, the items on port facilities are collected on a terminal basis instead of on a berth basis. The

[2] Port of Guangzhou ranked 12th, but the operational data is not available.

first item collected in the "terminal facility" was the length of linear quay of the terminal. As some terminals are designed with an "**L**" shape, in practice, only quay cranes equipped in the linear leg of the terminal can be deployed in the quay operation. The second item collected was the "density of quay cranes." These first two items were used to calculate the possible number of quay cranes that could be assigned for quay operation by the terminal operator. The third item collected was "density of transtainer," which measures the number of transtainers (yard cranes) assigned to support quay cranes during quay operation. The fourth item collected was the "terminal area," which measures the ratio between the terminal area and the "linear quay length."

In the category of "container mix," the items collected included all numbers of containers loaded and unloaded in a quay operation, such as the number of 40-ft and 20-ft containers and the number of loaded and empty containers. With regard to the "business environment," most factors found in the literature review could not be quantified. In this study, only two factors were collected. The first is the average cargo growth rate of the port between 2005 and 2007. As Chinese ports enjoyed a high growth rate since the 1990s, this study tested whether "cargo growth rate" could influence "quay efficiency." The second factor is the "operating years" of the terminal operator. Compared with Hong Kong, Kaohsiung and Busan, most Chinese ports are relatively young; therefore, this study tested whether "operating years" could influence quay efficiency. The factors collected for the analysis are summarized in Table 6.

Ship type is another major factor that may influence "quay efficiency." However, data on ship types of each call were not available, and the only information available was on the mother vessel deployed by the sample company, as shown in Table 7. Generally, the capacity of a vessel ranges between 5,600 TEUs and 7,000 TEUs; the overall length ranges between 285 and 300 m; and the breadth of the vessel ranges between 40 and 42.8 m.

In 2007, 20 records of the operational data of the mother vessels called at each port were collected successfully; thus, the total number of records collected for the seven ports is 140. Together with the facility data and business environment data, these were summarized for analysis.

Table 6 Summary of the variables considered

Categories	Items	Unit measured
Terminal facilities	Linear quay length	Measured by meter
	Quay crane density	Ratio of quay cranes and linear quay length on a 300 m basis
	Transtainer density	Ratio of transtainers and quay cranes
	Terminal area	Ratio of terminal area and quay length
Container mix	Full 40-ft containers discharged	Moves
	Full 20-ft containers discharged	Moves
	Empty 40- ft containers discharged	Moves
	Empty 20-ft containers discharged	Moves
	Full 40-ft containers loaded	Moves
	Full 20-ft containers loaded	Moves
	Empty 40-ft containers loaded	Moves
	Empty 20-ft containers loaded	Moves
Business environment	Average growth rate of the port in the last three years	Percentage
	Operating years of the terminal operator	Years

Table 7 Particulars of the mainline vessel of the sample shipping line

Capacity	Draft Designed	Length	Breadth
7,024TEU	14.2M	300.0M	42.8M
5,652TEU	12.7M	285.0M	40.0M

Source: Shipping line

4.2 Research Findings

This study first analyzed the correlations between different variables and "quay efficiency." The summary of the correlation analysis is shown in Tables 8 and 9. With regard to the relevance of "container mix (as shown in Table 8)," four items were found to have statistically significant relationships with "quay efficiency:" "the number of both **40-ft** and **20-ft empty** containers **discharged**," "the number of 40-ft full containers **loaded**" and "the number of **40-ft full** container **discharged**." The impact of "the number of 40-ft full container discharged" is "**negative**," which means the higher the number of 40-ft full containers discharged, the lower the „quay efficiency"to be achieved.

With regard to the "terminal facility (as shown in Table 9)," two items were found to have a strong statistically significant relationship with "quay efficiency": "linear quay length" and "quay crane density." On the "business environment (as shown in Table 9)," "operating years of the terminal operator" was identified to have a statistically significant relationship with "quay efficiency." The impact of "operating years", however, is "**negative**," which means younger terminal operators (in this case, all are Chinese ports) are able to provide higher quay efficiency. One of the possible explanations is that terminal operators established in recent years in China have learned comprehensive operational and management skills from its neighboring ports, and enjoy the „late-comer" advantages. Thus, they designed the terminal with longer linear quays equipped with state-of-the-art facilities and use a modern terminal management system. As a result of the abovementioned factors, they are able to achieve higher quay efficiency.

Table 8 Summary of correlation analysis of container mix

	D_F40	D_F20	D_M40	D_M20	L_F40	L_F20	L_M40	L_M20
Pearson Correlation	-0.223**	-0.154	0.650**	0.291**	0.185*	-0.162	-0.088	-0.071
Sig. (2-tailed)	0.008	0.069	0.000	0.000	0.028	0.055	0.303	0.404
N	140	140	140	140	140	140	140	140

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 9 Summary of the correlation analysis of the terminal facility and business environment

	Terminal facility				Business environment	
	Quay Length	Crane Density	TT Density	Terminal Area	Growth Rate	Op Years
Pearson Correlation	**0.725****	**0.716****	-0.025	-0.165	0.107	**-0.263***
Sig. (2-tailed)	**0.000**	**0.000**	0.772	0.052	0.209	**0.002**
N	140	140	140	140	140	140

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The aim of the second step of the analysis is to determine the linear relationship between all the variables and "quay efficiency" through regression analysis. The result of the regression models is shown in Table 10, the R-square of the regression model is 0.784, which can explain most of the cases and can be used to estimate "quay efficiency" in the major ports of North East Asia with high reliability. The summary of the ANOVA analysis result is shown in Table 11. The coefficients of the regression model are presented in Table 12, the beta value of the model shows that the "linear quay length" is the one with the best explanatory power, which is also a critical factor influencing "quay efficiency." Furthermore, the regression formula, which is comprised of the selected variables, is shown as <formula 1>:

Table 10 Summary of the regression model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.885	**0.784**	0.776	21.611

a Predictors：(Constant), Quay Length, TT Density, Op Years, Load M40, Crane Density

Table 11 Summary of ANOVA analysis

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	225,558.431	5.000	45,111.686	96.590	0.000
	Residual	62,116.408	133.000	467.041		
	Total	287,674.839	138.000			

a Predictors：(Constant), Quay Length, TT Density, Op Years, Load M40, Crane Density

b Dependent Variable: Quay efficiency

Table 12 Summary of coefficients

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	198.569	22.593		8.789	0.000
	Linear Quay Length	0.190	0.017	**1.125**	**11.259**	**0.000**
	TT Density	-72.687	7.562	-0.521	-9.612	0.000
	Op Years	-1.593	0.210	-0.314	-7.587	0.000
	Load M40	-0.138	0.030	-0.214	-4.618	0.000
	Crane Density	-14.408	6.651	-0.199	-2.166	0.032

Dependent Variable: Quay efficiency

$$\text{Quay efficiency} = 198.569 + 0.19\,X_1 - 72.687\,X_2 - 1.593\,X_3 - 0.138\,X_4 - 14.408\,X_5 \quad (1)$$

Where X_1 is linear quay length

X_2 is TT density

X_3 is operating years of the terminal operation

X_4 is the number of 40-feet empty containers loaded

X_5 is crane density

5. Conclusions

5.1 Findings

This paper examined the factors influencing “quay efficiency,” and the cases selected were container terminals from the top seven ports in North East Asia. This study has several contributions. First is the quantification of the relationship between “total container moves” and “quay efficiency” on a terminal basis. Regression curves have been identified with high reliability to estimate the “quay efficiency” to be achieved by the terminal operator.

The second contribution of this study is the identification and quantification of the factors influencing “quay efficiency” on a regional basis, specifically the region of North East Asia. These factors have been categorized into three groups: “terminal facility,” “container mix,” and “business environment.” In terms of “terminal facility,” both “linear quay length” and “crane density” have been identified as having a statistically significant relationship with “quay efficiency.” On items regarding “container mix,” the number of “40-ft and 20-ft empty containers discharged,” and “40-ft full container loaded” have been identified to have a positive impact on “quay efficiency,” but the number of “40-ft full container discharged” has been identified to have a „negative‟ impact on „quay efficiency.‟ On “business environment,” only “operating years” has been identified to have a negative impact on “quay efficiency.” In the regression model, the formula with high reliability has been created to estimate the “quay efficiency” that can be achieved by terminal operators in the major ports of North East Asia.

The findings of this study can help terminal operators review planning and working procedures, and improve “quay efficiency.” With regard to academic research, the findings may help researchers to have a deeper understanding of terminal planning and operation management.

5.2 Limitation of This Study

Due to the limitation in data collection, this study was only able to examine the "quay efficiency" achieved by one terminal operator in one port. In most ports, there is more than one terminal operator that provides quay operation service. Therefore, the research findings of this study represent only a part of the whole picture. Another limitation is that this research was unable to examine the impact of the containership with different capacities on "quay efficiency" because the capacity of the mother vessels deployed by the sample company ranged only between 5600 and 7200 TEUs. As a consequence, no operational data was available for this study to examine the relationship between the containership with different capacities (e.g., mega containership with a capacity of 12,000 TEUs) and "quay efficiency."

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Port Attributes Related to Container Terminal Efficiency in China and its Neighboring Countries: The DEA Approach

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Abstract

This paper examines factors affecting the efficiency of container terminals in China and its neighboring countries. These factors include ownership structure, hinterland size, and intra- and inter-port competition. We investigate the operational efficiency of our sample container terminals by using a two-stage procedure: data envelopment analysis (DEA) in the first stage, which is followed by Tobit regression analysis in the second stage to examine factors affecting container terminal efficiency. A bootstrapping method proposed in the literature is used in the regression analysis to avoid potential bias in estimation. We further examine the efficiency change over time by Malmquist index method. We find, among others, that (i) container terminals with higher percentage of Chinese ownership may be less efficient than its counterparts; (ii) container terminal efficiency is positively correlated with hinterland size (in terms of GDP); and (iii) intra- and inter-port competition may enhance container terminal efficiency.

1. Introduction

There have been many empirical studies of the productive efficiency of seaport operations (e.g., Tongzon, 2001; Turner, *et al.*, 2004; Cullinane and Song, 2006; Lin and Tseang, 2007; Liu, 2009; Wu and Goh, 2010). For example, Turner, *et al.* (2004) collected fourteen years of data on 26 container seaports in North America, used data envelopment analysis (DEA) to compute relative productivity measures for the seaports in question,[1] and then regressed their productivity on a number of explanatory factors in an attempt to determine which factors differentiated more productive container seaports from less productive seaports. They found that higher measures of seaport productivity were associated with the higher number of Class 1 railroads serving the seaport, concluding that "this is clear support for the importance of rail service quality, perhaps including frequency of service, and rail service competition, to the success of container seaports."[2] Several authors also

[1]Stochastic Frontier Analysis (SFA) is also a commonly used method of estimating port efficiency (e.g., Coto-Millan, *et al*., 2000; Tongzon and Heng, 2005; Sohn and Jung, 2009). However, SFA also has some well-known weaknesses. For example, it imposes some specific functional forms (e.g., the Cobb-Douglas function) on the estimation.

[2] Dresner (2007) documented the dramatic shift in container traffic from the Port of Baltimore to the Port of Norfolk over the past twenty years. This shift is attributed to a number of factors, including railroad companies‟ preference for Norfolk over Baltimore. It was claimed that the railroads prefer to concentrate their business at ports other than Baltimore for economic reasons. Norfolk Southern, one of the two Class 1 railroads serving Baltimore, prefers to concentrate its business at its homeport in Norfolk. The other Class 1 railroad, CSX, prefers to concentrate much of its business in New York. Because the final destination of most container traffic is not the local markets at either Norfolk or Baltimore, the availability of high-quality rail services at Norfolk is conducive to its competitiveness.

argued that hinterland access is an important factor in the competitiveness of a seaport when it competes with other seaports (Notteboom, 1997; Kreukels and Wever, 1998; Fleming and Baird, 1999).

This paper adds to the stock of this body of literature on seaport efficiency, which mainly focuses on ports located in advanced markets, but less on the emerging markers (a few exception includes, Wu and Goh, 2010). In particular, there is lack of studies investigating efficiency of major ports in China (except Shanghai and Shenzhen, the two largest ports in mainland China), which may be due to difficulties in obtaining good quality data. Yet studying port efficiency in China is considerable important for several reasons. In last few decades, lots of multinational companies have relocated their manufacturing sites to China. In the supply chain of those companies, the intermediary or final products will be shipped to different parts of the world by sea. This has induced a huge demand in seaport service in the region. Given this, China and its neighboring regions have made a huge capital investment in their port facilities in recent years. However, as discussed below, the seaport facility investment still could not meet the rapid growth in demand. As a result, how to use the seaport facilities more efficiently is an important issue to the industry in the region. On the other hand, we also observe some important differences between ports in China and their counterparts around the world, including ownership structure, imbalance of inbound/outbound cargos, serving an export-oriented economy, etc. It will be interesting to see whether we would obtain different empirical results by using Chinese seaport data, comparing with those in the literature. Hence, this paper investigates the efficiency of the container seaports at the coastal cities in mainland China and its neighboring regions (see Table 1).

Table 1. List of cities considered in the study

Global rank in 2008	City	Twenty-foot Equivalent Units (TEU) (1,000)
1	Singapore	29,918
2	Shanghai	27,980
3	Hong Kong	24,248
4	Shenzhen	21,414
5	Busan	13,425
7	Ningbo	11,226
8	Guangzhou	11,001
11	Qingdao	10,320
12	Kaohsiung	9,677
14	Tianjin	8,500
22	Xiamen	5,035
23	Dalian	4,503

Source: American Association of Port Authorities (AAPA)

In the paper, we use a two-stage procedure, beginning with DEA in the first stage, which is then followed by Tobit regression analysis (Tobin, 1958), to examine the determining factors of efficiency at these seaports. In addition, we also use bootstrapping method proposed by Simar and Wilson (2007) in order to avoid potential serial correlation among the estimated coefficients in the second-stage regression. Our empirical results suggest that ports with higher percentage of Chinese ownership may be less efficient. We also find that seaports serving a hinterland (in terms of GDP) may be more efficient than their counterparts, depending on our definition of hinterland. The empirical results also support the argument that intra- and inter-port competition may enhance seaport efficiency.

The remainder of this article is organized as follows. Sections 2 and 3 discuss our methodology and data, respectively. Section 4 reports the empirical results regarding seaport efficiency level and its growth. Section 5 presents concluding remarks.

2. Methodology

To investigate the factors affecting seaport efficiency, we use a two-stage procedure (see, for example, Ali and Flinn, 1989; Kalirajan, 1990). In the first stage, we use the non-parametric, linear programming-based method of data envelopment analysis (DEA) (Charnes, *et al*., 1978) to calculate the productive efficiency of each seaport. In the second stage, we run regression models to examine the effects of ownership structure, hinterland size, and intra- and inter-port competition on the productive efficiency of seaports.

Firm efficiency is reflected by the relationship between the outputs that the firm produces and the inputs that the firm uses in a given period of time. In other words, given a certain amount of input, a more efficient firm can produce more output (i.e., an output-oriented approach).[3] When firms use multiple inputs to produce multiple outputs, firm efficiency can be obtained by using a non-parametric technique such as DEA, with the most efficient firms forming an efficient frontier. By DEA, we obtain the DEA efficiency score, D^{kt} (also known as the Shepard"s distance function) of container terminal *k* in year *t* computed under the assumption of a constant return to scale.[4] Note that D^{kt} must be less than or equal to 1; the larger the score, the higher the efficiency of container terminal *k* in year *t*. Thus, if container terminal *k* is the most efficient in year t (i.e., if it is on the efficient frontier), then $D^{kt} = 1$. In particular, container terminals with an efficiency score of unity are located on the frontier in the sense that their outputs cannot be further expanded without a corresponding increase in input. Container terminals with an efficiency score below one are inefficient. The DEA model defines the efficiency score of any container terminal as the fraction of the airport"s output that can be produced for an airport on the efficient frontier with the same level of input.

It is noteworthy that because the efficiency scores have a upper bound of one, there may be a truncated bias in the OLS regression model. Thus, in the second stage, we use the Tobit regression model (Tobin, 1958) instead. The Tobit model can be represented as follows:

$$\hat{D}^{kt} = \alpha + \beta_1 * (Chinese\ ownership) + \beta_2 * (hinteralnd\ \ GDP) + \beta_3 * (hinteralnd\ \ population) \\ + \beta_4 * (No.\ of\ \ terminals) + \beta_5 * (Distance\ to\ the\ nearest\ port) + \varepsilon^{kt} \quad (1)$$

$$\hat{D}^{kt} = \begin{cases} 1 \ \ if\ D^{kt} \geq 1 \\ D^{kt}\ if\ D^{kt} < 1 \end{cases}$$

While such two-stage analysis (employing either the ordinary least squares model or the Tobit model) have been used extensively in the literature,[5] Simar and Wilson (2007) argued that DEA efficiency estimates are complicated and may be serially correlated, which would lead standard approaches to inference, based on regression, to be invalid. They proposed the use of bootstrapping procedures to solve this problem and leads to better estimation and inference for the model parameters. The proposed bootstrapping procedures use the original data to generate a new set of samples that are then used to estimate the regression parameters and conduct statistical inference. Banker and Natarajan (2008), however, argued that the two-stage procedure used in the existing literature yields consistent estimators of the impact of contextual variables under the assumption of a less restrictive data-generating process than that assumed in Simar and Wilson. Nevertheless, in our work, we report the results achieved using the typical Tobit models and those based on the data obtained using the bootstrapping procedures proposed by Simar and Wilson. In addition, Chernick (2008) suggested that if the OLS regression analysis is appropriate, bootstrapping methods will provide nearly the same answer as in the OLS (and also in the Tobit model). Thus, given the results of the two models, we can check whether the bootstrapping procedures are necessary in order to obtain consistent estimates using the

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[3] With DEA, 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). We chose to use the output-oriented model because most inputs of seaport production that we selected (e.g., number of berth and port area) were assumed to be quasi-fixed.

[4] The reciprocal of the Shepard"s distance function, also known as Farrell output measure, is also reported in some studies in the literature. In such cases, the larger the index, the less the firm"s efficiency.

[5] See, e.g., Ali and Flinn (1989), Kalirajan (1990) and Ray (1991).

two-stage approach to explain the DEA measures.

Having examined efficiency levels for the sample container terminals, we also look at the changes in efficiency levels. Efficiency growth is measured using the Malmquist index:

$$M_k^{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \underbrace{\frac{D_k^{t+1}(x^{t+1}, y^{t+1})}{D_k^t(x^t, y^t)}}_{EFFECH} \times \underbrace{\left[\frac{D_k^t(x^{t+1}, y^{t+1})}{D_k^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_k^t(x^t, y^t)}{D_k^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}}}_{TECH} , \qquad (2)$$

where D_k^t is an output distance function for container terminal k at period t we obtained from DEA. The superscripts on x and y indicate the time periods of the data used to calculate the efficiency scores. A Malmquist index M_k^{t+1} that is greater (less) than unity indicates that the overall efficiency of container terminal k has increased (decreased) from period t to period t+1. Note that equation (2) also represents a decomposition of the efficiency change from period t to period t+1. The ratio outside the brackets on the right-hand side measures the change in the "technical efficiency (*EFFECH*)" of container terminal k from period t to period t+1. A figure that is greater (smaller) than unity implies that technical efficiency has improved (declined) in reference to the production frontier from period t to period t+1. The bracketed term represents the geometric mean of the shift in the production frontier. When the value of this term is greater (less) than unity, the "technology (*TECH*)" of the industry has progressed (regressed) from period t to period t+1.

3. Sample Container Terminals And Variable Construction

Sample container terminals

We consider a panel data set for 21 major container terminals in China and other cities in the region (as shown in Table 2) for the period between 2003 and 2007. The data are compiled from various sources, including the annual Containerization Yearbooks from 1995 to 2005,[6] the Chinese Ports Yearbook, company annual reports and websites, and statistical yearbooks from various countries.

Table 2. Sample container terminals and their operators

Location	**Container terminal name**	**Operator name**	**Chinese ownership**
Shenzhen	Container Terminal (CHIWAN)	Chiwan Container Terminal Co Ltd	51%
Shenzhen	Shekou	Shekou Container Terminal	51%
Shenzhen	Yantian	Yantian International Container Terminals Ltd	27%
Dalian	Dayaowan Container Terminal	Port of Dalian Authority and Port of Singapore Authority	51%
Guangzhou	Xingang Terminal/ Xinsha Terminal	Guangzhou Container Terminal Co Ltd	51%
Ningbo	Beilun Container Terminals	Ninbo Beilun International Container Terminals	51%
Qingdao	Qianwan Qianwan Container Terminal	Qingdao Qianwan Container Terminal Co Ltd	51%
Shanghai	Bao Shan Terminal/Zhanghuabang Terminal/Jun Gong Lu Terminal	Shanghai Container Terminals Ltd	50%

[6] The Containerization Yearbook is the most commonly used data source for similar studies in the literature. However, it is found that some of the data in the yearbook, especially those for facilities and equipment, are not up-to-date. This may lead to severe problems in measuring DEA scores and its annual growth. Given this, we have verified whether these data are consistent with announcements on company websites and news, and we have made updates if needed.

Shanghai	Shanghai East Container Terminals	Shanghai East Container Terminals Co Ltd	51%
Shanghai	Shanghai Pudong International Container Terminals	Shanghai Pudong International Container Terminals Ltd	40%
Shanghai	Waigaoqiao Terminal	Shanghai Port Container Co Ltd	100%
Tianjin	Container Terminal	Tianjin Port Container Terminal co Ltd	0%
Tianjin	CSX Orient Container Terminal	CSX Orient (Tianjin) Container Terminal co Ltd	51%
Xiamen	Xiamen Haitian Port	Xiamen Haitian Container Terminals Ltd.(XHCT)	100%
Busan	Hanjin Gamcheon Container Terminal	Hanjin Shipping Co Ltd	0%
Busan	Shinsundae Container Terminal	Pusan East Container Terminal co Ltd	0%
Busan	Sin Gamman Container Terminal	Dongbu Pusan Container Terminal Co Ltd	0%
Busan	Jasungdae Container Terminal	Hutchison Korea Terminals	0%
Singapore	Brani Terminal/Keppel Terminal/Pasir Panjang Terminal/Tanjong Pagar Terminal	PSA	0%
Kaohsiung	Terminals 1-5	Lien Hai Terminal and Stevedoring Co Ltd	0%
Hong Kong	Terminals 1-9	Modern Terminals Ltd/Cosco- HIT Terminals (Hong Kong) Ltd/ Hong Kong International Terminals Ltd	0%

To calculate the DEA score, one must first identify outputs that a container terminal produces and the inputs it uses in producing those outputs. We consider five physical inputs: number of berths, total berth length, land size, number of quay cranes and yard gantries. On the output side, we consider the cargo throughput (in terms of TEU) as representing container terminal output. The summary statistics for the inputs and outputs we considered is given in Table 3. It is noted that the growth rates of the five inputs were only from 6.1% to 32.8% in the period between 2003 and 2007, while the output was increased by 64.7%. These figures suggested that although the container terminal investment was increased significantly in recent years in the region, it still could not meet the rapid growth in demand. As a result, how to use the container terminal facilities more efficiently would be an important issue to the industry in the region.

Table 3. Summary statistics

		Inputs					Output
		Berth (no.)	Total Length (m)	Size (m²)	Quay Crane (no.)	Yard Gantries (no.)	Throughput (TEU)
2003	Mean	7.6	2,306	1,088,220	25.1	57.3	3,347,588
	SD	8.5	2,463	797,618	42.9	76.6	4,275,870
2004	Mean	8.2	2,499	1,107,268	23.5	62.7	4,035,918
	SD	8.6	2,554	834,549	27.7	77.9	4,709,534
2005	Mean	8.3	2,639	1,106,012	25.3	72.1	4,558,695
	SD	8.6	2,537	834,671	27.5	77.9	5,093,165
2006	Mean	8.8	2,749	1,106,012	26.8	73.0	4,962,429
	SD	8.5	2,577	834,671	28.4	80.6	5,398,010
2007	Mean	9.0	2,811	1,154,949	28.8	76.1	5,512,176
	SD	8.5	2,616	874,646	29.8	83.2	6,078,212

Variable construction

In the second stage, we run the regression model in (1) to examine the relationship of Chinese ownership, hinterland size, and inter- and inter-port competition intensity with container terminal. The dependent variable is the efficiency score D^{kt} obtained via DEA in the first stage. The independent variables are as follows:

Chinese ownership: As in other industries in China, foreign investment is encouraged in the seaport industry because it is seen as a factor improving container terminal operational efficiency. We obtained the percentage of Chinese ownership from the Chinese Ports Yearbook as shown in Table 2. Container terminals outside China (namely, Busan, Singapore, Kaohsiung and Hong Kong) are 0% Chinese-owned.

Intra-port competition: In the study, we consider the number of the container port terminal operators at the city as a proxy for the intra-port competition. We assume that more operators at the city will lead to fiercer intra-port competition at the city.

Hinterland size: To construct the variable capturing the hinterland size, we first need a measure of the hinterland served by a particular port. For a port at mainland China and Hong Kong, we consider those provinces located within a radius of 500 kilometers of the port as its hinterland. As a robustness check, we also consider the case that the ports only serve its own province as hinterland in our regression analysis. On the other hand, Busan and Kaohsiung serve South Korea and Taiwan as their hinterlands respectively. The hinterland for Singapore includes Singapore itself and Malaysia. In the following analysis, we will consider both population and gross domestic produce for a hinterland as independent variables. Those figures in 2007 are given in Table 4.

Table 4. Ports' Hinterlands (for provinces in 500 kilometers)

Location	Port	Hinterland	Population ('000)	GDP (USD MN.)
Shenzhen	Container Terminal (CHIWAN)	Guangxi/Grangdong/Hunan/Jiangxi /Fujian/Hong Kong	292,162.80	1,014,643.21
Shenzhen	Shekou	Guangxi/Grangdong/Hunan/Jiangxi/ Fujian/Hong Kong	292,162.80	1,014,643.21
Shenzhen	Yantian	Guangxi/Grangdong/Hunan/Jiangxi/ Fujian/Hong Kong	292,162.80	1,014,643.21
Dalian	Dalian Container Terminal	Liaoning/Jilin	93,580.00	214,417.68
Guangzhou	Xingang Terminal/ Xinsha Terminal	Guangxi/Grangdong/Hunan/Jiangxi/ Fujian/Hong Kong	292,162.80	1,014,643.21
Ningbo	Beilun Container Terminals	Zhejiang/Jiangxi/Anhui/Jiangsu/ Shanghai/Fujian	286,100.00	1,036,366.98
Qingdao	Qianwan Container Terminal	Shandong/Hebei/Jiangsu	239,350.00	860,087.83
Shanghai	Bao Shan Terminal/Zhanghuabang Terminal/Jun Gong Lu Terminal	Shanghai/Jiangsu/Anhui/Zhejiang/ Jiangxi	250,290.00	914,760.71
Shanghai	Shanghai East Container Terminals	Shanghai/Jiangsu/Anhui/Zhejiang/ Jiangxi	250,290.00	914,760.71
Shanghai	Shanghai Pudong International Container Terminals	Shanghai/Jiangsu/Anhui/Zhejiang/ Jiangxi	250,290.00	914,760.71
Shanghai	Waigaoqiao Terminal	Shanghai/Jiangsu/Anhui/Zhejiang/ Jiangxi	250,290.00	914,760.71
Tianjin	Container Terminal	Shanxi / Hebei / Shandong / Liaoning / Inner Mongolia / Beijing / Tianjin	291,540.00	1,011,426.67

Tianjin	Tianjin Orient Container Terminal	Shanxi / Hebei / Shandong / Liaoning / Inner Mongolia / Beijing / Tianjin	291,540.00	1,011,426.67
Xiamen	Xiamen Haitian Port	Fujian / Guangdong / Zhejiang / Jiangxi	224,580.00	849,538.77
Busan	Hanjin Gamcheon Container Terminal	South Korea	48,456.37	1,041,903.18
Busan	Shinsundae Container Terminal	South Korea	48,456.37	1,041,903.18
Busan	Sin Gamman Container Terminal	South Korea	48,456.37	1,041,903.18
Busan	Jasungdae Container Terminal	South Korea	48,456.37	1,041,903.18
Singapore	Brani Terminal/Keppel Terminal/Pasir Panjang Terminal/Tanjong Pagar Terminal	Singapore/ Malaysia	31,762.60	300,197.43
Kaohsiung	Terminal 1-5	Taiwan	22,828.56	384,768.00
Hong Kong	Terminal 1-9	Guangxi/Grangdong/Hunan/Jiangxi/ Fujian/Hong Kong	292,162.80	1,014,643.21

Inter-port competition intensity: like Yuen and Zhang (2009), we use the (log) distance of the seaport where a particular container terminal located from the nearest other seaport in our sample as a proxy for the intensity of inter-port competition.[7] In particular, we consider a seaport to be facing more competition if there is another one close in proximity. For example, the distance between the Shekou and Hong Kong seaports is only about thirty-two kilometers, indicating that the Shekou seaport is considered to be facing strong competition from the Hong Kong seaport in our analysis.

4. Empirical Results

This section presents the results for our two-stage analysis to investigate container terminal efficiency and its growth. Section 4.1 contains the results for the container terminal efficiency, in which we first report the efficiency for our sample container terminals each year from 2003 to 2007. In addition to this, we investigate the influence of ownership structure, hinterland size, and competition on the container terminal efficiency by different regression models. Similarly, Section 4.2 reports the efficiency growth for the sample container terminals, and followed by results from different regression models.

4.1 Efficiency

Efficiency scores

The resulting efficiency scores for the 21 sample container terminals for the period between 2003 and 2007 are shown in Table 5. In 2007, the Qingdao Qianwan, Shanghai Waigaoqiao Terminal, Busan Shinsundae Container Terminal, Kaoshiung and Hong Kong Ports were considered the most efficient (i.e., DEA efficiency score, D^{kt}, equal to unity), while the Busan Hanjin Gamcheon Container Terminal, Shekou Port, and Tianjin CSX Orient Container Terminal were the least efficient terminals. It is noted that some investments in container terminals, such as berths, are largely indivisible. As a result, the container terminals may need to invest in those facilities before their capacity is fully utilized. Given this, we may need to be particularly careful when we interpret the results from DEA. For example, the 2003 efficiency score for Qingdao Qianwan is 0.124 in 2003. This large number may not necessarily indicate that the container terminal was very

[7] The most commonly used proxy for market competition is the Herfindahl index (HHI). Constructing HHI requires very comprehensive market data for the whole study period, which are not available; thus, we cannot use HHI as our proxy for inter-port competition.

inefficient during that period but may instead have resulted from a significant increase in inputs after Phase II of its development plan, which ended that year.

Table 5. Efficiency scores

Location	**Port Name**	2003	2004	2005	2006	2007
Shenzhen	Container Terminal (CHIWAN)	1	1	1	1	0.656
Shenzhen	Shekou	1	0.811	0.754	0.714	0.51
Shenzhen	Yantian	1	1	0.9	1	0.811
Dalian	Dayaowan Container Terminal	0.475	0.667	0.674	0.721	0.643
Guangzhou	Xingang Terminal/ Xinsha Terminal	0.539	0.643	0.524	0.594	0.575
Ningbo	Beilun Container Terminals	0.624	0.795	0.765	0.744	0.742
Qingdao	Qingdao Qianwan Container Terminal	0.124	0.872	0.942	1	1
Shanghai	Bao Shan Terminal/Zhanghuabang Terminal/Jun Gong Lu Terminal	0.869	0.86	0.792	0.836	0.671
Shanghai	Shanghai East Container Terminals	0.299	0.859	1	1	0.928
Shanghai	Shanghai Pudong International Container Terminals	1	1	1	1	0.973
Shanghai	Waigaoqiao Terminal	1	1	1	1	1
Tianjin	Container Terminal	0.522	0.62	0.643	0.665	0.662
Tianjin	CSX Orient Container Terminal	0.624	0.591	0.587	0.568	0.529
Xiamen	Xiamen Haitian Port	0.519	0.47	0.457	0.868	0.557
Busan	Hanjin Gamcheon Container Terminal	0.701	0.658	0.599	0.56	0.45
Busan	Shinsundae Container Terminal	1	1	1	1	1
Busan	Sin Gamman Container Terminal	0.531	0.65	0.755	0.733	0.629
Busan	Jasungdae Container Terminal	0.586	0.669	0.771	0.735	0.638
Singapore	Brani Terminal/Keppel Terminal/Pasir Panjang Terminal/Tanjong Pagar Terminal	1	0.998	1	1	0.856
Kaohsiung	Terminal 1-5	1	1	1	1	1
Hong Kong	Terminal 1-9	1	1	1	1	1
	Mean	0.734	0.817	0.817	0.845	0.754

Regression results

In the second stage, we run the Tobit regression model given in (1) (Model 1) and the regression model with the bootstrapping procedures proposed by Simar and Wilson (2007) (Model 2). As mentioned in the variable construction section, we also considered a narrower definition of hinterland served by the seaports, and the regression results with and without bootstrapping procedures based on it are also reported in Models 3 and 4 respectively. The results are shown in Table 6. The signs of the estimated coefficients of Chinese ownership in the four models suggest that the container terminal efficiency and Chinese ownership are negatively correlated, and the relationship is significant in all four models. Having also included variables related to the seaport‟s hinterland, we found in Model 4 that container terminal efficiency is positively correlated with provincial gross domestic product (GDP), and the coefficients are significantly different from zero. The result implies that a port serving a larger hinterland is more efficient than its counterparts. However, the coefficient is no longer significant in other models. On the other hand, we find that container terminal efficiency is negatively correlated with the figures for the hinterland population and that the coefficients are significantly different from zero in Models 2, 3 and 4.

For variables related to intra-port competition, the signs of the estimated coefficients of the proxy for intra-port competition imply that the container terminal efficiency and intra-port competition are positively correlated, this relationship is found to be significant in all four models. In other words, container terminals with more intra-port competition are more efficient than their counterparts. On the other hand, the container terminal efficiency is found to be positively correlated with inter-port efficiency, as the efficiency is negatively correlated with the distance to the nearest port, and the coefficients are statistically significant in all four models

As noted in Chernick (2008), when the regression results with and without bootstrapping procedures are not very different, the regression without bootstrapping is an appropriate method for the analysis. Comparing Models 1 and 2, and Models 3 and 4, it is important to note that the standard errors are found to be less in the model with bootstrapping procedures proposed by Simar and Wilson (2007). This may suggest that the proposed bootstrapping procedures may be important for improving the statistical inference accuracy in the second-stage regression analysis.

Table 6. Regression results regarding efficiency scores

	Model 1		Model 2		Model 3		Model 4	
	Large hinterland definition				Small hinterland definition			
	Without bootstrapping		With bootstrapping		Without bootstrapping		With bootstrapping	
	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error
Constant	0.828***	0.100	0.936***	0.053	0.913***	0.118	1.040***	0.067
Chinese ownership	-0.270***	0.098	-0.259***	0.053	-0.297***	0.102	-0.295***	0.057
Hinterland GDP	0.000	0.000	0.000	0.000	0.000	0.000	0.000**	0.000
Hinterland population	-0.000	0.000	-0.000*	0.000	-0.000*	0.000	-0.000***	0.000
No. of terminals operated by different operators	0.018**	0.008	0.017***	0.004	0.014*	0.008	0.012***	0.004
Distance to nearest port	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000

* 10% significance
** 5% significance
*** 1% significance

4.2 Growth in efficiency

Table 7 presents the descriptive statistics for efficiency growth rates and their two components as defined in (2). The mean of Malmquist indexes from 2004 to 2007 are larger than unity, suggesting that on average, the overall efficiency of the sample container terminals has improved each year. We also find that the figures for technical efficiency (EFFECH) are greater than unity in 2004 and 2006, while they are less than unity in 2005 and 2007. This implies that technical efficiency has improved (worsened) in reference to the production frontier in 2004 and 2006 (in 2005 and 2007). On the other hand, the technological change (TECH) is greater than unity from 2004-2007, suggesting that the technology of the industry has progressed each year.

Table 7. Descriptive statistics for efficiency growth rates

	Malmquist index		Technical efficiency (EFFECH)		Technological change (TECH)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation

2004	1.244	1.316	1.200	1.350	1.037	0.076
2005	1.041	0.099	0.997	0.086	1.044	0.061
2006	1.065	0.220	1.040	0.200	1.024	0.057
2007	1.190	0.173	0.882	0.116	1.190	0.176

We run an OLS regression to examine the factors affecting efficiency growth and its two components. In addition, as in Section 4.1, we also run the regression model with the bootstrapping procedures proposed by Simar and Wilson (2007). The results are presented in Table 8. We find that the results obtained using the OLS model and that with the bootstrapping procedures are not very different. This suggests that OLS regression is an appropriate method of data analysis (Chernick, 2008). We find that the efficiency growth is negatively correlated with Chinese ownership, and the coefficients are statistically significant in Models 1 and 2. The OLS regression results also show that efficiency growth is negatively correlated with the hinterland GDP, and the coefficients are statistically significant in the four models. These results are consistent with those presented in the existing literature on airport productivity in China. For example, Fung, *et al*. (2008) find that efficiency figures for airports in different regions are converging. On the other hand, we find in Models 3 and 4 that efficiency growth is positively correlated with the hinterland population, and the coefficients are statistically significant. Finally, in Models 1 and 2, we find the efficiency growth is positively correlated with intra- and inter-competition, and the relationships are statistically significant.

Table 8. Regression results on the Malmquist Index

	Model 1		Model 2		Model 3		Model 4	
	Large hinterland definition				Small hinterland definition			
	Without bootstrapping		With bootstrapping		Without bootstrapping		With bootstrapping	
	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error
Constant	0.981***	0.066	0.983***	0.066	0.993***	0.245	0.984***	0.250
Chinese ownership	-0.273***	0.074	-0.276***	0.073	0.019	0.346	0.020	0.349
Hinterland GDP	-0.000***	0.000	-0.000***	0.000	-0.000*	0.000	-0.000*	0.000
Hinterland	-0.000	0.000	-0.000	0.000	0.000**	0.000	0.000**	0.000
population								
No. of terminals operated by different operators	0.025***	0.006	0.025***	0.006	-0.014	0.025	-0.013	0.025
Distance to nearest port	-0.001***	0.000	-0.001***	0.000	0.001	0.001	0.001	0.001

* 10% significance
** 5% significance
*** 1% significance

The regression results for technical progress (TECH) are presented in Table 9. The two tables suggest that the results achieved using the OLS model and those based on the model with the bootstrapping procedures are not very different. As shown in Table 10, we find that technical progress is positively correlated with the hinterland GDP, and the coefficients are statistically significant (at 10% significance level) in all three models. However, the relationship between the technical progress and the hinterland population is negative and statistically significant in Models 1 and 2. On the other hand, we find that the technical progress is negatively correlated with the distance to nearest port, and the coefficients are statistically significant in Models 1 and 2. The results provide empirical evidence that the inter-port competition may enhance the technology level of the whole industry

Table 9. Regression results for TECH

	Model 1		Model 2		Model 3		Model 4	
	Large hinterland definition				Small hinterland definition			
	Without bootstrapping		With bootstrapping		Without bootstrapping		With bootstrapping	
	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error
Constant	1.056***	0.050	1.057***	0.050	1.071	0.045	1.070*	0.045
Chinese ownership	0.048	0.056	0.049	0.057	0.040	0.063	0.037	0.065
Hinterland GDP	0.000*	0.000	0.000*	0.000	0.000*	0.000	0.000	0.000
Hinterland population	-0.000***	0.000	-0.000***	0.000	0.000	0.000	0.000	0.000
No. of terminals operated by different operators	-0.006	0.005	-0.006	0.005	-0.003	0.005	-0.003	0.005
Distance to nearest port	-0.000***	0.000	-0.000***	0.000	0.000	0.000	0.000	0.000

* 10% significance
** 5% significance
*** 1% significance

Lastly, the OLS results of technical efficiency (EFFECH) are given in Table 10. The results show that technical efficiency is negatively correlated with provincial GDP, and the coefficients are statistically significant in the four models. These results may suggest a phenomenon that container terminal efficiency are converging among different regions as mentioned above. We also find that technical efficiency is positively correlated with the hinterland population, and its coefficients are statistically significant in Models 3 and 4.

Table 10. Regression results for EFFECH

	Model 1		Model 2		Model 3		Model 4	
	Large hinterland definition				Small hinterland definition			
	Without bootstrapping		With bootstrapping		Without bootstrapping		With bootstrapping	
	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error	Estimation	Standard error
Constant	1.185***	0.295	1.177***	0.297	0.924***	0.252	0.930***	0.241
Chinese ownership	0.148	0.330	0.138	0.330	-0.017	0.356	-0.014	0.352
Hinterland GDP	-0.000***	0.000	-0.000***	0.000	-0.000***	0.000	-0.000**	0.000
Hinterland population	0.000	0.000	0.000	0.000	0.000***	0.000	0.000**	0.000
No. of terminals operated by different operators	-0.006	0.029	-0.007	0.029	-0.010	0.026	-0.010	0.026
Distance to nearest port	0.001	0.001	0.001	0.001	0.000*	0.001	0.001*	0.001

* 10% significance
** 5% significance
*** 1% significance

5. Concluding Remarks

This paper examined the efficiency of container terminals in China and its neighboring countries. We calculated the DEA efficiency scores of 21 sample container terminals and their growth during each year between 2003 and 2007. Furthermore, we used regression models to examine the factors affecting container terminal efficiency score and its growth. Specifically, we used both the Tobit model and a regression model with bootstrapping procedures as proposed by Simar and Wilson (2007). For the analysis of DEA scores, we found that there is a significant difference between the results achieved using the two models, which probably implies that bootstrapping procedures are necessary to obtain consistent estimators in regression models.

Our empirical results showed that the percentage of Chinese ownership is negatively correlated with container terminal efficiency in some of our regression models. Second, we found that container terminals serving a larger hinterland (in terms of population) are more efficient than ports with a smaller hinterland. However, the correlation is no longer significant in the regression model with bootstrapping procedures. The empirical results also supported the argument that intra- and inter-port competition may enhance container terminal efficiency. In one of our regression model, we found that efficiency growth is positively correlated with the hinterland population. On the other hand, we found that the inter-port competition and increasing hinterland GDP may lead to enhancement of the technology level of the whole industry. Finally, the results also suggest the phenomenon that technical efficiency gap between ports serving hinterlands with high and low GDP is converging.

As other studies using DEA, this paper only focused on how efficient the physical inputs of a container terminal have been used to produce outputs. Although some „soft" inputs and outputs, for example, government policies, service quality and users" perception, are important to determine a container terminal performance, those factors could not be, or are hardly, included in DEA. As a result, we may also need to use other methodologies as a supplement to obtain a comprehensive evaluation for container terminals. For example, Zhang, *et al*. (2010) use the Analytic Hierarchy Process to evaluate container terminals based on opinions from industry experts and users.

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The Impact of the Container Security Initiative on the Port Logisitics industry in Taiwan based on Risk Assessment

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Abstract

This paper evaluates the impact of risk factors from the Container Security Initiative on Taiwan's shipping industry by employing a risk management matrix to identify the severity and frequency of CSI risk factors, and discovers some appropriate risk management alternatives.

This paper's findings are as follows: (1) The majority of risk factors have a moderate risk level, and possible alternative risk management measures include risk prevention, self-retention, and insurance. (2) Ensuring a balance between the efficiency of maritime logistics and supply chain security is of vital importance to any trading countries dealing with security risk issues. (3) The government should encourage the private sector to design and market security hardware and software, which will promote the growth of the domestic security industry and generate employment opportunities.

Keywords: *Supply chain, security, risk management, shipping*

1. Introduction

The US has substantially strengthened national security measures in the wake of the devastating 911 terrorist attacks, and its Container Security Initiative (CSI) requires that that inbound container or cargo from foreign commercial ports be pre-inspected. The CSI has been implemented in order to prevent the smuggling of WMDs onto American soil and ensure the pre-inspection of high-risk cargo using X-ray container inspection machines. After imposing these measures at the start of 2002, the US has signed MOUs with the world's twenty largest ports with major outbound container traffic to the US. As of the end of July 2007, 53 ports in 23 countries had signed MOUs with the US. The initial stage of CSI called for implementation at the world's twenty largest ports, and implementation has now been expanded to the world's sixty largest ports, including the ports of Kaohsiung and Keelung in Taiwan. The port of Kaohsiung signed a CSI MOU with the US on June 15, 2006.

According to an estimate by the Brookings Institute, the costs associated with US port closure resulting from a detonated WMD could amount to $ 1 trillion, if 12-day closure would cost approximately $58 billion (U.S. GENERAL ACCOUNTING OFFICE, 2003) Any disruption to maritime trade has significant implications to economic activity and world trade. It has been suggested that investment in the United States dropped by 0.2% of GDP because of the ongoing threat of terrorism (Saxton, J. 2002). The US General Accounting Office has claimed that container security and expansion of key customs programs will require greater attention to critical success factors.

On the other hand, some scholars recognize that America's demand, enforced via bilateral agreements and international organizations, that countries exporting goods to the US implement security inspection procedures, not only creates many inconveniences for supply chain operations, particularly with regard to efficiency and effectiveness, but also adds to logistics costs due to the need for increased security and greater manifest transmission costs. Haralambides argues that the risk brought by route control and distortion of inter-port fair competition will inevitably have the largest impact on ports in developed countries (HARALAMBIDES, HE. 2002). While international regulation driven by one country's national interests represents a break with the past, it is sure to result in much greater risk in comparison with the more diversified traditional methods formulated and implemented by the international maritime community.

Johnston argued that American lawmakers should adopt a more equitable balance between an efficient deregulated environment and a regulated environment meeting security requirements. The implementation of CSI requires bilateral agreements between the US and other countries. CSI requires the pre-inspection of high-risk containers, but the majority of containers need not be considered security threats (JOHNSTON, VR. 2004). If a container is recognized as high-risk, once a high-risk container originating at a CSI port arrives at a US port, the local government customs authority and US customs officer deployed in the country of origin will jointly determine whether the container had been subjected to pre-shipment inspection.

Although to date there have been no terrorist or extremist attacks on seaport or airport traffic infrastructures or facilities in Taiwan, the government of Taiwan has introduced various security initiative (such as the WCO SAFE framework, CSI, AEO, and ISPS) in compliance with global trends in the fight against terror. Since CSI has been implemented in Taiwan for several years, what effect has it had on shipping industry at the port of Kaohsiung? How should the shipping industry deal with supply chain security risks as required by CSI and the 24-hour rule? This paper seeks to investigate these issues.

Ho and Ho claimed that the process of risk management can be divided into risk identification, risk analysis, and risk control (HO, M. W., HO, K.H. 2006) This paper therefore employs the following research process: Highlighting CSI assessment factors to identify risks, then using a risk management matrix to confirm the severity and frequency of security risks, and finally providing some appropriate risk management alternatives.

The purpose of the paper is to: (1) review supply chain risk management definitions and concepts, (2) determine the impact of CSI on the shipping industry, (3) identify CSI-related risk assessment factors affecting the shipping industry, and (4) suggest risk management alternatives for the shipping industry and relevant government agencies.

The reminder of this paper is organized as follows: The second section consists of a literature review and examines risk management and CSI definitions and concepts; the third section explains the research methodology, including the risk management matrix, assessment factors, questionnaire design, and data collection; the fourth section performs empirical analysis based on the risk management matrix; and the final section offers some conclusions and provides suggestions for the shipping industry and academic researchers.

2. Literature Review

2.1 Risk Management

Supply Chain Security (SCS) has formed a key part of integrated supply chain risk management since the 911 terrorist attacks, and is a crucial factor for enterprises and governmental authorities. SCS generally includes physical security, access control, personnel security, education and training awareness, procedural security, documentation processing security, trading partner security, conveyance security, and crisis management and disaster recovery.

As for the definition of SCS, Tang argued that SCS involves adopting policies, procedures, and technologies to protect supply chain property (including products, facilities, equipment, information, and personal) against robbery, damage, terrorist threat, and to hinder introduction or unauthorized smuggling of illegal goods, personnel, or WMDs in the supply chain (TANG, C. S. 2006). Supply chain risk management involves identifying and managing risk, and minimizing vulnerabilities by negotiation between supply chain members. Supply chain security management is broad in scope, and encompasses raw material vendors, semi-finished and finished product manufactures, exporters and shippers, freight forwarders, customs brokers, shipping and global logistics service providers, importers, and consignees, and these parties work in a complex environment. In order to narrow the scope of research, this study focuses on shipping service providers, including shipping companies, custom brokers, freight forwarders, and third party logistics firms.

According to Maritime Administration of the US Department of Transportation, tools that can be used to systematically identify risk include questionnaire surveys, review of corporate loss history, analysis of corporate financial reports and meeting records, checking of other corporate records and documents, construction of operational flowcharts, continuous facility examinations, and consulting from internal and external experts, etc.

Security interruptions have previously occurred at different places in supply chain procedures. For instance, supply chain vulnerabilities may occur at the commodity, supplier, supply chain partner, supply chain facility, cargo transporter, personnel, and information levels (HARLAND, C., BRENCHELY, R., WALKER, H. 2003). SCS therefore involves commodity security, shipping security, port security, and personnel security (SARATHY, R. 2006). Because they can be used to transport illegal immigrants, firearms and other weapons, smuggled goods, and especially WMDs, containers are usually considered the focal point of SCM. If a port was seriously damaged by the explosion of an atomic weapon, this might cause 100 billion dollars in port lock-out losses and 5.80 billion dollars in port recovery losses (ROSKE, L. B. 2006).

The role of a modern port goes far beyond that of merely providing services to ships and cargo. Apart from being the traditional interface between sea and land, ports are often the best locations for supplying value-added logistics services, and provide centralized locations for liaison and communication between trading network partners. Logistics and supply chains associated with port activities have the goal of ensuring optimal management of all supply chains, not for just in one individual environment.

Risk management reduces the negative effects of uncertain future losses by making those losses less likely, less severe, or more predictable, allowing more effective allocation of an organization’s scarce resources. Risk management has been defined as the process of making and carrying out decisions that will minimize the adverse effects on an organization of accidental losses.

While traditional risk management involves only pure risk, not business risk, risk management functions can be expanded to include management of liquidity risk, political risk, technological risk, catastrophe response planning, and security and fire safety risk. In particular, security and fire safety risk implies failure to protect facilities and personnel from acts perpetrated by criminals, terrorists, and disgruntled personnel (U.S. DEPARTMENT of TRANSPORTATION MARITIME ADMINISTRATION, 1998).

Enterprises adopt risk management for the purpose of protecting assets, profits, and business operations from exposure to risk in order to avoid damage to assets, reduction in profits, and interruption of business. Enterprises that have adopted risk management therefore periodically implement risk monitoring. Schmid et al. defined the main elements of risk management as risk identification, risk assessment, risk analysis, risk reduction, and risk monitoring (SCHMID, C., DART, P., JOHNATON, L., STERLING, L. and THORNE, P. 1999). Williams suggested that the process of risk management includes the aspects of risk identification, risk analysis, risk reduction, transfer, acceptance and risk monitoring (WILLIAMS. T. M. 1993). Norrman and Jansson state that the Ericsson Company's risk management procedures include risk identification, risk assessment, risk handing, and risk monitoring (NORRMAN, A., JANSSON, U. 2004). The purpose of risk management is to eliminate an enterprise’s risk exposure in an uncertain supply chain environment. Risk management strategies include those to remove, reduce, avoid, and transfer risks(Clark, RC, Pledge, M and Needler, HMJ. 1990).

The five risk management procedures consist of (SUNG, M, J. 2005):

1. Identifying and measuring loss exposure.
2. Identifying and examining alternative techniques for dealing with this exposure.
3. Selecting the most appropriate risk management alternatives consistent with the organization’s risk financing philosophy.
4. Implementing the selected alternatives.
5. Monitoring and improving the selected alternatives.

Risk Management can be broadly divided into risk identification, risk analysis and risk control (HO, M. W., HO, K. H. 2006).

A variety of techniques can be used to systematically identify losses; these include insurance company checklists, flow chart methods, analysis of past losses, review of financial statements, inspection, interviews with employees, and examination of trade journal articles concerning insurance. When gauging exposure to losses, all loss exposures can be considered to be composed of frequency and severity dimensions.

It should be noted that in reference to research on the impact of supply chain security on shipping service providers that this issue is still fresh, and relevant laws and regulations are still inadequate; as a consequence, most companies are not familiar with the real purpose of supply chain security (HARLAND, C., BRENCHELY, R., WALKER, H. 2003). Furthermore, it is difficult to collect a firm's internal financial statements and documents since these are likely to be confidential materials. Therefore, regarding to the impact of CSI on the shipping industry, we use three methods (including literature review, interviews with personnel, and a questionnaire survey) to identify risk assessment factors, judge risk level via a risk management matrix, and explore appropriate risk management alternatives.

2.2 Container Security Initiative

One-half of US import trade volume reaches American shores by marine transportation, and approximately nine million containers arrive at US ports annually. Under the CSI, the US customs authority signs bilateral reciprocal agreements with the customs authorities of major foreign ports; these agreements provide for the assignment of officers to pre-inspect US-bound containers at local ports. This model can prevent the transport of high-risk containers to the US, and thereby realizes the concept of "offshore prevention."

US port security procedures can be classified as national port and foreign port measures. With regard to foreign port measures, (1) outbound container manifests must be transmitted to the US customs authority within 24 hours, (2) the national standard inspection center performs cargo inspection tasks, and (3) in accordance with CSI MOU terms, US custom officers stationed overseas carry out inspection tasks. Established to prevent terrorist attack from occurring in the American homeland, the US Department of Homeland Security is second in size only to the Department of Defense. Since shipping containers may be used to transport nuclear weapons and explosives, shipping-related facilities must implement security risk management mechanisms; these mechanisms must (1) keep seaports and airports safe for travelers; (2) ensure the inspection and examination of luggage, cargo, and containers; (3) maintain safety procedures with sufficient assurance and efficiency; and (4) maintain economic operations while avoiding supply interruptions (HUTCHINS, G. 2003).

Port security measures require cooperation between private industry and public regulators with respect to development, financing, and implementation of various security plans and agreements (AMERCIAN ASSOCIATION OF PORT AUTHORITIES, 2004). The initial stage of CSI called for implementation at the world's twenty largest ports, and implementation has now been expanded to the world's sixty largest ports, including the ports of Kaohsiung and Keelung in Taiwan. The port of Kaohsiung signed a CSI MOU with the US on June 15, 2006.

In general, the impact of CSI management can be analyzed from a positive angle and from a negative angle. From a positive angle, MIT researchers verified that CSI management can enable firms to obtain considerable benefit, including a 29% reduction in transportation time, a 30% increase in cargo deliveries, 31% shorter problem resolution time, and a 14% reduction in stock over-capacity problems [1]. The FIATA (Fédération Internationale des Associations de Transitaires et Assimilés) web site also provides evidence supporting security precautions undertaken to minimize the threat of terrorism. Security measures should be standardized and established in close cooperation with the affected industry, however. Cui noted that after the US implemented CSI, the Korean government conducted a review of new CSI-related venture business models, and reached the following conclusions: (1) The CSI-related RFID market is projected to reach a size of 2-3 billion dollars in 2010. (2) Port security facility and access system interchange, cargo information analysis and tracking, education and training, and logistic security identification services can create 30 billion dollars in value-added effects. (3) Implementing and maintaining the current security system, and development and sale of container security equipment can create 3,500 employment opportunities (CUI, C. X. 2006).

From a negative impact angle, the Japan External Trade Organization (JETRO) found that the requirement that high-risk containers exported to the US must be inspected results in delayed cargo loading. Furthermore, in accordance with the 24-hour rule, when shipping companies request that shippers deliver cargo to a container yard 48 hours ahead of time, this adds to the shipper's cost burden due to the pressure of increased stock retention, and also forces the shipping company to ask the shipper to pay a surcharge for outbound manifest handling, which constitutes another cost burden for the shipper (JAPAN EXTERNAL TRADE ORGANIZATION, 2008).

FIATA has also leveled the criticism that CSI causes a great deal of inconvenience for freight forwarders, since: (1) although all transport industry forwarders encounter various security initiatives, the fact that these security transmission systems are not unified results in numerous problems. (2) As it is hard to determine whether current and future measures will actually prevent terrorist attacks, security measures should deal with concrete matters. (3) Current security measures require the disclosure of sensitive commercial confidential information (such as seller's name, buyer's name, commodity description, destination country, etc.); after the legal deadline has expired, private information service providers may sell the aforementioned information to any interested parties (OECD, 2004).

Liu notes that Japanese research on the impact of US 24-hour rule found that it extends lead time and increases transport cost. Extension of lead time implies that shippers must deliver cargo to a container terminal 48 hours ahead of time; this not only worsens inventory and interest burden, but also increases warehouse and transportation costs (LIU, L. B. 2007).

In addition, carriers must request shippers to pay additional costs of 25 dollars per one B/L. Barnes and Oloruntoba claimed that while it seems as if various security measures such as ISPS, CSI, and C-TPACT, etc. will diminish shipping terror activity at the cost of a small bit of performance, when conducted improperly, these measures may affect business operations and firms' ability to compete (BARNES, P., OLORUNTOBA, R. 2005). In effect, US implementation of the CSI requirement that export manifests be transmitted to the US customs authority at least 24 hours before shipment on board increases operating time and also poses the risk of disclosure of classified documents.

As the Korean government implements container inspection in accordance with CSI standards, other governments or industries encountering similar issues must reflect on the following considerations (CUI, C. X. 2007): (1) The US imposes stricter inspection standards on cargos from countries where security measures are not performed. (2) Shipping companies must face many costs entailed by compliance with US-imposed security standards. For example, since it costs approximately 30-50 dollars to inspect each container, inspecting 1.8 million TEU of containers shipped to the US annually on European ships will cost an estimated 90 million dollars. Furthermore, if annual container volume from Asia to the US reaches 13.70 million TEUs, inspection costs are expected to exceed 680 million dollars. (3) Security inspection costs 100-125 dollars per container, and cargo handling time is delayed by 1-3 days. (4) After July 2012, any import cargo to the US will be subject to 100% inspection; this will cause increasingly heavy operating and cost burdens for shippers, carriers, customs brokers and forwarders, and other relevant supply chain partners.

Taiwan's Ministry of Finance is responsible for CSI matters, including signing the CSI MOU with the US, formulating standard CSI operating procedures for Taiwan, and establishing inspection equipment and personnel in the port of Kaohsiung to cooperate with the American CSI team stationed in Kaohsiung. This investigated CSI performance in Taiwan by conducting personal interviews with several specialists involving in CSI tasks in Kaohsiung from June to September in 2009 (these personnel were affiliated with Yang Ming Line, Wan Hai Line, Evergreen, OOCL, APL, Han Jin, OOCL logistics, China International Freight, Pacific Star Express, and Yes Logistics). Some of their relevant comments are summarized below:

1. CSI and the 24-hour rule stipulate that manifests must be sent to the US customs authority 24 hours before shipment, and other countries, such as Canada and China also require shipping companies to follow the same rule; this therefore allows countries to impose higher trade barriers.
2. Customs brokers send shipping order documents by fax or e-mail to shipping companies, and shipping companies must then incorporate relevant information into export manifests for transmission to the US.

3. If shippers and customs brokers do not provide information concerning specific cargo and supply chain parties in compliance with US CSI requirements, they may receive a cargo release message from the customs authority but be unable to make a shipment immediately. This will not only cause loss of trading payments and business reputation, but also force the firms involved to bear responsibility for cargo shut-out expenses.
4. Shipping companies must invest in costly transmission system R&D in order to meet anti-terror requirements; these expenses ought to be shifted to the client.
5. The number of ant-terror security measures is increasing, and these constitute trade barriers by reducing the custom clearance rate and increasing logistic costs.
6. Due to rising inspection equipment purchase and maintenance costs, the customs authority has had to regularly increase its annual budgets.
7. The extension of the 24-hour rule to Canada and China has created additional document data-input responsibilities and cargo inspection costs for exporters and transporters.
8. Export cargo may be subject to double inspection under the C3 system (including export application document examination and container inspection by the Taiwan customs authority) and CSI system, which may hinder customs clearance efficiency and increase exporters' costs.
9. The target of CSI inspections is not limited to export and transshipment containers bound for the US; the fact that the scope of inspections has been extended to import containers in Taiwan forces importers to pay extra inspection and container haulage expenses.
10. International shipping companies must ask shippers, customs brokers, and freight forwarders to send shipping orders by fax or e-mail to their document departments, and must also request delivery of cargo to designated warehouses or container terminals. As a result, the lead time for Japan without the 24-hour rule is one day, but the lead time for America with the 24-rule is two days.

3. Research Methodology

3.1 Risk Management Matrix

This study measures risk level in terms of frequency and severity on five-point Likert scales. Sung suggests that risk level can be represented as the sum of the means for both risk frequency and severity, hence the sum of the means for frequency and severity can form a risk matrix chart (SUNG, M, J. 2005). Shang and Tseng classify risk categories including a low risk level (designated as 2-4), moderate risk level (designated as 5-7) and high risk level (designated as 8-10) (SHANG, K. C., TSENG, W. J. 2010).

The purpose of Risk Management Matrix is to determine the effects of security risks from CSI and the 24-hour rule on the shipping industry based on risk frequency and risk severity, and also discover the appropriate risk management alternatives to deal with security risk.

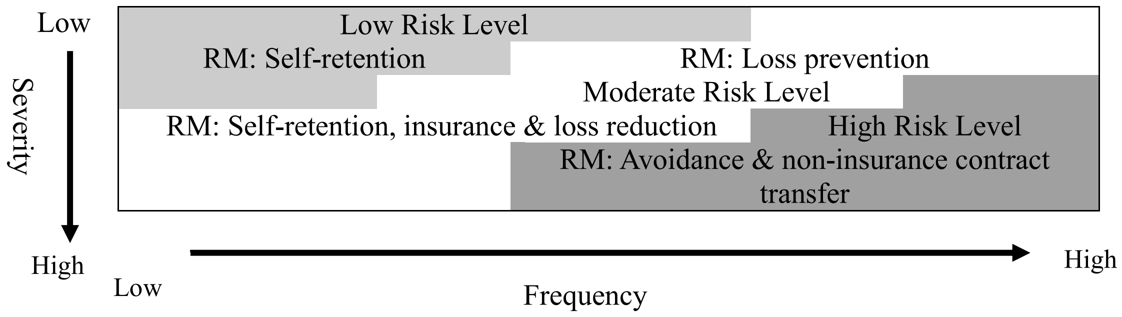

Figure 1: The Risk Management Matrix
Source: SUNG, M, J., (2005)

With regard to risk management alternatives, this paper adopts the US General Accounting Office’s line of thinking concerning the classification of risk management alternatives by risk exposure level: Self-retention can be used at a low risk level, risk retention and insurance transferal can be used for a moderate risk level, loss control can be used for a high risk level, and risk avoidance and non-insurance transferal can be used for an extremely high risk level (see Figure 1). ***Exposure Avoidance*** is the decision to eliminate a particular activity, operation, or asset because of high severity and high frequency loss factors. ***Loss control*** comprises loss prevention and loss reduction. ***Loss prevention*** seeks to decrease the probability of loss, as in the example of adopting an employee safety and health program. ***Loss reduction*** seeks to reduce the severity of losses after they have occurred; an example of loss reduction is the installation of automatic sprinklers to reduce losses after a fire has started. ***Contract transfer risk*** can be transferred to others by a non-insurance contract or by the purchase of insurance. ***Self-retention*** includes expensing of losses, an unfunded loss reserve, a funded loss reserve, borrowing to pay for losses, and using a captive insurer (U.S. DEPARTMENT of TRANSPORTATION MARITIME ADMINISTRATION, 1998), (SHANG, K. C., TSENG, W. J. 2010).

3.2 Assessment Factors

Assessment factors are divided into CSI and 24-hour rule dimensions; the majority of assessment factors were collected from past studies, including those performed by the OECD (OECD, 2004), Barnes and Oloruntoba (BARNES, P., OLORUNTOBA, R. 2005), Roske (ROSKE, L. B. 2006), Cui (CUI, C. X. 2006), (OECD, 2004), Liu (LIU, L. B. 2007), and the Japan External Trade Organization (JAPAN EXTERNAL TRADE ORGANIZATION. 2008). However, these studies make no mention of the impact of CSI and the 24-hour rule on the development of Taiwan's shipping industry, and few recent papers from Taiwan have discussed this issue. Furthermore, the general public is not familiar with CSI issues, and relatively few persons understand the real significance and actual functioning of CSI and the 24-hour rule. We relied on personal interviews to identify assessment factors associated with current situation in Taiwan's shipping industry caused by CSI and the 24-hour rule. For example, the current customs laws and regulations extending the scope of container inspection from export and transit cargo to import cargo have not been mentioned in previous studies or reports.

Moreover, in order to reduce the number of risk assessment factors, this paper conducted a pre-questionnaire test involving 20 individuals in charge of CSI tasks at shipping companies, forwarders, global logistics service providers, customs brokers, and the customs authority. The 15 key assessment factors ultimately identified comprise 7 CSI-related factors (A1-A7) and 8 24-hour rule-related factors (B1-B8) (see Table 1).

Table 1: Risk assessment factors connected with CSI and the 24-hour rule

Risk Assessment factor	Code	Source
CSI		
Shippers must bear responsibility for container inspection and haulage expenses.	A1	Personal interviews
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing injury to the shipper's reputation.	A2	Personal interviews
Cargo handling time may be prolonged to 1-3 days due to the need to perform security inspection of containers.	A3	Cui (CUI, C. X. 2006), (OECD. 2004)
Carriers must charge shippers an extra 25 dollars per B/L for additional CSI handling costs.	A4	Liu (LIU, L. B. 2007)
Export cargo may be subject to double inspection under the C3 system (including export application document examination and container inspection by the Taiwan customs authority) and CSI system, which may hinder customs clearance efficiency and increase exporters' costs.	A5	Personal Interview
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.	A6	Japan External Trade Organization (JAPAN EXTERNAL TRADE ORGANIZATION, 2008), Roske (ROSKE, L. B. 2006)

The scope of CSI inspections is not limited to exported and transshipped containers bound for the US; the fact that the scope of inspections has been extended to import containers in Taiwan forces importers to pay extra inspection and container haulage expenses.	A7	Personal Interview
24-hour rule		
Shippers have to bear the expense of cargo data transmission to the U.S. customs authority's AMS	B1	Liu (LIU, L. B. 2007)
Cargo data transmission to the carrier prior to 48 hours requires more lead time for inquiring about the name and address of the SCM service provider and performing document data key-in.	B2	Liu (LIU, L. B. 2007)
The fact that cargo must be delivered to the warehouse and container yard prior to 48 hours imposes a heavier stock volume and interest burden on shippers.	B3	Japan External Trade Organization (JAPAN EXTERNAL TRADE ORGANIZATION, 2008)
The shipping company may receive cargo prior to 48 hours to facilitate cargo delivery to the warehouse or container freight station within the stipulated time, which decreases the flexibility of manifest content revision by the cargo owner or shipper.	B4	Liu (LIU, L. B. 2007)
The lack of uniformity among security initiatives and security transmission systems hinders transmission operations.	B5	Barnes and Oloruntoba (BARNES, P., OLORUNTOBA, R. 2005), OECD (OECD, 2004)
Shipping companies' requests for export manifest processing surcharges increases the burden on cargo owners.	B6	Cui (CUI, C. X. 2006), (OECD, 2004)
The American 24-hour rule transmission mechanism has been imitated by such other countries as China and Canada, and is under consideration in Taiwan.	B7	Personal Interview
Confidential business documents (including name of buyer and seller, cargo description, destination, country, etc.) may be disclosed or sold to interested parties.	B8	Barnes and Oloruntoba (BARNES, P., OLORUNTOBA, R. 2005), OECD (OECD, 2004)

3.3 Questionnaire design

The questionnaire was composed of two sections. The first section attempted to determine the importance of security risks in terms of risk frequency and risk severity, and the risk frequency and risk severity scales were designed on the basis of the ideas of Tseng and Shang and from personal interviews with custom broker, freight forwarder, and third party logistics personnel. The questionnaire used five-point Likert scales to rate risk frequency and risk severity; with regard to risk frequency, 1 represented "once in more than 3 years," 3 represented "once is one year," and 5 represented "once in from 3 months to one half year"; with regard to risk severity, 1 represented "NTD 10,000 and under," 3 represented "NTD 50,000-100,000,"and 5 represented "NTD 500,000 and above" (see Table 2).

Another section of the questionnaire requested the respondent's demographic data, including type of business, job title, and working experience.

Table 2: Risk frequency and risk severity scales

Degree of Frequency		Scale	Degree of Severity	
Once in more than 3 years	Unlikely	1	Slightest	NTD 10,000 and under
Once in 1-3 years	Seldom	2	Slight	NTD 10,000-50,000
Once in one year	Passable	3	Passable	NTD 50,000-100,000

Once in one half year to one year	Occasional	4	Critical	NTD 100,000-500,000
Once in 3 month to one half year	Regular	5	More Critical	NTD 500,000 and above

Source: SHANG, K. C.,TSENG,W.J., (2010)

4. Empirical Analysis

4.1 Profile of questionnaire respondents

As shown in Table 3, a total of 100 questionnaires were issued to 15 shipping companies, 40 custom brokers, 30 freight forwarders and 15 shipping companies. All were domestic companies with offices in Kaohsiung. The majority of company names and addresses were obtained from local associations, such as shipping company and custom broker associations; other companies were obtained from name lists in shipping newspapers and magazines.

Questionnaires were mailed to specialists involved in CSI tasks and affiliated with shipping companies, custom brokers, freight forwarders, third party logistics firms, and shipping agencies in Kaohsiung; 65 questionnaires were returned, for a response rate of 65% (refer to table 3).

Among the respondents, 41.54% were affiliated with customs brokers, 29.23% with freight forwarders, and 15.38% with shipping agencies; 35.38% held a position of general manager or deputy general manager, 24.62% were staff members, and 23.08% were manager or deputy manager; in terms of working experience, 24% had 6-10 years of experience, 18.46% had 11-15 years, and 15.38% had 5 years or less. The respondents' titles, lines of business, and working experience suggest that their opinions are informed and representative. The fact that customs brokers and freight forwarders constituted high percentages of the respondents may imply that the results reflect objective opinions concerning the effect of CSI on the shipping industry (see Table 4).

Table 3: Survey response rate

Type of Business	Questionnaires sent	Questionnaires returned	Response Rate
Shipping Company	15	9	60%
Customs broker	40	27	68%
Freight forwarder	30	19	63%
Shipping Agency	15	10	67%
Total	100	65	65%

Source: Author's questionnaire profile (2010)

Table 4: Overview of respondent attributes

		Frequency	Percentage (%)
Type of Business	Shipping Company	9	13.85
	Customs broker	27	41.54
	Freight forwarder	19	29.23
	Shipping Agency	10	15.38
	Total	65	100
Job Title	General Manager or deputy general Manager	23	35.38
	Manager or deputy manager	15	23.08
	Director or deputy director	3	4.62
	Staff	16	24.62
	Sales representative	6	9.23
	Other	2	3.08

	Total	65	100
Working Experience	5 years or less	10	15.38
	6-10 years	15	23.08
	11-15 years	12	18.46
	16-20 years	9	13.85
	21-25 years	6	9.23
	26-30 years	7	10.77
	31 years and above	6	9.23
	Total	65	100

Source: Author's questionnaire profile (2010)

4.2 Basic statistical analysis

The perceived level of risk severity and frequency of assessment factors can be seen in Table 5. The top 3 factors in terms of risk severity are A6 (Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.), A2 (Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing injury to the shipper's reputation.) and B8 (Confidential business documents (including name of buyer and seller, cargo description, destination, country, etc.) may be disclosed or sold to interested parties.). When export cargo cannot be loaded on ship by the shipment date stipulated in contract, this will not only lead to a loss of business reputation, but also to serous financial loss, hence most of the survey respondents deemed these risk factors as the most importance impact factors with a high severity level.

The top 3 factors in terms of risk frequency are B5 (The lack of uniformity among security initiatives and security transmission systems hinders transmission operations.), B4 (The shipping company may receive cargo prior to 48 hours to facilitate cargo delivery to the warehouse or container freight station within the stipulated time, which decreases the flexibility of manifest content revision by the cargo owner or shipper.) and A6 (Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.). Because a majority of shippers and exporters are small or medium enterprises, new security system hardware and software installation and maintenance expenses are a heavy burden for these firms, and such systems must be modified or updated frequently.

Table 5: Perceived risk severity and frequency

Risk Assessment factors	Code	Severity			Frequency		
		Mean	S.D.	Rank	Mean	S.D.	Rank
CSI							
Shippers must bear responsibility for container inspection and haulage expenses.	A1	2.08	1.12	14	3.38	1.66	10
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing injury to the shipper's reputation.	A2	3.26	1.53	2	3.48	1.36	6
Cargo handling time may be prolonged to 1-3 days due to the need to perform security inspection of containers.	A3	2.15	1.11	13	3.28	1.39	13
Carriers must charge shippers an extra 25 dollars per B/L for additional CSI handling costs.	A4	2.03	1.24	15	3.34	1.45	11

Export cargo may be subject to double inspection under the C3 system (including export application document examination and container inspection by the Taiwan customs authority) and CSI system, which may hinder customs clearance efficiency and increase exporters' costs.	A5	2.31	1.31	9	3.42	1.50	8
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.	A6	3.57	1.48	1	3.55	1.21	3
The scope of CSI inspections is not limited to exported and transshipped containers bound for the US; the fact that the scope of inspections has been extended to import containers in Taiwan forces importers to pay extra inspection and container haulage expenses.	A7	2.55	1.39	7	3.40	1.47	9
24-hour rule							
Shippers have to bear the expense of cargo data transmission to the U.S. customs authority's AMS	B1	2.20	1.44	12	3.22	1.65	14
Cargo data transmission to the carrier prior to 48 hours requires more lead time for inquiring about the name and address of the SCM service provider and performing document data key-in.	B2	2.23	1.39	11	3.51	1.57	5
The fact that cargo must be delivered to the warehouse and container yard prior to 48 hours imposes a heavier stock volume and interest burden on shippers.	B3	2.69	1.22	4	3.52	1.38	4
The shipping company may receive cargo prior to 48 hours to facilitate cargo delivery to the warehouse or container freight station within the stipulated time, which decreases the flexibility of manifest content revision by the cargo owner or shipper.	B4	2.48	1.38	8	3.68	1.31	2
The lack of uniformity among security initiatives and security transmission systems hinders transmission operations.	B5	2.68	1.48	5	3.77	1.36	1
Shipping companies' requests for export manifest processing surcharges increases the burden on cargo owners.	B6	2.28	1.48	10	3.03	1.55	15
The American 24-hour rule transmission mechanism has been imitated by such other countries as China and Canada, and is under consideration in Taiwan.	B7	2.60	1.39	6	3.31	1.38	12
Confidential business documents (including name of buyer and seller, cargo description, destination, country, etc.) may be disclosed or sold to interested parties.	B8	2.75	1.41	3	3.43	1.24	7

Source: Author's questionnaire analysis result (2010)

4.3 Significant difference analysis

One-way analysis of Variance (ANOVA) was performed to examine the differences in the responses of the different groups. The results revealed that, for both risk severity and risk frequency factors, there were no significant differences in perception of risk assessment factors based on type of business among the demographic groups (which included shipping company, customs broker, freight forwarder and shipping agent). ANOVA analysis did not reveal any significant differences in perceived risk severity and frequency for different job title or working experience (see Table 6).

Table 6: ANOVA analysis of risk severity and frequency by type of business

Risk Assessment factors	Code	Severity			Frequency		
		Mean	F	Sig.	Mean	F	Sig.
CSI							
Shippers must bear responsibility for container inspection and haulage expenses.	A1	2.08	0.552	0.736	3.38	0.987	0.433
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing injury to the shipper's reputation.	A2	3.26	2.676	0.23	3.48	1.134	0.353
Cargo handling time may be prolonged to 1-3 days due to the need to perform security inspection of containers.	A3	2.15	1.278	0.285	3.28	1.029	0.409
Carriers must charge shippers an extra 25 dollars per B/L for additional CSI handling costs.	A4	2.03	0.505	0.771	3.34	1.268	0.290
Export cargo may be subject to double inspection under the C3 system (including export application document examination and container inspection by the Taiwan customs authority) and CSI system, which may hinder customs clearance efficiency and increase exporters' costs.	A5	2.31	1.202	0.320	3.42	2.023	0.089
Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.	A6	3.57	1.755	0.136	3.55	1.546	0.163
The scope of CSI inspections is not limited to exported and transshipped containers bound for the US; the fact that the scope of inspections has been extended to import containers in Taiwan forces importers to pay extra inspection and container haulage expenses.	A7	2.55	0.775	0.572	3.40	1.641	0.163
24-hour rule							
Shippers have to bear the expense of cargo data transmission to the U.S. customs authority's AMS	B1	2.20	2.578	0.036	3.22	3.347	0.10
Cargo data transmission to the carrier prior to 48 hours requires more lead time for inquiring about the name and address of the SCM service provider and performing	B2	2.23	1.087	0.377	3.51	1.324	0.267

document data key-in.							
The fact that cargo must be delivered to the warehouse and container yard prior to 48 hours imposes a heavier stock volume and interest burden on shippers.	B3	2.69	1.393	0.240	3.52	1.493	0.206
The shipping company may receive cargo prior to 48 hours to facilitate cargo delivery to the warehouse or container freight station within the stipulated time, which decreases the flexibility of manifest content revision by the cargo owner or shipper.	B4	2.48	0.650	0.663	3.68	1.057	0.394
The lack of uniformity among security initiatives and security transmission systems hinders transmission operations.	B5	2.68	1.903	0.107	3.77	1.158	0.340
Shipping companies' requests for export manifest processing surcharges increases the burden on cargo owners.	B6	2.28	1.158	0.341	3.03	1.228	0.307
The American 24-hour rule transmission mechanism has been imitated by such other countries as China and Canada, and is under consideration in Taiwan.	B7	2.60	0.967	0.445	3.31	1.234	0.305
Confidential business documents (including name of buyer and seller, cargo description, destination, country, etc.) may be disclosed or sold to interested parties.	B8	2.75	1.793	0.128	3.43	2.252	0.61

Source: Author’s questionnaire analysis result (2010)

4.4 Risk Management Matrix

According to the results of basic statistical analysis, the risk frequency and severity responses on the five-point Likert scale were classified as low risk level, moderate risk level and high risk level based on the mean values of risk frequency and risk severity. For example, A1 (Shippers must bear responsibility for container inspection and haulage expenses.) had mean severity and frequency values of 2.08 and 3.38, which were rounded to 2 and 3 respectively, indicating that A1 (S2.F3) was located on the moderate risk level of the risk management matrix.

A risk management matrix was used to analyze CSI risk levels for shipping in Taiwan. A majority of the risks constituted moderate-level risks, except for A6 (S4, F4), which was on the high-risk level, and could be mitigated via non-insurance contract transfer. The other moderate-risk level risk factors could handled via two kinds of risk management alternatives: loss prevention (A1, A3, A4, A5, B1, B2, B3, B4, B5 and B6) and self-retention, insurance, and loss reduction (A2, A7, B7 and B8) (see Figure 2 and Table 5).

Severity \ Frequency	**1 (F1)**	**2 (F2)**	**3 (F3)**	**4 (F4)**	**5 (F5)**
1 (S1)					
2 (S2)			A1, A3,A4,A5, B1,B6	B2,B4	
3 (S3)			A2,A7,B7,B8	B3,B5	

4 (S4)				A6	
5 (S5)					

Figure 2: Risk Management Matrix for the CSI
Source: Author's questionnaire analysis result (2010)

4.5 Risk Management Alternatives

As can be seen from Table 7, A6 (Cargo cannot be shipped on time and shut out by customs authority as the export application does not comply with CSI requirements, causing financial loss to the shipper.) is located on the high-risk level, and our recommended risk management alternatives is avoidance & non-insurance transfer, which means that the shipper can use business contracts or risk-pooling measures to share the risk with trading partners and thereby reduce finance losses. A1, A3, A4, A5 and B1-B6 are on the moderate-risk level, and are characterized by high frequency and low severity; they can be dealt with by means of the risk management alternative of loss prevention. For instance, in the case of A3 (Cargo handling time may be prolonged to 1-3 days due to the need to perform security inspection of containers.), it is recommended that shippers negotiate with the customs authority either directly or via the intermediary of a customs broker to reduce container inspection time. In the case of B2 (Cargo data transmission to the carrier prior to 48 hours requires more lead time for inquiring about the name and address of the SCM service provider and performing document data key-in.), it is recommended that, to avoid erroneous data key-in, a company can establish the double-checking system to reduce discrepancies and enhance staff job training to improve compliance with standard operating procedures.

A2, A7, B7 and B8 are on the moderate-risk level, and are characterized by high frequency and low severity; they can be dealt with via the proposed risk management alternatives of self-retention, insurance, and loss reduction. For instance, in the case of A2 (Cargo cannot be shipped on time, and is shut out by the customs authority as the export application does not comply with CSI requirements, causing injury to the shipper's reputation.), our suggestion is that shippers can use export liability insurance to cover serious reputation damage caused by CSI. In the case of B7 (The American 24-hour rule transmission mechanism has been imitated by such other countries as China and Canada, and is under consideration in Taiwan.), it is recommended that since the 24-hour rule has been introduced by other countries, export-driven countries should abide by this legal mandate as a cost of doing business.

Table 7: Risk Management Alternatives for CSI and the 24 hrs Rule Risk

Risk Factors	Risk Level	Risk Management
A6	High Risk	Avoidance & Non-Insurance Transfer
A1	Moderate	Loss Prevention
A3	Moderate	Loss Prevention
A4	Moderate	Loss Prevention
A5	Moderate	Loss Prevention
B1	Moderate	Loss Prevention
B2	Moderate	Loss Prevention
B3	Moderate	Loss Prevention
B4	Moderate	Loss Prevention
B5	Moderate	Loss Prevention
B6	Moderate	Loss Prevention
A2	Moderate	Self-Retention, Insurance, Loss Reduction
A7	Moderate	Self-Retention, Insurance, Loss Reduction
B7	Moderate	Self-Retention, Insurance, Loss Reduction
B8	Moderate	Self-Retention, Insurance, Loss Reduction

Source: Author's questionnaire analysis result (2010)

Panayides suggests that the indicators of maritime logistics include management of demand and supply to avoid surplus and shortfalls, the full utilization of resources, minimization of losses in transportation, cost reduction in transportation and storage, and meeting customer needs to fulfill and improve customer service and communication (OECD. 2004), (PANAYIDES, P.M.. 2006). Is the effect of the American CSI and the 24-hour rule on maritime logistics positive or negative? The findings of this paper concerning CSI risks reaching to the moderate level suggest that the shipping industry should pay attention to CSI and the 24-hour rule, and other new security measures, and set up risk management mechanisms or a special organization to deal with the most complicated problems. For instance, in the case of LCL (less than container load), one consolidated container may contain cargo from several shippers; if one shipper cannot provide detailed documents allowing the shipping company to produce a manifest, existing regulations forbid loading of such a container. This situation may damage an exporter's business reputation and cause financial losses.

Furthermore, the fact that the transmission mechanism imposed by the American 24-hour rule has been imitated by such other countries as China and Canada, and is under consideration in Taiwan, will lead to new trade barriers in importing countries, and will also force shippers and shipping companies to spend much time on document preparation and pay higher transmission expenses. However, export-driven companies are merely following mandatory regulation in order to do business.

After the introduction of CSI in Taiwan, the cost of container inspection and haulage expenses has been borne by carriers and shippers. The scope of CSI inspection in Taiwan is not limited to export and transshipment containers bound for the US, but also includes import containers, which are inspected for anti-smuggling purposes. However, we doubt whether it is really necessary for consignees to bear container inspection charges and haulage charges. Taiwan's customs authority should modify current security laws and regulations from the perspective of international trade and logistics facilitation.

5. Conclusions

The objective of the paper is to identify CSI risk assessment factors in the shipping industry and provide risk management alternatives for the shipping industry and concerned government agencies. After empirical examination employing a risk management matrix, this paper found that the majority of security risks connected with CSI and the 24-hour rules belong to the moderate-risk category, and appropriate risk management measures constitute loss prevention in the case of high frequency and low severity risks, and self-retention, insurance, and loss reduction in the case of low frequency and high severity risks. However, in the case of A6, which is characterized by high frequency and high severity risk, this paper proposes that an optimal alternative is avoidance & non-insurance transfer.

The findings of this study can be summarized as following:
Firstly, the paper supports the argument of Johnston that national lawmakers should adopt a more equitable balance between an efficient deregulated environment and a regulated environment meeting security requirements. Hence, to keep the balance between the efficiency of maritime logistics and supply chain security is of vital importance to trading countries dealing with security risk issues; security risk problems cannot be entirely resolved by cargo inspection and document examination geared to preventing terrorist attack.

Secondly, although there have been no terrorist attacks on seaport or airport infrastructure or facilities in Taiwan, the government of Taiwan is establishing new anti-terror regulations in line with the dictates of the US, WCO, and IMO. But since these regulations pose a more serious threat to the social order and traditional industry in Taiwan than the smuggling of illegal weapons, products, and drugs, current anti-terror laws and regulations, particularly those intended to combat smuggling, should be amended in light of the domestic operating environment.

Thirdly, in order to reduce the incidence of erroneous input in export manifests, shipping companies, forwarders, customs brokers, and global logistics service providers should design an auto matching system that can double-check data input and determine whether discrepancies exist. In addition, when sending information to the US customs authority, small- and moderate-sized forwarders and customs brokers formerly took advantage of the carrier system to transmit data, but transmission has become very expensive for these small and medium-sized companies. If appropriate transmission software can be designed by the government, and a free version issued to relevant firms, this would greatly assist ordinary users.

Fourthly, confidential business documents (including name of buyer and seller, cargo description, destination, country, etc.) may disclosed to the public or sold to interested parties concerned after the statutory period has expired. Because the disclosure of confidentiality business documents may seriously harm companies' interests, shippers recommend that the U.S government maintain the principle of confidentiality in formal communication channels with Taiwan custom offices and administrative organizations.

Fifthly, The lack of uniformity among security initiatives and security transmission systems hinders transmission operations. Hardware and software associated with various security initiatives is expensive; shippers can rely on large and medium-size shipping companies or forwarder to send data, resolving the problem of different security transmission system standards.

Finally, although CSI has various disadvantages for the government of Taiwan, which must bear the burden of maintaining security, it can also be considered a coin with two sides, and offers some opportunities to the shipping industry. The government should consider encouraging private firms to design and market relevant security hardware and software, which could generate new security business models and create security-related employment opportunities.

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Environmental Accounting – Disclosures of Environmental Liability and the Shipping Sector

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Abstract

In traditional financial statements reporting, environmental costs and benefits were typically ignored. About 30 year ago, some accounting scholars started to advocate the approach of social accounting, and they pointed out that a business entity should not focus on reporting financial performance only, a good set of accounting statements should report on an entity‟s environmentally sensitive actions on sustainability.

The Earth Summit (2002) established the *Global Reporting Initiative* to guide the accounting profession in reporting the environmental impact of the operations of business entities.

The aim of this conference paper is to investigate the development of accounting for environmental accountability, with particular reference to the shipping sector.

Keywords: Disclosure obligations, environmental liability, SEC, shipping, SOP 96-1

1. Introduction

Ships at sea can cause serious environmental damage in their day-to-day operations. Ships may:

- *burn fuel and illegally discharge used oil and/or bilge water,*
- *wash out tank vessels containing unpackaged chemicals, producing polluted rinse water, and*
- *generate domestic garbage from their crews.*

Most maritime economists acknowledge that GDP is a defective indicator of welfare. A ship accident or an oil spill can increase GDP but obviously decreases total welfare.[1] Consider China, where as international trades rise, ships are being built and put to the ocean each year, along with an associated increase in the tonnage of carbon dioxide. Are average Chinese citizens demanding higher environmental quality as they get richer? Probably. But environmental quality is not a goods on sale on the shelves of the shopping malls.

The primary function of economic policy is to recognize when the market fails to provide the right allocation of goods. China is attempting to provide for sound economic measurement of environmental quality. It is producing an experimental GDP figure that accounts for environmental damage and resource depletion.

Environmental goods are only deliverable if policy makers can be informed by sound measurement through environmental audits and disclosures. The aim of this conference paper is to investigate the development of accounting for environmental accountability, with particular reference to the shipping sector. The first section deals with the relationship between media attention and voluntary environmental disclosure. The second section discusses the environmental audit in Europe. The final section describes the environmental liabilities disclosures in the US.

[1] Mchugh, A. (2005) "Measure our welfare", The Australian Financial Review (15 August), p.22.

2. Media Attention and Voluntary Environmental Disclosure

In traditional financial statements reporting, environmental costs and benefits were typically ignored. About 30 year ago, some accounting scholars started to advocate the approach of social accounting, and they pointed out that a business entity should not focus on reporting financial performance only, a good set of accounting statements should report on an entity‟s environmentally sensitive actions on sustainability. In this section, the authors investigate what are the motivation factors for firms engaging in voluntary environmental disclosures.

A defining characteristic of corporate responsibility in the 21st century will be the need to communicate effectively with stakeholders on progress towards not only economic prosperity; but also social justice and environmental quality.[2] Researchers found from the recent history of corporate social and environmental reporting (CSER) that there exists a positive correlation between the number of disclosing social and environmental activities and better economic performance.[3]

Legitimacy theory researchers reasoned that non-disclosures of environmental liabilities would attract negative media attention, and negative media coverage hurts financial performances. Research was conducted to examining the role media coverage plays in increasing the public policy pressures faced by companies.[4] For example, Liu & Taylor (2008)[5] applied the media agenda-setting theory to study its relation with the disclosure of remuneration packages of a firm‟s directors and top executives. The researchers found that the more media attention during a year received by a firm relating to directors‟ and executives‟ remuneration; the greater was the additional (non-mandatory) disclosure of this information in the firm‟s annual report.

After the *Exxon Valdez* oil spill, Patten (1992)[6] uses legitimacy theory to explain the effect of the oil spill on an increase in annual report disclosures by petroleum firms other than Exxon. Many prior studies on corporate disclosures have provided evidence that firms do voluntarily disclose information in their annual reports as a strategy to manage their legitimacy.[7]

For international efforts in promoting non-legal required environmental disclosures, the Global Reporting Initiative (GRI) produces one of the world's most prevalent standards for sustainability reporting. Sustainability reporting is a form of value reporting where an organization publicly communicates their economic, environmental, and social performance. GRI seeks to make sustainability reporting by all organizations as routine as financial reporting.

The Earth Summit (2002) established the *Global Reporting Initiative* to guide the accounting profession in reporting the environmental impact of the operations of business entities. GRI Guidelines are regarded to be widely used. As of January 2009, more than 1,500 organizations from 60 countries use the Guidelines to produce their sustainability reports.[8]

3. Environmental Audit in Europe

International convention sets the standard of good behavior, but it does not acquire legal force unless being enacted into domestic law, but it exerts a stronger binding effect, at least psychologically than voluntary

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[2] Wheeler; D. and J. Elkington (2001) "The End of the Corporate Environmental Report? Or the Advent of Cybernetic Sustainability Reporting and Communication"; *Business Strategy and the Environment*; Vol. 10; No. 1; pp.1-14.
[3] Kolk, A. (2003) "Trends in Sustainability Reporting by the Fortune Global 250"; *Business Strategy and the Environment*; Vol. 12; No. 5; pp. 279-291.
[4] Brown, N. and Deegan, C. (1998) "The Public Disclosure of Environmental Performance Information - A Dual Test of Media Agenda Setting Theory and Legitimacy Theory"; *Accounting and Business Research;* Vol. 29; No. 1; pp. 21-41.
[5] Liu, J., and D.W. Taylor (2008) "Legitimacy and Corporate Governance Determinants of Executives' Remuneration Disclosures"; *Corporate Governance: an International Review*; Vol. 8; May (forthcoming)
[6] Patten, D.M. (1992) "Intra-industry Environmental Disclosures in Response to the Alaskan Oil Spill: a Note on Legitimacy Theory"; *Accounting; Organizations and Society;* Vol. 17; No. 5; pp. 471-475.
[7] Patten, D.M. (1991) "Exposure; Legitimacy; and Social Disclosure"; *Journal of Accounting and Public Policy;* Vol. 10; No. 4; pp. 297-308.
[8] http://www.globalreporting.org/AboutGRI/WhatWeDo/

disclosures. This section devotes to cross-national audit based on an international convention.

In 2000, the audit institutions of Cyprus, Greece, Italy, Malta, the Netherlands, Turkey, and the UK started a coordinated audit of marine pollution from ships based on the Marpol Convention.[9] Many auditors with international experience recognize the difficulty in conducting such audit, especially in reaching clarity on the meaning of audit concepts and criteria.[10]

The 2006 joint report on the coordinated audit[11] has two parts: The first part outlines an ideal situation: a country called "Maretopia" that has adopted many good measures to prevent marine pollution and environmental damage from ships. To describe such an ideal state, the report drew on good practices found in one or more of the national audits.

In the second part, the report presents findings from the national audits. In some cases, the report points to similarities in the national findings. In others, the report cites observations worth mentioning because of their nature or relevance for other countries. The report summarizes how countries took action to prevent pollution by:

(1) carrying out ship inspections and waste collection in ports
(2) dealing with offenders and preparing for incidents.

One of the report‟s purposes was to encourage countries to emulate good practices in learning from others‟ mistakes. To ensure the comparability of audit findings, an audit scheme of four main audit elements was established. From the beginning, the group agreed to audit the following:

(1) surveys and inspections of ships
(2) waste collection in ports
(3) dealing with offenders
(4) preparing for incidents.

4. Environmental Liabilities Disclosures in the US

National laws, such as court cases, regulations, and accounting standards, provides the strongest binding force in enforcing a standard of behavior. This section investigates the US laws relate to environmental liabilities disclosures.

The US has become more concern about environmental liabilities disclosures since 1990s. After the *Levine* case,[12] both the US Securities and Exchange Commission (SEC) and the Association of Certified Public Accountants (AICPA) issued policy documents in such area.[13] It is thus important for shipping companies involve US trades to understand the SEC's position on disclosure obligations of environmental liability.

[9] Knaap, P (2010) "Lessons from the Coordinated Audit on Marine Pollution from Ships" *International Journal of Government Auditing* (January), pp. 16 – 19.

[10] The 2007 INTOSAI/Working Group on Environmental Auditing (WGEA) paper titled *Cooperation Between SAIs: Tips and Examples for Cooperative Audits*. This paper was based primarily on experiences with cooperative environmental audits and is available on the WGEA Web site at *www.environmental-auditing.org* (under WGEA Publications). All of the paper‟s 22 tips apply to the Marpol audit.

[11] Netherlands Court of Audit, *Marine pollution from ships—Joint report based on national audits 2000 –2003*, The Hague, October 18, 2006 (http://www.courtofaudit.com/english/News/Audits/Introductions/2006/10/Marine_pollution_from_ships).

[12] *Levine v. NL Industries, Inc*. 717 F. Supp. 252 (S.D.N.Y. 1989), aff'd, 926 F.2d 199 (2d Cir. 1991).

[13] For example, the SEC issued Staff Accounting Bulletin No. 92 ("SAB 92") in 1993, which provides guidance to disclosure obligations relating to contingent environmental liability. See GAO-04-808, Environmental Disclosure: SEC Should Explore Ways to Improve Thinking and Transparency of Information, July 2004, at http://www.gao.gov/new.items/do4808.pdf in which the US Government Accountability Office reported that the SEC "is taking steps to increase the tracking and transparency of key environmental information." In 1996, the Association of Certified Public Accountants (AICPA) issued its Statement of Position (SOP 96-1) which provides even more guidance with respect to accounting for environmental liabilities.

In 1982, the SEC introduced Regulation S-K as part of its integrated disclosure rules. In addition to the general Rule 10b-5 requirement of full and fair disclosure, Regulation S-K contains two express rules concerning environmental reporting obligations: Item 101, paragraph (c)(i)(xii), requiring disclosure of the material effects of compliance with environmental laws; and Item 103, Instruction 5, requiring disclosure of pending environmental litigation when such litigation:

(1) is material

(2) involves a potential monetary loss exceeding ten percent of the corporation's assets, or

(3) is brought by the government seeking a monetary sanction that is likely to exceed $100,000.

Legal researchers observed that the SEC has stepped up its monitoring of environmental liability disclosure requirements since the 90s,[14] particularly in connection with corporations designated as "potentially responsible parties" ("PRPs") under the Comprehensive Environmental Response Compensation and Liability Act of 1980 ("CERCLA").[15] This enhanced enforcement was partially in response to a Wall Street Journal article that reported that certain SEC staffers had merely taken note of the failure of numerous corporations to disclose contingent CERCLA liabilities and criticized the lack of an imminent SEC crack down.[16]

5. *Levine* Case

In *Levine*, a holding company failed to disclose the non-compliance with environmental laws of its subsidiary in its Annual Report, the shareholders filed an action against the holding company. A uranium processing facility owned by the Department of Energy and operated by the subsidiary of the holding company. The shareholders argued that the holding company should disclose in its Form 10-K about violations of emissions standards at its uranium processing facility. The facility accounted for no more than 0.2% of the holding company's annual gross income. The operating contract required the Department of Energy to indemnify the holding company for liability related to environmental law violations.

The court dismissed the claim. The court determined that the holding company was not obligated to disclose the particular violations occurred at the uranium processing facility in Form 10-K for the following reasons:

1. *The Department of Energy was ultimately responsible for environmental liabilities*
2. *Since the facility accounted for no more than 0.2% of the holding company's annual gross income, the costs of compliance with environmental laws could not have impacted the holding company's capital expenditures, earnings, or competitive position.*
3. *The holding company was not aware of any legal proceedings contemplated with respect to the environmental violations, and thus the information could not be disclosed as a pending legal proceeding.*

On appeal, although the Second Circuit affirmed the lower court's dismissal,[17] the Second Circuit cautioned that the Form 10-K would require the disclosure about the cost of non-compliance with environmental regulations. In other words, the holding company would have had a duty to disclose the costs related to environmental violations of its subsidiary in its Form 10-K if:

1. *such costs had been material, and*
2. *the Department of Energy does not indemnity the liabilities of environmental law violation.*

6. SAB 92

About two years after the *Levine* decision, the SEC published SAB 92 in 1992, which answers a series of specific questions pertaining to accounting and disclosure obligations of the contingent environmental

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[14] Geltman, E. (1992) Disclosure of Contingent Environmental Liabilities by Public Companies under the Federal Securities Laws,16 Harv. Envtl. L. Rev. 129, 130-131.

[15] 42 U.S.C. §§ 9601-9675 (1988).

[16] See Amal K. Naj, See No Evil: Can $100 Billion Have "No Material Effect" On Balance Sheets? Huge Toxic-Waste Cleanup Will Burden Many Firms; S.E.C. Questions Disclosure: Death Between the Weeds, WALL ST. J., May 11, 1988, at 1.

[17] *Levine v. NL Indus., Inc.*, 926 F.2d 199 (2d Cir. 1991).

liabilities. SAB 92 only application to public US companies. SAB deals with the following issues relating to contingent environmental liabilities:

> *(1) Whether it is appropriate to offset in the balance sheet about a likely claim for recovery against a probable contingent liability, and report the net amount in the balance sheet. The interpretive response: ―not ordinarily" appropriate. SAB 92 stated that in order to present potential consequences of the contingent claim fairly, there should be separate presentation of gross liability and of related claim for recovery in the balance sheet.*
>
> *(2) For a situation where the reporting company is jointly and severally liable as a potentially responsible party, but there is a reasonable basis for apportionment of costs from the other parties. The issue is: whether the reporting company must recognize a liability with respect to costs apportioned to the other responsible parties. The interpretive response is no; however, if it is probable that the other parties will not fully pay costs apportioned to them, the reporting company should include a best estimate on the amount expects to pay.*
>
> *(3) SAB 92 states that if the amount of the obligation and the time are reliably determinable for a specific site, then the reporting entity may discount an environmental liability to reflect the time value of money. The notes to the financial statements should provide in detail the basis and amount of discounting.*
>
> *(4) SAB 92 provides that liabilities for site restoration or related exit costs that may occur on the sale or abandonment of a property should be disclosed in the notes to the financial statements. Such disclosures should generally include the nature of the costs involved, the total anticipated cost, the total costs accrued to date, and the range and amount of reasonably possible additional losses. In addition, the reporting company should disclose liability for remediation of environmental damage to a previously disposed of asset.*
>
> *(5) SAB 92 specifies that where a reporting company expects to incur site restoration costs, post-closure and monitoring costs, or other environmental exit costs at the end of the useful life of an asset, these costs can be accrued over the useful life of the asset. The accrual of the liability would be recognized as an expense.*

7. SOP 96-1 and SOP 03-2

The accounting profession has been relatively slow in addressing the challenges of environmental issues from an external perspective. Two recent statement of positions, SOP 96-1 "Environmental Remediation Liabilities"[18] and SOP 03-2 "Attest Engagements on Greenhouse Gas Emissions Information," address environmental issues for public companies. The following table provides a listing of the accounting and auditing authoritative guidance for companies facing environmental dilemmas:

Summary of Authoritative Accounting and Auditing Guidance for Environmental Issues
FAS 5: Accounting for Contingencies
FASB Interpretation 14: Reasonable Estimation of the Amount of a Loss - An Interpretation of FAS 5
FASB Interpretation 39 - Offsetting of Amounts Related to Certain Contracts
APB Opinion 20 - Accounting for Changes
AICPA SOP 94-6: Disclosure of Certain Significant Risks and Uncertainties
EITF 90-8: Capitalization of Costs to Treat Environmental Contamination
EITF 89-13: Accounting for the Cost of Asbestos Removal
SEC Staff Accounting Bulletin 92: Accounting and Disclosures Relating to Loss Contingencies

[18] Accounting Standards Executive Comm., Am. Inst. of Certified Pub. Accountants, Statement of Position 96-1: Environmental Remediation Liabilities (1996) [hereinafter SOP 96-1].

GASB Statement 18: Accounting for Municipal Solid Waste Landfill Closure and Postclosure Care Costs

In an effort to clarify the standards for disclosing environmental liabilities, the AICPA issued its Statement of Position (SOP) 96-1, which provides guidance on accounting issues related to the measurement and disclosure of environmental remediation liabilities.[19] This SOP96-1 provides professional accountants with much needed guidance on dealing with several aspects of environmental law that was not provided in the authoritative guidance listed in the above table.

SOP 96-1 applies to fiscal years beginning after December 15, 1996, and applies to all companies that prepare financial statements in accordance with generally accepted accounting principles.

The SOP identifies certain stages of a remediation effort as benchmarks that should be considered when determining that an environmental liability is probable, reasonably estimable, and therefore should be disclosed.[20]

In addition, SOP 96-1 requires that the entity also include in the estimate the incremental direct costs of the remediation effort.[21]

Overall, SOP 96-1 provides perhaps the most comprehensive coverage of the disclosure of environmental remediation liabilities arising under CERCLA. It does, however, have its limitations. One limitation is that it does not apply to accounting for the costs associated with the voluntary cleanup of contaminated sites.[22]

SOP 96-1 by its express terms also does not apply to situations where the government is seeking not only remedial costs but also natural resource damages,[23] nor does it apply to the frequently encountered litigation situation where hazardous substance contamination has resulted in a toxic tort action.

Another shortcoming is that SOP 96-1 also does not provide guidance on the accounting treatment associated with the costs incurred to comply with applicable environmental laws or the substantial attorneys' fees that arise in an effort to recoup costs through a contribution action that were above and beyond one's fair share of contaminated site costs. [FN255][24]

A final shortcoming is that the SOP 96-1standard fails to address climate change risk in any fashion.

Despite these limitations, SOP 96-1 is a very useful tool. It provides guidance in determining from an accounting and disclosure perspective how to treat environmental remedial costs that can arise as a result of CERCLA liability. One of the most helpful aspects of SOP 96-1 is a case study that is provided in Appendix B, where the concepts of the statement are applied to various events a PRP routinely encounters in the life cycle of a hypothetical Superfund site.[25]

SOP 03-2, "Attest Engagements on Greenhouse Gas Emissions Information," was issued on September 22, 2003. It was issued in response to the concerns of greenhouse gases existing in the atmosphere. Because of the

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[19] For a comprehensive account of the events leading up to this Statement of Position, see Howard B. Epstein and Aaldert Ten Veen, Position Statement Clarifies Liability Disclosures, *The National Law Journal* (Mar. 17, 1997) at B18.

[20] The scope of SOP 96-1 is limited to environmental remediation liabilities resulting from a threat of litigation, a claim, or an assessment.

[21] These incremental direct costs would include: the cost of completing the remedial investigation/ feasibility study; fees of law firms for work related to determining the extent of required remedial actions; fees of engineering and consulting firms for site investigations and developments of remedial action plans; and the costs of post-remediation monitoring required by the remedial action plan.

[22] SOP 96-1 does not apply to the voluntary cleanup of contaminated property, nor does it apply to remedial activities that may arise as a result of the cessation of facility operations. SOP 96-1, at 48-49.

[23] Id.

[24] SOP 96-1, at 33.

[25] SOP 96-1, at 90-95.

Kyoto Protocol, a voluntary agreement signed by companies to reduce the effects of greenhouse gases, some US companies with foreign operations may have to meet emission targets set forth in the Kyoto Protocol. SOP 03-2 also provides example of letters and reports that can be used by professional auditors in providing attest engagements concerning greenhouse gas emissions.

8. FIN 47

The latest pronouncement from the accounting profession through FASB that has implications for the financial treatment of environmental liabilities is FASB Interpretation Number 47 (FIN 47), which became effective December 31, 2005.[26]

FIN 47 arose out of a need for more consistent financial accounting treatment of liabilities associated with the sale or shut down of tangible assets such as ports or shipyards.

Examples of the need to account for such liabilities provided in FIN 47 include the hypothetical situation that the owner of an old shipyard that contains asbestos, the owner must account for the liabilities associated with the future need to remove and properly dispose of the asbestos in the event demolition. Thus, FIN 47 has broad environmental liability disclosure implications for potential future events.

9. Environmental Disclosures after Sarbanes-Oxley Act (S-O Act)

Although the S-O Act does not expressly change any of the environmental disclosure requirements, it did lead to greater scrutiny on quantifying and certifying environmental liabilities.[27] In particular Section 404 of the S-O Act requires CEOs and CFOs to make a number of certifications, including that internal controls are designed so that material information relating to the company is made known to them, that they have evaluated these controls within 90 days prior to filing, and that all significant weaknesses in the controls have been disclosed to the auditors and the audit committees.[28] In addition, the S-O Act requires that outside auditors review these certifications about the adequacy of controls.[29] Therefore, reporting companies must carefully consider how they can quantify environmental liabilities, disclose those liabilities and set up the appropriate controls to assure that estimates are properly and timely evaluated and updated.[30]

10. Conclusion

As our planet becomes increasingly aware of the importance of environmental issues, so too must companies understand their social responsibilities with respect to the environment. And as the SEC intensifies its scrutiny on disclosure regarding environmental liabilities, the companies must familiar their disclosure obligations under the SEC law.

Acknowledgements

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[26] Fair Value Measurements, Statement of Fin. Accounting Standards No. 157, §5 (Fin. Accounting Standards Bd. 2006); Accounting for Conditional Asset Retirement Obligations, FASB Interpretation No. 47, at FIN47-2 (Fin. Accounting Standards Bd. 2005) [hereinafter FIN 47].
[27] McKenna, Long & Aldridge LLP, After Sarbanes-Oxley: Environmental Cost Estimations, Disclosures, and Controls, Environmental Advisory (March 31, 2005), at http://www.boardmember.com/network/mckenna_env0305.pdf.
[28] Id.
[29] Id.
[30] See Id.

Inspection Policy of a Port State Control Authority

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Abstract

A port State control authority (PSCA) undertakes inspections to enforce that ships visiting its ports meet the required standards. By doing so, the PSCA wants to reduce the frequency of shipping accidents and to minimize expected social loss in its territorial water. Due to resources constraints, port States control authorities realize it impractical to inspect all the ships. The general approach taken by them is to set overall inspection rates to ensure that a certain number of ships are inspected, and use targeting factors to focus resources on those ships most likely to be substandard. In this paper, we use a Stackelberg game to model a PSCA's problem of setting an overall inspection rate. Then, based on mechanism design theory, we propose an inspection scheme which can help the PSCA to differentiate between good and substandard ships. Our results can help port States control authorities to design inspection policies at their waters under various circumstances.

1. Introduction

Detrimental environmental and social impacts caused by shipping accidents threaten the interest of port States. Examples of accidents are easy to recollect; the grounding of the *Exxon Valdez*, the capsize of the *Herald of Free Enterprise*, and the *Estonia* passenger ferry are some of the most widely publicized accidents in maritime transportation. Inspection of ship safety is an administrative measure to reduce the occurrence of shipping accidents (Viladrich-Grau, 2003; Li and Zheng, 2007). So port States control authorities, under the guide of the Port State Control (PSC) programmes, conduct port inspections to prevent shipping accidents from occurring in their waters.

Port State authorities recognise that inspecting all ships would be both impractical due to the resources constraints, and unnecessary since not all ships are substandard. The general approach taken by regional port States control authorities is to set overall inspection rates, and to use targeting factors to focus on those ships most likely to be substandard. In this paper, we first investigate how to set an optimal overall inspection rate for a port State control authority. Then, based on a mechanism design model, we show that the port State authority can use an inspection scheme to let a shipowner truthfully reveal the information about his ship's status. In the scheme, the shipowner is required to select an inspection rate according to its own status. The scheme, if appropriately designed, can ensure that the substandard ship would select a higher inspection rate, and a well-run ship would select a lower inspection rate. This mechanism, together with the targeting factors method, can help authorities to focus inspection resources on those substandard ships. Thus, those shipowners of substandard ships would like to make enough efforts to meet the requirements of the authorities.

The paper proceeds as follows. In Section 2, we first briefly summarizes the history of port inspection policies during the development of the PSC programmes, and then review the literature. In section 3, we use a Stackelberg game to obtain an overall inspection rate for a port State control authority. In section 4 we use a mechanism design model to design an inspection scheme under which a shipowner would truthfully reveal his ship's status. Section 5 concludes this paper.

2. Literature Review

Before the 1980s, decisions concerning port inspections were not regarded as a potential means of making shipping safer. Originally, there were no conventions to guarantee the enforcement of the PSC programmes, which refers to a state's jurisdiction over ships in its ports. Traditionally, a ship is legally regarded as a floating island of the flag State's territory and hence the ship must be subject to the exclusive jurisdiction of its flag State. `Flag State' refers to the state whose flag a ship flies and whose nationality a ship bears. Flag State jurisdiction was be restricted by the enforcement of the PSC programmes and hence legal conflict could arise between them. It took a long time to deal with such issues and to determine the content of port State jurisdiction. The final text of the provisions on "Enforcement by Port States" was completed and included in Art.218 of the United Nations Convention on the Law of the Sea 1982 (UNCLOS 1982).

Although the concept of port state control is quite new, there is a flourishing development of the PSC programmes. Based on the provisions of UNCLOS 1982, regional PSC organizations appeared, such as the Paris MOU based on the Paris Memorandum of Understanding on Port State Control 1982, and the Tokyo MOU based on the Memorandum of Understanding on Port State Control in the Asia-Pacific Region 1993. These organizations conduct port inspections and determine the target inspection rates in different regions. For example, the target inspection rate of the Paris MOU is 25%. The target annual inspection rate of the Tokyo MOU is 75%, increasing from the original target of 50% since it was achieved in 1996. To maintain the effect of port inspections, it is therefore common in port States to further increase the frequency of port inspections and hence to force the shipowners to increase effort levels to keep their ships at higher safe levels.

Li and Cullinane (2003) analyse the various methods by which shipowners might reduce their maritime liability risk, and derive a conceptual approach to the application of cost-benefit analysis in maritime safety regulation. They advocate the adoption of the approach as a means of ensuring that safety regulation sets optimum targets such that the level of compliance yields maximum economic benefit.

Ships that visit a port are assigned targeting factors according to a scoring system designed by the port. The Paris MOU, for example, assigns an overall targeting factor to ships, whereas United States Coast Guard has developed a boarding priority matrix for the purpose of calculating a targeting factor. Li (1999) and Xu et al. (2007) attempt to improve these scoring systems, and help port States control authorities identify risky ships. Other attempts focus on the introduction of new technical or management measures. An optimal monitoring technique by combining the satellite information was investigated by Florens and Foucher (1999). Gawande and Bohara (2005) analysed an optimal contract which mixes penalties based on the amount of pollution ex post with penalties based on the extent of noncompliance ex ante. An integrated inspection support system was investigated by Hamada, Fujimoto and Shintaku (2002).

3. Setting the Overall Port Inspection Rate

In this section, we study the problem of a port State control authority that sets an overall port inspection rate. We first formulate this problem, and then solve the problem.

3.1. Introduction and the formulation of the game

We consider a port State control authority and ships calling at the port. Let $\theta, \theta \in [a,b]$, denote the status of a ship in terms of its likelihood to pass the inspection. Note that the likelihood depends on factors such as owner/operator, flag, history, ship type and age, maintenance, etc. A ship of smaller θ is more likely to be substandard. Those ships are differentiated only by θ, which we refer to as a ship's type. The port authority and the shipowners share common beliefs regarding the probability distribution of types, $G(\theta)$; with $G(\theta) = g(\theta)d\theta$. The leader in the game is the PSCA, and the followers are shipowners. The sequence of events is as follows: the port State control authority selects its inspection rate first, then a shipowner decides his effort level to pass the inspection under the given inspection rate. For expositional convenience, we assume that one ship has a shipowner and each shipowner is an independent decision unit. When no confusion is caused, we interchangeably use a ship and a shipowner.

When a ship is inspected, a cost is incurred, which includes penalty cost due to delay of delivery, extra salaries paid to seafarers, operational expenses during the inspection period, fine imposed by the port State authority, loss of future business for not passing inspection, etc. Let r denote the inspection rate, e_θ denote type θ shipowner's effort level, $M_\theta(e_\theta)$ denote the expected accident cost for the ship given an effort level e_θ, and $Q_\theta(e_\theta,r)$ denote the expected cost caused by inspection, $\theta\in[a,b]$. For a given inspection rate r, the θ type shipowner's cost function $F_\theta(e_\theta,r)$ can be expressed as

$$M_\theta(e_\theta)+Q_\theta(e_\theta,r)+e_\theta$$

The shipowner would choose an effort level to minimize $F_\theta(e_\theta,r)$. Let $e_\theta^*(r)$ denote type θ shipowner's optimal effort level when the inspection rate is r, $\theta\in[a,b]$.

The objective of a port State authority is to minimize expected social loss. Let $D_\theta(e_\theta)$ denote the expected damage and recovery cost caused by the type θ ship when the shipowner's effort level is e_θ, $\theta\in[a,b]$. Let $C_\theta(r)$ denote the expected social loss when inspection level is r and the ship's type is e_θ, $\theta\in[a,b]$. The social loss includes cost of resources used for inspection, operational costs, the opportunity cost of the ship, etc. When the inspection rate is r, type θ shipowner would choose an effort level $e_\theta(r)$, and the port State authority's objective function can be expressed as

$$D_\theta(e_\theta(r))+C_\theta(r)\cdot$$

For type θ ship, the port State authority's problem can be formulated as

$$\min_r D_\theta(e_\theta(r))+C_\theta(r)$$
subjet to
$$e_\theta^*(r)=\arg\min_{e_\theta} F_\theta(e_\theta,r).$$

Let r_θ^* denote the optimal inspection rate for type θ ship, $\theta\in[a,b]$. Then the overall inspection rate for the PSCA is

$$\int_a^b r_\theta^* dG(\theta). \qquad (1)$$

3.2. Solving the Game

3.2.1. Assumptions

We assumes that type θ ship's accident cost $M_\theta(e_\theta)$ is an decreasing function in the shipowner's effort level e_θ, thus $dM_\theta/de_\theta<0$. Further, we assume that the effort level e_θ follows the law of diminishing returns, which means that with increasing effort level, the effect to lower accidents cost decreases. Thus, we have $d^2M_\theta/de_\theta^2>0$.

We assume that given an effort level e_θ, $Q_\theta(e_\theta,r)$, the cost caused by inspection, increases with inspection level r, since higher inspection level usually results in a longer inspection time, higher probability of detention, more extra salaries paid to seafarers, higher operational expenses, etc. For a given inspection level r, we assume that $Q_\theta(e_\theta,r)$ decreases with effort level e_θ, and follows the law of diminishing returns.

Therefore, we have $\partial Q_\theta(e_\theta, r)/\partial e_\theta < 0$ and $\partial^2 Q_\theta(e_\theta, r)/\partial e_\theta^2 > 0$.

The damage and recovery cost, the main concern of the port State control authority, is the social loss caused by shipping accidents. Since a shipowner's effort level can affect the frequency of shipping accidents, the expected damage and recovery cost decreases in the shipowner's effort. Further, we assume that the law of diminishing returns holds for a shipowner's effort level. Let $D_\theta(e_\theta)$ denote the damage and recovery cost resulted from type θ ship when the shipowner's effort level is e_θ, then we have $dD_\theta(e_\theta)/de_\theta < 0$ and $d^2 D_\theta(e_\theta)/de_\theta^2 > 0$.

The inspection cost of the PSCA include salaries paid to inspectors, purchasing cost of inspection devices, operational costs, etc. We assume that the cost function $C(r)$ is an increasing function of inspection level r. And we assume that $d^2 C(r)/dr^2 < 0$.

3.2.2. Solving the Game

A shipowner observes the port State authority's inspection rate before choosing his effort level. Given an inspection level, type θ shipowner would choose an effort level to minimize his cost function, and the shipowner's problem can be described as

$$\min_{e_\theta} F_\theta(e_\theta, r) = \min_{e_\theta} [M_\theta(e_\theta) + Q_\theta(e_\theta, r) + e_\theta] \quad (2)$$

In the following proposition, we show that there exists an optimal effort level for the type θ shipowner.

Proposition 1. *Suppose that $M_\theta(e_\theta)$ and $Q_\theta(e_\theta, r)$ satisfies the assumptions in Section 3.2.1, then there exists one and only one optimal effort level for type θ shipowner's problem given by (2).*

Proof. According to the assumptions in Section 3.2.1, we can show that $F_\theta(e_\theta, r)$ is concave. Therefore, there exists one and only one optimal effort level for the shipowner of type θ.

Let $e_\theta^*(r)$ denote the optimal effort level of the type θ shipowner when the PSCA's inspection level is r. Thus, type θ shipowner's optimal response function is $e_\theta^*(r)$.

The objective of the port State control authority is to minimize the social loss, and her problem can be describes as

$$\min_{r_\theta} D_\theta(e_\theta(r_\theta)) + C(r_\theta)$$

Since the PSCA can expect that type θ shipowner will choose his optimal effort level $e_\theta^*(r)$, the port State authority's objective function can be simplified to

$$\min_{r_\theta} D_\theta(e_\theta^*(r_\theta)) + C(r_\theta)$$

The port State authority's problem can be described as

$$\min_{r_\theta} D_\theta(e_\theta^*(r_\theta)) + C(r_\theta)$$

subjet to

$$e_\theta^*(r_\theta) = \arg\min_{e_\theta} F_\theta(e_\theta, r) \cdot$$

The port State control authority can set the optimal inspection rate r_θ^* for the ship of type θ by solving the above problem. To set an overall inspection rate, the PSCA can take the expectation of r_θ^* as given in (1).

4. An Inspection Scheme Based on Mechanism Design Theory

In last section, we obtain the optimal inspection rate r_θ^* that a port State authority should set for type θ ship, $\theta \in [a,b]$. If a ship of type θ is inspected at rate r_θ^*, the social welfare is maximized. Since r_θ^* decreases with θ, a substandard ship is inspected more frequently and a well-run ship is inspected less frequently. By doing so, the resources of the port States authorities can be focused more efficiently on ships most likely to be substandard. To differentiate between good and substandard ships, port States authorities consider weighting ship inspection rate according to the target factor assigned to the ships. They select some criteria such as the ship's flag, age and type, history, which are believed to directly influence how well a ship is likely to be operated, and allocate points to each criterion. Thus, a ship can be assigned a targeting factor according to a scoring system. The Paris MOU, for example, assigns an overall targeting factor to ships, whereas the US Coast Guard (USCG) has developed a boarding priority matrix for the purpose of calculating a targeting factor.

Although a ship's target factor is useful for a PSCA to estimate the ship's likelihood of being substandard, the PSCA does not know exactly if the ship is substandard or not because some privately owned information is still not known to the PSCA. For example, two ships with the same target factor may have different likelihoods to be substandard if the two shipowners make different efforts on maintenance. In this section, we first propose an inspection scheme based on mechanism design theory. Then we simplify the scheme to make it easier to implement. Finally, we propose a procedure to integrate a scoring system with the inspection policy derived from the mechanism model.

Mechanism design is a principal-agent model, and can be used to encourage the agent to reveal his privately owned information. Let the PSCA be the principal and a ship be the agent. The types of the agent is distributed on $[a,b]$, and the port authority and the shipowners share common beliefs regarding the probability distribution of types, $G(\theta)$; with $dG(\theta) = g(\theta)d\theta$. For a ship of type θ, the shipowner's cost is $F_\theta(e_\theta, r)$ when his effort is e and the inspection rate is r. The social loss, which the port authority want to minimize, is $D_\theta(e) + C_\theta(r)$. For an inspection rate r, the authority can evaluate a shipowner's effort which minimizes his total cost, and estimate the social loss. Of all the possible inspection rates, the authority would select an inspection rate which minimize the social loss.

If the PSCA knows the exact type of the ship, the port State authority's problem is a typical Stackelberg game, and has been solved in Section 3. The PSCA's optimal inspection rate for type θ ship is r_θ^*, and type θ shipowner make effort of $e_\theta^*(r)$. In this case, social welfare optimality is achieved, and good (substandard) ships are imposed a low (high) inspection rate. Unfortunately, the PSCA does not know for sure if a ship is in good status or not. In this section, we use a mechanism design model to formulate this problem.

According to mechanism design theory, the PSCA, for the benefit of social welfare, can set an inspection rate for each type of ship, i.e., $r(\theta)$. The inspection rate for a substandard ship is high and the one for a good ship is low. Each shipowner is expected to choose an inspection rate of his type. However, a shipowner has an incentive to choose a low inspection rate to save time and cost. To force the shipowner to truthfully reveal his ship's status, the PSCA impose an appropriate penalty on ships denoted by $t(\theta)$, $\theta \in [a,b]$. Let the mechanism be $\{r(\theta), t(\theta)\}, \theta \in [a,b]$, and $p(\theta, e)$ be the detention probability of the ship of type θ when the effort is e. Then the mechanism design problem can be formulated as

$$\min_{\{r(\theta),t(\theta)\}} \int_a^b [D_\theta(e_\theta^*(r)) + C_\theta(r)]dG(\theta)$$

subjet to

$$\arg\min_e [F_\theta(e, r(\theta)) + t(\theta)r(\theta)p(\theta,e)] \le \arg\min_e [F_\theta(e, r(\theta')) + t(\theta')r(\theta')p(\theta,e)], \theta' \in [a,b] \quad (3)$$

where (3) are the incentive compatibility constraints. In (3), $t(\theta)r(\theta)p(\theta,e)$ is the expected penalty cost, and $\arg\min_e[F_\theta(e,r(\theta))+t(\theta)r(\theta)p(\theta,e)]$ is type θ ship's total cost when the inspection rate is $r(\theta)$. $\arg\min_e[F_\theta(e,r(\theta'))+t(\theta')r(\theta')p(\theta,e)]$ is type θ ship's total cost when the inspection rate chosen by the shipowner is for another type θ'. These constraints ensure that the shipowner of type θ would choose the inspection rate designed for his type, that is, the shipowner would truthfully reveal his type. Note that in this problem, no participation constraint is imposed because a shipowner is forced to participate.

A closed-form solution of the above problem is complicated. We only discuss some intuitive insights. To save time and cost, shipowners would like to choose a low inspection rate. To make the owner of a substandard ship to choose a high inspection rate, the port authority can set penalty $t(\theta)$ increasing with θ such that, the penalty on a substandard ship for detention is much higher than the savings from choose a low inspection rate designed for a good ship. In this case, a shipowner would not report a substandard ship as a good one, because the savings in choosing a lower inspection rate may be lower than extra penalty cost he has to pay in case of not passing the inspection.

The inspection scheme represented by $\{r(\theta),t(\theta)\}$, $\theta\in[a,b]$ is difficult to implement because of high transaction cost incurred due to too many possible inspection rates. We propose an inspection scheme which is much easier to implement. In the scheme, a PSCA sets two different inspection rates, denoted as r_L and r_H and the respective penalties denoted by t_L and t_H. A shipowner chooses r_L (r_H), and pays penalty t_L (t_H) if his ship does not pass the inspection.

If we assume that the ship types has a monotonicity property, then there exists a critical point $\bar{\theta}$ such that a type of θ, $\theta\in[a,\bar{\theta}]$, would choose r_H and a type in $[\bar{\theta},b]$ would choose r_L. In other words, types distributed on $[a,b]$ are divided into two parts, a type of θ, $\theta\in[a,\bar{\theta}]$ chooses a lower inspection rate, and a type of the other segment chooses a higher inspection rate. If we assume that the ship types has a continuity property, then the type of $\bar{\theta}$ would be indifferent to choosing r_L or r_H. For simplicity and easier implementation, t_L can be normalized to be 0.

Thus we have

$$\min_e F_{\bar{\theta}}(e,r_L)=\min_e F_{\bar{\theta}}(e,r_H)+r_H t_H p(\theta,e^*(\theta)).$$

Therefore, the PSCA's problem is

$$\min_{(r_L,r_H,t_L)}\int_a^{\bar{\theta}}[D_\theta(e_\theta^*(r_H))+C_\theta(r_H)]dG(\theta)+\int_{\bar{\theta}}^b[D_\theta(e_\theta^*(r_L))+C_\theta(r_L)]dG(\theta)$$

subjet to

$$\min_e F_{\bar{\theta}}(e,r_L)+r_L t_L p(\theta,e^*(\theta))=\min_e F_{\bar{\theta}}(e,r_H).$$

The numerical solution of the above problem is not difficult to obtain, although the closed-form solution is complicated. Next, we propose a procedure to set an inspection policy for a port State control authority.

First, we can use the method in Section 3 to obtain an overall inspection rate r_0 for a port State authority. Then, the PSCA can design an inspection rate r_H for ships more likely to be substandard, an inspection rate r_L for ships more likely to be good. Each ship can choose an inspection rate itself and the penalty t_L for detention is imposed on the ship when r_L is chosen. Note that $r_L<r_0<r_H$, which means inspection rate for ships likely to be substandard (good) is higher (lower) than the overall inspection rate. Finally, the PSCA can use a scoring system to assign a target factor for each ship, and adjust inspection rate for some ships when necessary. For example, if a ship is likely to be substandard according to a scoring system, but chooses a low inspection rate, then the PSCA may inspect the ship with a higher rate.

Compared to a scoring system, the inspection scheme represented by (r_L, r_H, t_L) has two advantages. First, in the case when two ships have the same score, it is possible that one is likely to be substandard for reasons such as poor maintenance and the other is likely to be good for reasons such as good maintenance. Then the scoring system cannot differentiate between the two ships, while the inspection scheme (r_L, r_H, t_L) might be able to do so. Second, under the scheme (r_L, r_H, t_L), ships reveal their information themselves, which saves the cost to collect and maintain information for scoring a ship.

5. Discussion and Conclusion

In this paper, we first use a Stackelberg game to study the overall inspection rate which should be appropriate for a port State authority, and we show the processes to obtain the optimal inspection level for the PSCA. Our results can help the port State authority to set the overall inspection rate for calling ships. Then we apply mechanism design theory to design an inspection scheme which imposes a higher inspection rate on ships more likely to be substandard. This scheme can improve the ability of port States control authorities to select ships more likely to be substandard. Moreover, the inspection scheme can be integrated with scoring systems used by port States authorities currently.

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The Effect of Shipowners' Effort in Vessels Accident: A Bayesian Network Approach

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Abstract

This paper presents an innovative approach to integrate logistic regression and Bayesian Network together into risk assessment. The approach has been developed and applied to a case study in the maritime industry, but it can also be utilized in other sectors. Applications of the use of Bayesian networks as a modeling tool in maritime applications have recently been demonstrated widely. A common criticism of the Bayesian approach is that it requires too much information in the form of prior probabilities. And that this information is often difficult, if not impossible, to obtain in risk assessment (Yang et al., 2008). Traditional and the most common way to estimate the prior probability of accidents is by expert estimation. There are some typical problems associated with using the subjective probability, provided by expert, as a measure of uncertainty in risk analysis.

In this research, a binary logistic regression method is used to provide input for a BN, making use of different resources of data in maritime accidents.

Keywords: Bayesian Network, Marine Accident, Logistic Regressin, Risk assessment

1. Introduction

The concept of risk assessment and management are becoming more and more widely used in hazardous industries. Numerous researches have been done on this area (Kristiansen, 2005). Risk is commonly defined as a measure of the probability of a hazard related incident occurring, and the severity of harm or damage that could result (Manuele, 2003). So risk assessment is widely recognized as a systematic and science-based process for describing risk (Vose, 1996). The main targets of are usually in preventing occupational accidents or disasters. In order to be able to focus on high-risk areas, both the absolute risk level and the relative importance of different causes have to be quantified, which is one of the challengers safety managers face when trying to understand the complex safety systems, particularly in the case of rare events (Szwed, 2006). Once this risk information has been quantified, manager and decision makers can use it to focus on the risk control options, develop appropriate policies and allocate resource that will mitigate risk.

However, rare event risk information inherently suffers from a sparseness of accident data. So the expert judgment is often used to develop frequency data for the risk analysis (Moslesh et al., 1988; Morgan and Henrion, 1991). Nevertheless, expert judgment must be used with care (Anderson et al., 1999). Kahneman et al. (1982) discuss the numerous biases and heuristics that are introduced when humans process information and attempt to provide judgments.

Logistic regression has proven to be a powerful modeling tool for predicting the probability of occurrence of an accident, by fitting data to a logit function. And Bayesian network (BN) is a method that has been developed to improve the understanding of the effects of different causes on the risk [Netjasov and Janic, 2008]. In order to construct a BN, it is necessary to specify the relationships among variables and their conditional probability distributions. In this research, an innovative approach to integrate logistic regression and Bayesian Network together into risk assessment was presented. All the conditional probabilities and prior probabilities of the nodes of the BN are obtained through the application of a binary logistic regression.

A case study about the maritime risk assessment has been carried out using the integrate of the logistic regression and the BN. Shipping has always been characterized as a relatively risky business (Li and Wonham, 1999). Even with the development of modern ship building technology and the innovative navigation equipment, shipping accidents are still a major concern. The courses for shipping accidents are various and complex. Using BNs, marine accidents can be analyzed to identify the most important causes and to determine the relationships among these causes. The logistic regression method and a database collected data from different sources were used to provide the prior probabilities for the BN' s nodes.

The remainder of this paper is organized as follows. The following section reviews the recent relevant literature. Section 3 presents the methodology of integrate logistic regression and Bayesian Network together into risk assessment. A case study of the maritime risk analysis is used to illustrate the application of the proposed model in Section 4, followed by the conclusion in Section 5.

2. Literature review

BN has been increasingly recognized as a powerful tool to support causal inference. Using a BN, the most important causes of an accident can be identified and, most of all, the relationship among these causes can be determined. The distinct features of a BN were summarized by Ren et al. (2008) as:

Its ability to conduct inference inversely.
Its ability to incorporate new observations in the network.
Its inherent causal and probabilistic semantics which can be used to handle missing or incomplete data.
It has both a causal and probabilistic semantics.

Because of these advantages, BNs have been applied in many areas including risk assessment of building structures under fire (Gulvanessian, et al., 2001), manufacturing industry (Jones et al., 2009), workplace accidents (Martin, ea al., 2009) and business risk (Zhu and Deshmukh, 2003). In the maritime safety area, Eleye-Datubo et al. (2006) used BN to examine a typical ship evacuation in an accidental risk scenario. Trucco et al. (2008) developed a Bayesian Belief Network to model the maritime transport system by integrating human and organizational factors into risk analysis. The conditional probabilities for the BN have been estimated by means of expert judgment. Ren et al. (2008) assessed the offshore safety by combining Reason"s "Swiss Cheese" model and BN. The prior probabilities were obtained by the domain experts" judgments. It has been found that BN modeling heavily relying on expert' s personal experiences may be error prone. Eleye-Datubo et al. (2008) examined the transfer of oil to an oil tanker. A BN model was created to examine system safety. In the research, given a certain event happening, it was possible to investigate other factors either influencing or influenced by the event in the overall risk analysis.

In spite of BN remarkable power and advantage, there are some inherent limitations. A common criticism of the Bayesian approach is that it requires too much data in the form of prior probabilities, and that such data is often difficult, if not impossible, to obtain in risk assessment (Yang et al., 2008). The size of the conditional probability table (CPT) quickly becomes quite large when more child nodes are added, leading to complexity and difficulty in computation (Eleye-Datubo et al., 2006).

Traditional and the most common way to estimate the probability of accidents is to contemplate accident frequency, which is regarded as the first type of studies that addressed safety level (Soares and Teixeira, 2001). However, the scarcity of accident statistics makes for limitations. Firstly, statistics describe the relationship between characteristics, and an accident doesn' t describe the degree of influence of the frequency determining factors. Secondly, specific criteria, assumptions and factors examined were applied in most statistical analyses, and these may not be easily compared with other sources (Romer, et al., 1995). In addition, statistics describe only the past, which may not be useful in predicting the occurrence of a future accident (Gaarder et al, 1997). Historical performance of a safety system can often be measured readily, whereas prediction of future performance is typically difficult, especially as the facts show that maritime accidents are typically very rare events (Chang and Yeh, 2004; Hockaday and Chatziioanou, 1986).

In practice, expert estimation is another common way in risk analyses with little or no relevant historical data. However, there are some typical problems associated with using the subjective probability, provided by expert, as a measure of uncertainty in risk analysis. Firstly, experts are failure to consider all possibilities with respect to human error affecting technological systems (Slovic, et al., 1979). Secondly, experts are easy affect by operational experience (Skjong and Wentworth, 2001). Kahneman et al. (1982) discuss the numerous biases and heuristics that are introduced when humans process information and attempt to provide judgments.

Logistic regression has proven to be a powerful modeling tool for predicting the probability of occurrence of an accident, by fitting data to a logit function. In recent years logistic regression has been suggested as an appropriate analytical technique to use for the multivariate modeling of categorical dependent variables (Uncles, 1987). There is some research in the maritime domain that has used a logistic regression model. Bergantino and Marlow (1998) used a logistic regression model to analyze the decision making process of vessel owners when adopting flags of registration. Jin et al. (2002, 2005) developed a fishing vessel accident probability model for fishing areas off the northeastern United States, using logistic regression along with their database.

Given this background of BNs, the main aim of this paper is to investigate the effects of various risk factors and determine the relationships among them with the application of a binary logistic regression method to the collected data. The research methodology is developed in the following section.

3. Research methodology

A BN is a probabilistic graphical model that represents a set of random variables and their conditional independencies in a directed acyclic graph (DAG). The DAG consists of a set of nodes representing variables and edges representing the probabilistic causal dependence among the variables.

The causal dependence between variables is expressed by the structure of nodes, which gives the qualitative part of causal reasoning in a BN. The relationship between variables and the corresponding states are given in a CPT attached to each node, which constructs the quantitative part.

3.1. Establish nodes with dependencies

In order to construct a BN, the first step is to specify the graphical representation of the nodes (i.e. the structure). The structure may be defined using prior information, by means of an estimate made from the data or a combination of the two. The nodes with edges directed into them are called “child” nodes and the nodes with edges departing from them are called “parent” nodes.

An influence diagram (ID) is a BN augmented with decision and utility nodes. ID is used for modeling decision processes and for computing utilities of available strategies. For making the best possible decisions, the utilities were associated with the state of ID. These utilities are represented by utility nodes. Each utility node has a utility function. Once the decisions are made, the probabilities of the configurations of the network are fixed. The expected utility of each decision can be computed. Based on the maximum expected utility principle, the highest expected utility can be chosen.

3.2. Create CPT and prior probabilities for each node

Having established the influencing nodes together with the dependencies, a CPT can be developed for each node or event. Theoretically, the CPT may be formulated using historical data, expert judgments or a combination of the two.

In this research, a binary logistic regression method is used to provide the conditional probability (P) of a ship involved in a casualty. The binary logistic regression model provides the necessary coefficient (β) in order to compute the estimated probability of casualty given a certain combination of conditions (dependent variables X).

In a binary regression, a latent variable y_i^* is mapped onto a binominal variable y_i, where $y_i^* \in (-\infty,+\infty)$. While y_i^* is unobservable, y_i is observable:

$$y_i = 1 \quad \text{accident}, \quad \textit{if} \quad y_i^* > 0,$$

$$y_i = 0 \quad \text{no accident}, \quad \textit{if} \quad y_i^* \leq 0.$$

Consider a random m-dimensional variable $X = (X_1, \cdots X_m)$. Each variable may be discrete having a finite or countable number of states, or continuous.

Defining the latent variable as a function of X

$$y_i^* = \sum \beta_i X + \mu_i \tag{1}$$

where β represents a column vector of unknown parameters (the coefficients) describing the magnitude of the contribution of each risk factor. u represents a (unobservable) stochastic component.

This now gives:

$$E(y_i|X) = P(y_i = 1|X) = P(y_i^* > 0|X) = P(\mu_i > -\beta_i X) = 1 - F(-\beta_i X) \tag{2}$$

Function F can take different forms and for this study the logistic cumulative distribution function for F is chosen. The general model can therefore be written in the form

$$p_i = \frac{e^{\sum \beta_i X}}{1 + e^{\sum \beta_i X}} \tag{3}$$

Given a subset X of variables x_i, if one can observe the state of every variable in X, the conditional probability can be calculated using Equation 3.

3.3. Generate posterior probabilities

A BN can be used to estimate how probabilities of each node are affected by both prior and posterior knowledge. Once the structure and parameters have been determined from the available data, the Bayesian network is ready to draw inferences. Using the following three equations the probabilities of interest can be calculated.

The joint probability

$$P(Y = y_j, X = x_i) = P(X = x_i) \times P(Y = y_j|X = x_i) \tag{4}$$

The marginalization rule

$$P(Y = y_j) = \sum_i^m P(X = x_i) \times P(Y = y_j|X = x_i) \tag{5}$$

The Bayesian rule

$$P(X = x_i|Y = y_i) = \frac{P(X=x_i) \times P(Y=y_j|X=x_i)}{P(Y=y_j)} \tag{6}$$

3.4. Validation of the constructed model

Validation is an important aspect of this methodology as it will provide a reasonable amount of confidence to the results produced. In this study a sensitivity analysis for validation of the model has been developed, the following two axioms must therefore be satisfied:

Axiom 1. A slight increase/decrease in the prior subjective probabilities of each parent node should certainly result in the effect of a relative increase/decrease of the posterior probabilities of the child node.

Axiom 2. The total influence magnitudes of the combination of the probability variations from x attributes (evidence) on the values should be always greater than the one from the set of x-y ($y \in x$) attributes (sub-evidence).

4. Marine safety case study

In this section, a case study is presented to demonstrate the above methodology for conducting marine safety assessment.

4.1. Establish nodes with dependencies

As indicated above, the first step is to establish the nodes with relevant dependencies. Judging from the previous research and analysis of casualty data, the nodes that have been established to indicate influencing factors to the marine accident include vessel age, size and the efforts of flag states and classification societies and shipowners.

As aforementioned, vessel age, size, flag, classification society and vessel type have been identified as the major contributory factors to ship accidents. Although there are some other influencing factors, a careful analysis of historical accident data indicated that their effects on the probability of accident are completely trivial.

The proposed framework, including all the factors which may contribute to the accident, is illustrated in Figure 1.

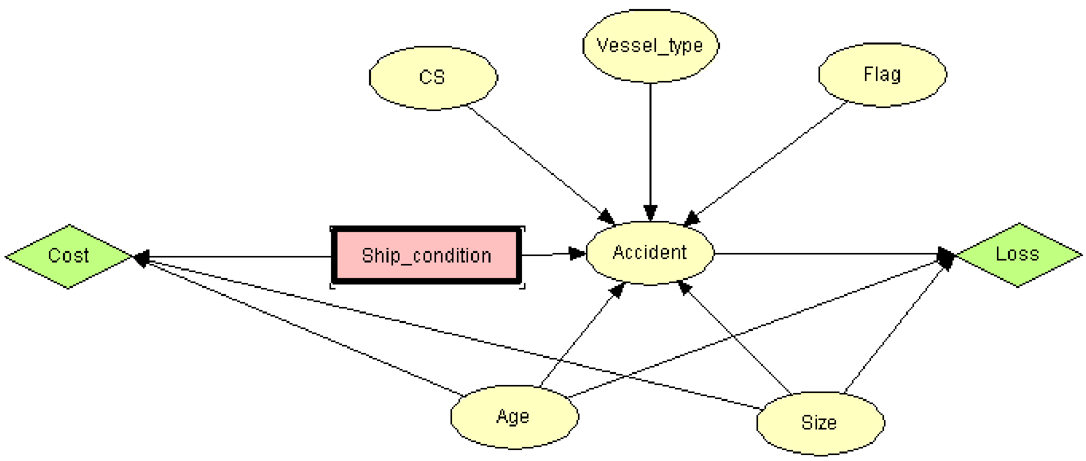

Figure 1. The BN model of shipping accidents

The BN consists of three types of nodes. The first type is the chance node. Classification society (CS), vessel type, vessel flag (Flag), age and size do not have any parents, because there are no arrows pointing towards them. The node of Accident is child node. The links between the nodes represent causal relationships between the nodes. An arrow means that the parent‟s node has an impact on the state of the child node. The rectangle represents a decision node (shipowner effort), making a standard effort or a substandard effort. The arrow between the decision node and the accident node means that the decision has an impact on the occurrence probability of accident.

Utility node (Cost), the third type node, is associates with the state of the decision node. The utility node has a utility function enabling us to compute the expected utility of a decision. The node of cost represents the cost associated with the shipowner‟s effort; meanwhile it depends on the states of age and size. Another utility node, Loss, gathers information about the loss once the accident happens. Similarly, the magnitudes of the loss depend on the state of vessel age and size.

4.2. Create CPT and prior probabilities for each node

The next step is to establish a CPT for each node. For this study, a total dataset with three sub-datasets has been built. The total dataset is a combination of accounting for approx 130,000 vessels, including information about 10,000 lost vessels and 120,000 existing vessels, counting more than 90% of worldwide commercial tonnage.

The first sub-dataset containing the basic information (static data) of a vessel has been compiled from various sources, including the World Shipping Encyclopedia (WSE) (Lloyd‟s Fairplay, 2008). The static data describes each vessel, with over 200 variables such as identity (IMO) number, nationality, date of building, tonnage, etc.

The second is a casualty dataset that comprises 8,023 records covering the time period from 1993 to 2008, and is a compilation of data in World Casualty Statistics by Lloyd's Register of Shipping (Lloyd‟s Fairplay, 1993-2008) and the International Maritime Organization (IMO). World Casualty Statistics (Lloyd‟s Fairplay, 1993-2008) consists of 2,552 casualty records for the time period of 1993 to 2008. The IMO website provides 6,876 casualty records. The casualty dataset includes accident records of collisions, contacts, fires and explosions, founderings, hull/machinery damage, and miscellaneous wrecks/strandings/groundings.

The third is an inspection dataset comprising 370,000 inspection cases in 59 countries for the time period January 1999 to December 2008. These countries are member States of three main Memoranda of Understanding (MoU) on Port State Control (PSC) under the coordination of the IMO, including the member states of China, Japan, India, France, the UK and Canada etc.

The following equation shows the model used to estimate the occurrence probability of an accident.

$$X\beta_i = \beta_0 + \beta_1 VA + \beta_2 VS + \sum_{i=1}^{5} \beta_{i+2} VT_i + \beta_8 CS + \beta_9 FS + \varepsilon_i \qquad (7)$$

where vessel age (VA) and vessel size (VS) are continuous variables. Vessel types (VT) include general cargo ship, bulker, container ship, tanker and passenger/ferry ship, which are dummy variables. $VT_1 = 1$, if it is a general cargo ship; otherwise $VT_1 = 0$. The classification society (CS) and flag state (FS) are also dummy variables. If the vessel is classed by a member of the International Association of Classification Societies (IACS), then $CS = 1$, otherwise $CS = 0$. If the vessel‟s flag is open registry, then $FS = 1$; otherwise $FS = 0$. ε_i represents a (unobservable) stochastic component.

The model can be processed using the data collected and the logistic regression procedure available within the SAS software. (SAS, 1990)

Table 2 presents logic regression of vessel safety level for the model applications and partial effects of the coefficients and the significance level of the variables of interest. The results indicate that the model fits the data well. For example, for Model I (Table 2) the likelihood ratio statistic is 9766.4, which is well above the 20.09 critical value for significance at the 0.01 level for 8 degrees of freedom. All the variables are highly significant with p-values less than 0.01. The sign of an estimated logistic coefficient suggests either an increase or decrease in the occurrence probability of accident.

Table 1. Model Fit Summary

variable	label of variable	coefficient	P-value
VA	Vessel age	-0.03	0.000
VS	Vessel size ln (gt)	0.24	0.000
VT1	General Cargo	1.11	0.000
VT2	Bulker	0.33	0.000
VT3	Container	0.33	0.000
VT4	Tanker	0.07	0.006
VT5	Pass./Ferry	0.72	0.000
CS	Classification Societies	-1.54	0.000
FS	Flag state	0.37	0.000
Observation		127073	
Number of accidents		6930	
Number of nonaccidents		120143	
Likelihood Ratio		9766.4	

Using the above result, when a vessel‟s characteristic data is available, the probability of the vessel being involved in an accident can be predicted using Equation (8).

$$\hat{p}_i = \frac{e^{\sum \beta_i X}}{1 + e^{\sum \beta_i X}} \quad (8)$$

In the binary regression, $\mathbf{x_i}$ contains independent variables such as age, size, flag, and classification society. ε_i represent the (unobservable) stochastic component, which including some subjective causes, such as shipowners‟ effort, crew training, and some objective causes, such as the safety equipment and ship structure. Those components are all associate with the ship safety condition. So in this research the ε_i were used to separate all the ships as standard or substandard ship.

$$\varepsilon_i = y_i - \hat{p}_i = y_i - \frac{e^{\sum \beta_i X}}{1 + e^{\sum \beta_i X}} \quad (9)$$

where y_i is observed result of one accident, accident($y_i = 1$) or non-accident $(y_i = 0)$, $\hat{p}_i$ is the predicted probability of the vessel being involved in an accident.

A positive ε_i means that the accident has happened, however the estimated probability of casualty is less than 1. This means that this accident could have been avoided and this shipowner could have made a substandard effort or the other safety equipment not good enough. This type ships were defined as substandard ship.

A negative ε_i means that the estimated probability of casualty is larger than 0, however the ship has not been involved in an accident. This indicates that this shipowner could have made a standard effort or the ship‟s safety condition is good, which decreases the probability of accident occurrence. This type ships were defined as standard ship.

Certainly, ε may include other information besides shipowners‟ effort, though it may be trivial. With the further development of the dynamic shipping database, more variables may be used to measure Ship safety condition more accurately.

In Equation (4), the VA and VS as continuous variables need to be transformed into dummy variables when being modeled in BNs. According to different ages, VA has been separated into 3 groups. For example, the average age of containership is 6.3. 3 groups based on their ages are defined as new (≤ 5years), medium (6-10 years) and old (> 10 years). Similarly, VS has been separated into 2 groups based on the average ship size. The proportion of each group defined is used as the conditional probability of each node in the BN model. For example, 92.38% of containerships are classified by the IACS members while only 32.36% of passenger ships are classified by the IACS members. Table 2 lists the conditional probabilities of each node using the model.

Table 2. The Conditional Probability of Each Node

	%	Container	Dry Cargo	Bulk	Tanker	Passenger
CS	Non-IACS (CS1)	7.62	59.53	21.94	31.82	67.64
	IACS (CS2)	92.38	40.47	78.06	68.18	32.36
FS	Closed Registered (FS1)	38.87	63.66	34.09	53.36	80.57
	Open Registered (FS2)	61.13	36.34	65.91	46.64	19.43
VA	New (VA1)	51.35	23.91	56.44	48.74	24.18
	Medium (VA2)	14.51	18.34	18.08	18.93	23.69
	Old (VA3)	34.14	57.75	25.48	32.33	52.13
VS	Lower Average (VS1)	47.33	48.64	37.91	52.88	62.85
	Over Average (VS2)	52.67	51.36	62.09	47.12	37.15

When putting the coefficient β_i into Equation (5), it is possible to obtain the conditional probabilities of accident. The CPT is too large to show in one network due to the fact that there are 7 nodes in this model. Table 3 lists the containership‟s conditional probabilities of an accident under different conditions. Others conditional probabilities are shown in the appendix.

Table 3. The Conditional Probability of an Accident under Different Conditions

Shipowners' efforts	**Stan**											
Vessel size	**Lower**											
Vessel age	**New**				**Average**				**Old**			
Flag state	**Closed**		**Open**		**Closed**		**Open**		**Closed**		**Open**	
Classification society	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**
Accident	0.08	0.05	0.33	0.06	0.05	0.04	0.19	0.05	0.05	0.03	0.07	0.04
Non-accident	0.92	0.95	0.67	0.94	0.95	0.96	0.81	0.95	0.95	0.97	0.93	0.96
Shipowners' efforts	**Stan**											
Vessel size	**Over**											
Vessel age	**New**				**Average**				**Old**			
Flag state	**Closed**		**Open**		**Closed**		**Open**		**Closed**		**Open**	
Classification society	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**	**Non IACS**	**IACS**
Accident	0.20	0.07	0.18	0.08	0.31	0.05	0.43	0.07	0.35	0.04	0.09	0.04
Non-accident	0.80	0.93	0.82	0.92	0.69	0.95	0.57	0.93	0.65	0.96	0.91	0.96
Shipowners' efforts	**SUB**											
Vessel size	**Lower**											
Vessel age	**New**				**Average**				**Old**			
Flag state	**Closed**		**Open**		**Closed**		**Open**		**Closed**		**Open**	

Classification society	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS
Accident	0.12	0.21	0.30	0.19	0.15	0.19	0.20	0.19	0.13	0.09	0.19	0.18
Non-accident	0.88	0.79	0.70	0.81	0.85	0.81	0.80	0.81	0.87	0.91	0.81	0.82
Shipowners' efforts	SUB											
Vessel size	Over											
Vessel age	New				Average				Old			
Flag state	Closed		Open		Closed		Open		Closed		Open	
Classification society	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS	Non IACS	IACS
Accident	0.34	0.22	0.52	0.22	0.20	0.20	0.21	0.32	0.37	0.12	0.40	0.17
Non-accident	0.66	0.78	0.48	0.78	0.80	0.80	0.79	0.68	0.63	0.88	0.60	0.83

4.3. Maintenance cost and accident lost

The repair and maintenance cost is a vital element for operations of any shipowner. Numerous factors affect both the amount and the time of repair and maintenance. Vessel age, steel price and even regional price differentials will affect the maintenance cost. A simple example is presented here to demonstrate the effect of the cost. Normally, the repair cost increase with vessel age. Approximate repair and maintenances cost was estimated by Drewry Shipping Consultants Ltd (Drewry annual report 2007/08). Although there may be significant variations around those estimates, this information shows some „rule of thumb‟ guidelines for the analysis. Such cost estimates are summarized in Table 4.

Table 4. Estimated Approximate Repair and Maintenance Cost Based on the Age Variable

Age(Years)	Scheduled Repair	Unscheduled Repair
0-4	0.80	0.40
5-9	1.00	1.00
10-14	1.25	1.75
15-20	1.60	2.00
>20	2.00	1.35

Note: the base cost level relates to ships of 5-9 years of age
Source: Drewy

If a shipowner makes the standard effort, both the scheduled and unscheduled repair and maintenance are done by the shipowner. If only scheduled repair is done by the shipowner, then a substandard effort is made.

The data of maintenance cost was gathered from Drewry‟s publication „ship operating cost annual review and forecast 2007/08‟. The database includes the repair and maintenances cost of different types of vessels with different sizes for a period of 2001-2010. In Table 4, the estimated repair and maintenance costs are estimated under different conditions.

Table 5. Estimated Approximate Repair and Maintenance under Different Conditions ($)

Vessel size	**Lower**					
Vessel age	**New**		**Average**		**Old**	
Ship safety condition	**Stan**	**SUB**	**Stan**	**SUB**	**Stan**	**SUB**
bulk	-200175	-120105	-440385	-190166	-447057	-266900
tankers	-383775	-230265	-844305	-364586	-857097	-511700
Container	-168510	-101106	-370722	-160084	-376339	-224680
Gen cargo	-157650	-94590	-346830	-149767	-352085	-210200

Vessel size Vessel age Ship safety condition	New		Over Average		Old	
	Stan	SUB	Stan	SUB	Stan	SUB
bulk	-319650	-191790	-703230	-303667	-713885	-426200
tankers	-580650	-348390	-1277430	-551617	-1296785	-774200
Container	-208200	-124920	-458040	-197790	-464980	-277600
Gen cargo	-184650	-110790	-406230	-175417	-412385	-246200

In terms of cost, the loss of different ships under different situations may be various. An example in Table 6 is used to show the levels of losses for ships with different ages and sizes.

Table 6. Estimated Losses due to Accidents under Different Conditions ($M)

Vessel age	New		Average		Old	
Vessel size	**Lower**	**Over**	**Lower**	**Over**	**Lower**	**Over**
bulk	-31	-67	-28	-53	-11	-20
tankers	-14	-80	-9	-40	-7.6	-15
Container	-30	-104	-22	-75	-10	-38
Gen cargo	-10	-20	-3	-5.6	-2	-4.4

Having established the CPT for each node and the utility table for each configuration of decision alternative and outcome state for the determining variable, normalization is required, which means the probability values should be non-zero and a combined value for each CPT of 1. Inputting the probability data and the utility data into the Hugin software (Hugin, 2008), normalization has been carried out automatically by this software. A prior probability of accident can get too. With regard to the containership, taking into account all of the prior probabilities, the probability of accident is estimated to 23.69%. This is illustrated in Figure 2.

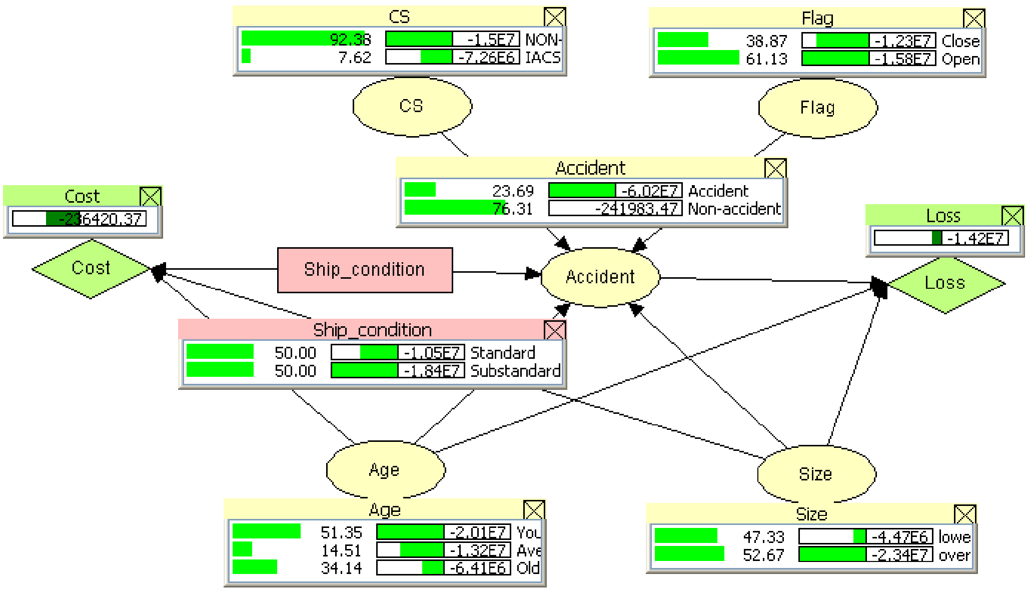

Figure 2: Prior probability of containerships' accidents

The capacity for drawing inference is the great advantage of the BN statistical tool. BN is useful for estimating, in probabilistic terms, changes in one or more variables in response to the introduction of new evidence. Sensitivity refers to how sensitive a model's performance is to minor changes in the input parameters. Sensitivity analysis is particularly useful in investigating the effects of inaccuracies or incompleteness in the parameters of a BN model on the model's output. The most natural way of performing sensitivity analysis is to change the parameters' values and then, using an evidence propagation method, to monitor the effects of these changes on the posterior probabilities. Thus one of the most important sensitivity analysis aspects is to analyze how they change when prior probabilities take different values.

4.4. The effect of different factors

4.4.1 The effect of ship safety condition

Ship safety condition has an important effect on the occurrence probability of accident. Having locked all the other nodes, meaning that those parameters will not change, a useful scenario that can be run in this model is to simulate the standard or substandard ships. Figure 3 illustrates the containership owner‟s effect.

From the scenario, if a ship is a standard ship (100% standard nodes), it can be observed that the accident probability will decrease to 17.95% in Figure 4. If, on the other hand, ship is a substandard (100% substandard node), it can be observed that the accident probability will increase to 29.44%. The expected loss of the standard ship have an accident is 1.02M $ and the cost of maintain a standard ship is $300,000$, the expected overall cost of the shipowner is 1.05M$. However, about the substandard ship, the expected loss of the accident is 1.82M$ and the cost the standard effort $170,690. The expected overall cost of the shipowner is 1.84M$, which is a significant increase compared to the above figure of 1.05M$. We can conclude that although the maintenance cost is higher to keep a standard ship, but the expected overall cost is lower than the substandard ship.

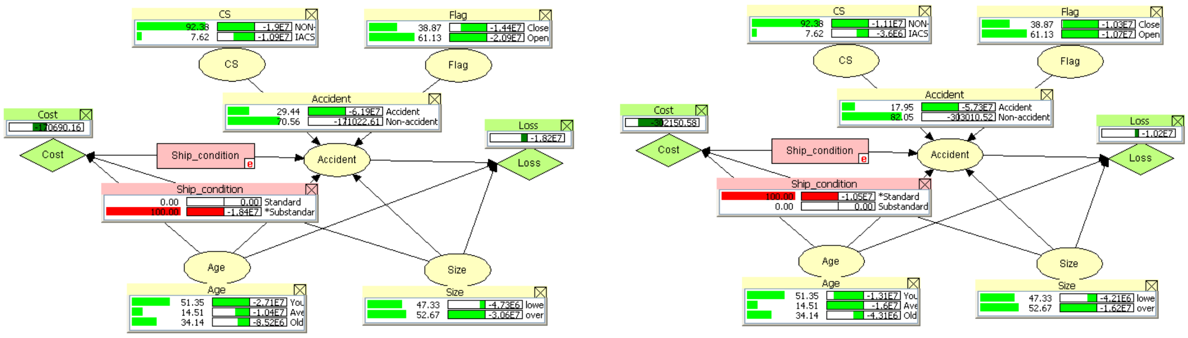

Figure 3. Ship owner's effect on the probability of accident (container ship)

The sensitivity analysis with respect to the give vessel types are shown in Table 7. As can be seen in the last column of Table 7, the changes of the posterior probabilities are evident in the accident occurrence probability when ship safety condition changes from standard to sub-standard. The average change for the give vessel types is 112.82%. The largest change among them is bulk carriers (163.52%), and then is the tankers (142.07%). The least effected by ship safety condition is containerships (64.01%).

Table 7. The Effect of ship safety condition

Type	Prior probabilities	Posterior probabilities		Changes of posterior probabilities (%)
		Standard effort	Sub-standard effort	
Container	23.69	17.95	29.44	64.01
Dry Cargo	13.41	8.82	18.00	104.08
Bulk	**12.91**	**7.10**	**18.71**	**163.52**
Tanker	8.74	5.11	12.37	142.07
Passenger	9.25	6.37	12.13	90.42
		Average change (%)		112.82

4.4.2 The effect of classification society

Figure 4 illustrates the effect of the IACS members on the occurrence probability of accidents (containerships).

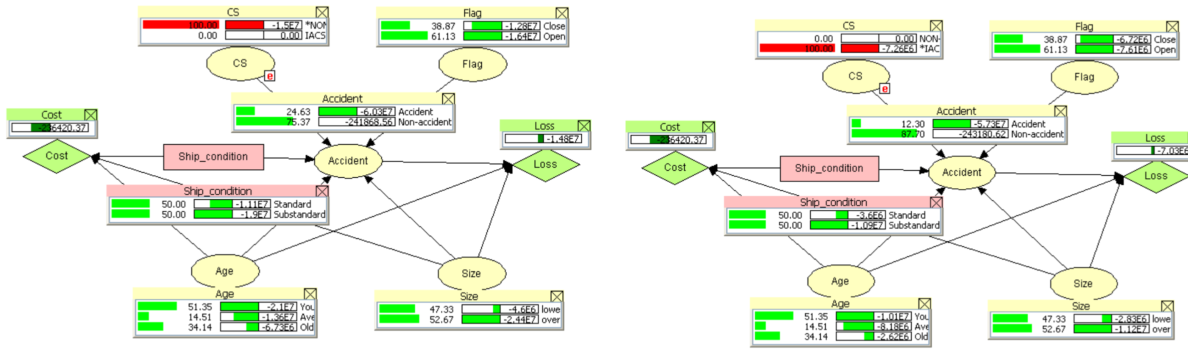

Figure 4. Ship classification societies' effects on the probability of accidents (containerships)

From Figure 4, if a ship is classified by a member of the IACS (100% IACS), the accident probability will decrease to 12.30%. If, on the other hand, a ship is classified by a non-IACS member (100% non-IACS), the accident probability will increase to 24.63%.

The sensitivity analysis results of the five vessel types are shown in Table 8. As seen in the last column of Table 8, the changes of the posterior probabilities are evident when the ship‛s classification society changes from an IACS member to a Non-IACS member. . The average change of the five vessel types is 103.95%. The largest change among them is passenger ships (129.61%), and then is the bulk carriers (113.65%). The least affected by the classification societies is dry cargo ships (64.01%).

Table 8. The effect of Classification Society

		Posterior probabilities		Change between posterior
Type	Prior probabilities	IACS	NON-IACS	probabilities (%)
CONTAINER	23.69	12.3	24.63	100.24
DRY CARGO	13.41	9.17	16.3	77.75
BULK	12.91	10.33	22.07	113.65
TANKER	8.74	6.65	13.2	98.50
PASSENGER	9.25	4.93	11.32	129.61
		Average change (%)		103.95

4.4.3 The Effect of Flag State

The vessel registered in a FOC country probably has greater intention of slackening off its safety management, which may result in a higher accident possibility.

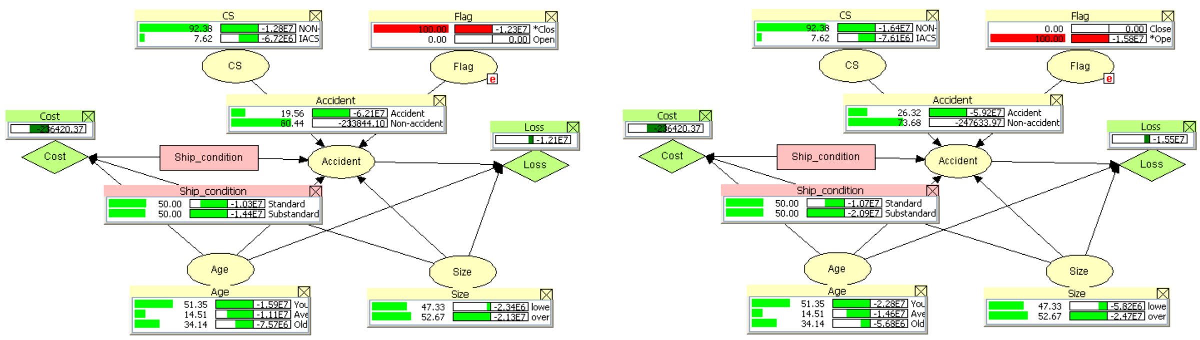

Figure 5. The effect of Vessel's Flag State (containership)

From Figure 5, if a ship is registered a closed registry (100% FS1 variables), the accident probability will decrease to 19.56%. If, on the other hand, the ship is registered an open registry (100% FS2 variables), the accident probability will increase to 26.32%.

The sensitivity analysis results of the five vessel types are shown in Table 9. As seen in the last column of Table 9, there are clear changes of the posterior probabilities clearly when the ship"s registration changes from an open registry to a closed one. . The average change of the five vessel types is 22.66%. The largest change among them is containerships (34.56%), and then is the dry cargo ships (29.64%). The least affected by flag states is passenger ships (6.79%).

Table 9. The effect of Flag State

		Posterior probabilities		Change between posterior probabilities (%)
Type	Prior probabilities	CLOSED	OPEN	
Container	23.69	19.56	26.32	34.56
Dry Cargo	13.41	12.11	15.7	29.64
Bulk	12.91	10.81	13.99	29.42
Tanker	8.74	8.21	9.27	12.91
Passenger	9.25	9.13	9.75	6.79
		Average change (%)		22.66

4.4.4. The effect of vessel size

When the vessel"s size increases, its maneuverability at sea may be reduced, leading to a higher chance of being involved into an accident.

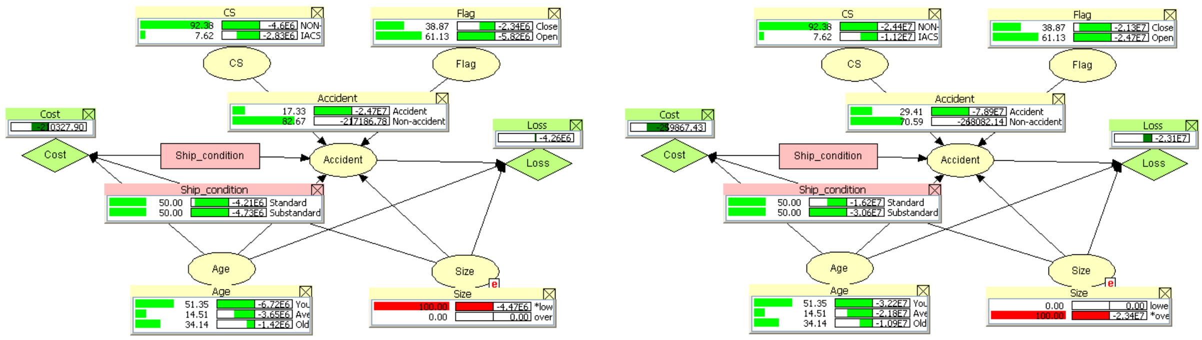

Figure 6: The effect of Vessel's Size (container ship)

From Figure 6, if a ship has a large size, the accident probability increases to 29.41%. If, on the other hand, the ship has a small size, the accident probability decreases to 17.33%.

The sensitivity analysis results of the five vessel types are shown in Table 10. As seen in the last column of Table 10, there are changes for the posterior probabilities a large ship is changed to a small ship. The average change of the five vessel types is 78.45%. The largest change among them is tankers (157.17%), followed by passenger ships (83.57%). The least effected by vessel size is bulk carrier (27.06%).

Table 10. The effect of Vessel Size

		Posterior probabilities		Change between posterior probabilities (%)
Type	Prior probabilities	VS1	VS2	
container	23.69	17.33	29.41	69.71

dry cargo	13.41	10.47	16.2	54.73
bulk	12.91	11.05	14.04	27.06
tanker	8.74	5.02	12.91	157.17
passenger	9.25	7.06	12.96	83.57
		Average change (%)		78.45

4.4.5 The effect of vessel age

The results of this model suggest that an increase in vessel age contributes to a decrease in the probability of accident. From Figure 7, it can be observed that the accident probabilities of new, medium and old vessels will be 26.61%, 22.34% and 19.89%, respectively.

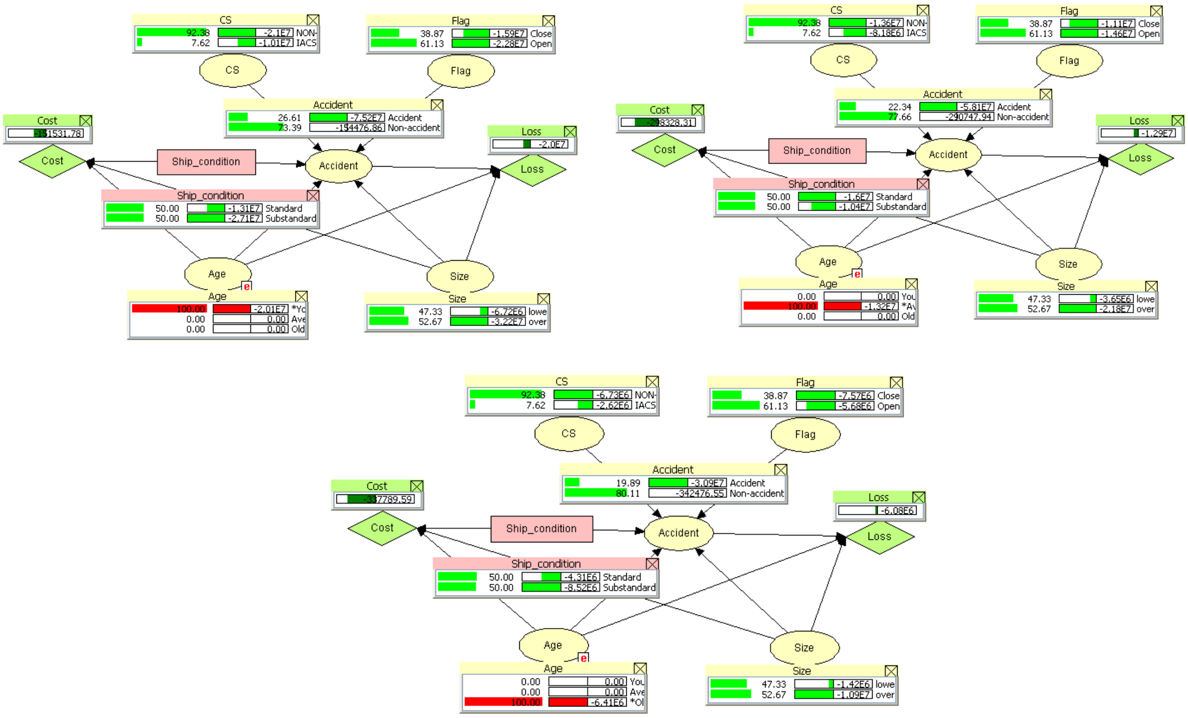

Figure 7. The effect of Vessel's Age (containerships)

The sensitivity analysis results of the five vessel types are shown in Table 11. The changes of the posterior probabilities are clearly shown when a new ship is changed to an old ship. The average change of the five vessel types is 34.77%. The largest change among them is passenger ships (49.37%), and then is the dry cargo ships (38.08%). The least affected by the vessel age factor is containerships (5.25%).

Table 11. The effect of Vessel Age

		Posterior probabilities		
Type	Prior probabilities	VA1	VA2	VA3
container	23.69	26.61	22.34	19.89
dry cargo	13.41	18.12	14.17	11.22
bulk	12.91	14.48	12.95	9.39
tanker	8.74	9.61	9.28	7.11
passenger	9.25	12.68	11.96	6.42

4.4.6 The effect of vessel type

Vessel type determines the vessel‟s function in seaborne transportation, and principally affects the possibility of a certain vessel potentially suffering a particular type of marine peril.

Table12. The effect of Vessel Type

Type	Prior probabilities
container	23.69
dry cargo	13.41
bulk	12.91
tanker	8.74
passenger	9.25

Table 12 reveals that occurrence probabilities of accidents vary among different vessel type groups. Containership has the largest accident probability, followed by dry cargo ship. Containership is the most liable ship type in terms of accident occurrence, followed by general cargo. Tanker has the smallest accident probability.

4.5. Discussion of the obtained results and validation of model

From Tables 7-11, it can be concluded that shipowers‟ effort is the largest single influencing factor on ship accident occurrence. The average change between posterior probabilities is 112.82% if the shipower made a sub-standard effort compare with the standard effort. Followed factor is classification society. The average change between posterior probabilities is 103.95%. Clearly for different ship types, such influencing factors have different levels of impacts on possible accident occurrence. The age of a ship does not really influence the level of accident occurrence probability as much as the other four factors above do. Actually the accident occurrence probability of a ship decreases slightly with the age of the vessel. This may appear to be arguable at first glance. However, this finding is reasonable in a sense that as times goes more experience and knowledge can be obtained by the operators to manage the ship, thus reducing possible accident occurrence.

Model validation is possibly the most important step in the model building process. It provides confidence to the results of the model. The two axioms described in Section 3.3 must be satisfied.

Table 13. Sensitivity Analysis

Type	Prior probabilities	Sub standard effort	Non-IACS	Open registered	Over size	New ship
	P(A=A1)	P(A=A1|SE =SE2)	P(A=A1|S E=SE2, CS=CS2)	P(A=A1|S E=SE2, CS=CS2,F S=FS1)	P(A=A1|SE =SE2, CS=CS2,FS =FS1,VS=V S2)	P(A=A1|S E=SE2, CS=CS2,F S=FS1,VS =VS2,VA= VA1)
Container	23.69	29.44	30.28	34.63	43.76	52.41
Dry Cargo	13.41	18	21.22	24.77	30.16	41.33
Bulk	12.91	18.71	29.59	31.02	35.33	39
Tanker	8.74	12.37	17.1	18.59	28.56	35.98
Passenger	9.25	12.13	14.67	14.9	18.67	27.17

Examination of the model, illustrated in Table 13, reveals that when the ship safety condition is set at 100% substandard, the accident probability increases from 23.69% to 29.44% for a containership. The third column in Table 13 illustrates that when SE=SE2 (i.e. 100% sub-standard) and CS=CS2 (i.e. 100% non-IACA member) are given, the accident probability is larger than the one when SE=SE2 is given. This analysis process continues and consequently, the values in the last column are larger than any value presented in the same row in Table 13. This is in harmony with Axiom 2 in Section 3.4, thus validating the model.

5. Conclusions

This paper presents an approach to integrate logistic regression and Bayesian Network together into risk assessment, which has been developed and applied to a case study in the maritime industry. Bayesian networks as a modeling tool in maritime applications have recently been demonstrated widely. However, Bayesian approach requires too much prior probabilities information, which is often difficult to obtain in risk assessment. Expert estimation, the traditional way to estimate the prior probability of accidents, must be used with care.

In this research, a binary logistic regression method is used to provide input for a BN, making use of different resources of data in maritime accidents. By taking into account different actors (i.e. age, size, etc.) and their mutual influences, maritime risk assessment using the BN enables to identify the factors that have the greatest impact on the accident occurrence. In the case study, we conclude that although the maintenance cost is higher to keep a standard ship, but the expected overall cost is lower than the substandard ship. IACS members enforce strict regulations to improve the safety level of their vessels. It can be concluded that vessels" classification by the IACS or non-IACS members affects the accident probability, especially for the passenger ship. There is a significant change of accident probability when vessels use open or closed registration. In terms of contributions to vessel accident occurrence probability, there is a significant difference between large and small ships, especially in the tanker section. The results of this model also suggest that an increase in vessel age associates with a decrease in the probability of accident.

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A Decision Support System for IAV-based Container Port Operations

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Abstract

The IAV (Intelligent Automatic Vehicle) is the next generation of concept vehicle used for transporting containers horizontally in port. It is expected that IAVs could be used as an upgrade of the AGVs, trucks, Reach Stackers (RSs) and Straddle Carrier (SCs) being used in current port operation. Compared to the aforementioned equipments, the IAV has a more advanced mechanical, electrical and control sub-systems. It is expected that IAV-based container movement systems will be more efficient, easier to set up and require less space to operate. However, in order to fully utilize the strength of IAVs in port operation, we need to adapt previous decision making methods in container port operations such as space allocation, vehicle dispatching and routing, traffic control and deployment of cranes. This is because previous decision making methods are mainly designed for AGV, truck and SC and have not considered the special features of IAV and may not be directly applied to the IAV-based port operation. The aim of the paper is to identify these decision-making problems and propose an initial solution to each of them. In the paper, we will firstly give an introduction to the IAV. Then we will give a detailed description on how IAVs will be used in the container terminal. At last, we will go through the decision-making problems in the IAV-based container terminal and propose some heuristic decision-making rules or methods taking the special features of IAVs into consideration. This study is an initial attempt to use IAVs in container port operation and will contribute to the further development of IAVs in container port practice.

Keywords: container, shipping, logistics, DSS, IAV

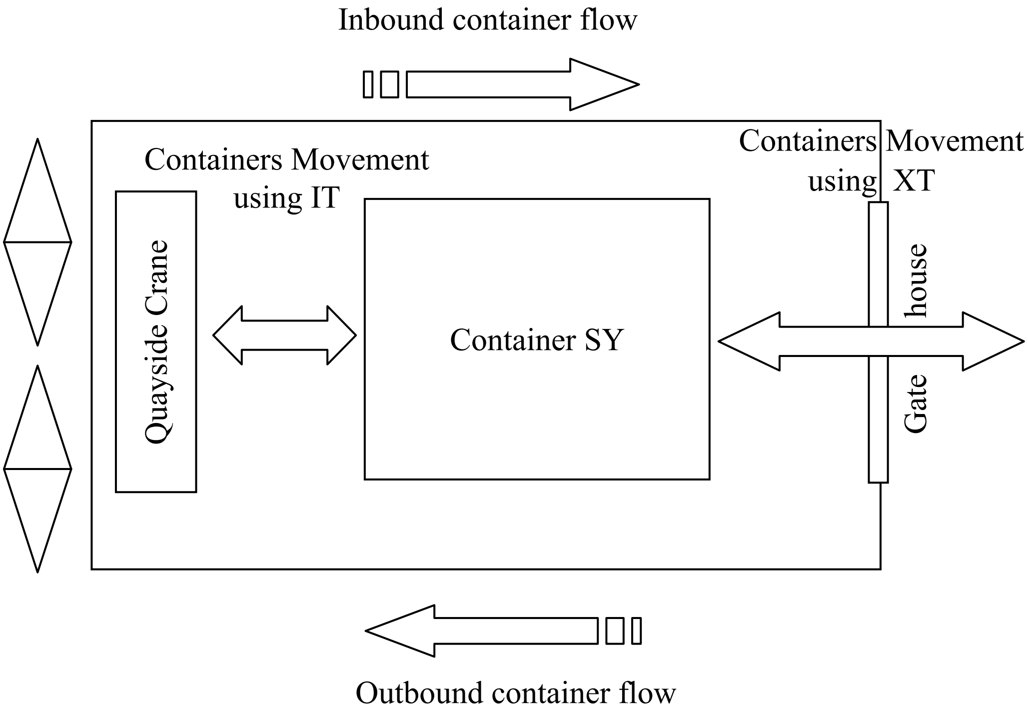
1. Introduction

Containerised shipping is one of the most important forms of transporting cargoes at sea. The importance of containerised shipping can be evidenced by the fact that the majority of cargoes in the international trade are moved by container shipping. Therefore, it is be of vital importance to improve the efficiency of containerised shipping. Since Container Terminal (CT) is a very important element in container shipping system and its efficiency has a significant impact on the performance of whole container shipping system, this study will focus on how to improve the efficiency of CT in this study.

CT is an interface between seaborne and inland transportation, and its main function is to transfer full and empty containers between container vessel and inland transportation equipments including truck and rail cars. A CT normally needs to handle two types of container flows, one is the inbound container flow, and the other is the outbound container flow. The outbound containers are delivered into the CT by customers' External Trucks (XT) through the gate house at the CT, and then these containers will be dropped off in the Storage Yard (SY). After a short stay in CT, these stored containers will be retrieved and loaded onto an interval vehicle using Yard Crane (YC) and then loaded onto the vessel which will call at the ports the containers are destined for. The inbound containers flow has a reverse process. Initially, the inbound containers are unloaded from a container vessel by a Quayside Crane (QC), and moved by the Internal Vehicles (IVs) to the container

SY, and then delivered to the customers. The designing CT layout also centres on this purpose. Figure 1 shows a typical layout of a CT.

Figure 1: A typical layout of CT



In the above container port, the IVs are very important facilities to handle the inbound and outbound container flows. In the current port operation practice, there are several types of IVs which are used for moving containers, e.g., trucks, AGVs, RSs and SCs. These IVs are normally used to move containers horizontally between quay and SY or different blocks in the SY. However, in some ports, the function of IVs is to move containers not only horizontally but also vertically. For example, some CTs use RSs and SCs to move and lift on/off containers. The performance of these vehicles significantly impacts the efficiency of CT, and consequently the efficiency of the whole container shipping system. To further improve the efficiency and cost-effectiveness of CT, a concept vehicle IAV (Intelligent Automatic Vehicle) (Merzouki, Djeziri and Ould-Bouamama, 2009; Khalil, Merzouki and Ould-Bouamama, 2009) has been proposed as an upgrade of existing IV recently as shown in Figure 2.

The development target of IAV is to act as an upgrade of trucks and AGVs in the large-size ports and RSs and SCs in medium/small-size ports.

Figure 2: A scene of IAV working in the port using 3-D animation
Source: http://www.numexia.com/index.php?page=logistique-portuaire&hl=en_GB

The IAV has a number of good features. Firstly, the IAV is an unmanned vehicle, and thus the labour cost can be reduced dramatically. Secondly, the IAV does not need the sensors beneath the road to guide its running, and the IAV does not have to move along a fixed path full of sensors like the AGV does. As a result, it can have greater manoeuvrability, and can be easily set up without the need to change the port infrastructure. Thirdly, IAVs can be coupled physically or even virtually like a train, which makes it possible to have a greater efficiency of transporting containers than the other vehicles. Furthermore, IAV normally works with a cassette to move containers, and this setting can reduce the waiting time of IAV under the QC and save the investment on the YCs in the SY for the small/medium-size container port as a cassette can carry two tiers of containers.

As IAV is still in the concept stage, the port operators lack the knowledge of using the equipments, and it will be an interesting topic to investigate how to use IAV in the port operation and make the various decisions in the port operation. Towards this end, the paper aims at proposing an initial plan on how to use IAV in the container port and a preliminary decision-making framework relating to the use mode.

The paper is structured as follows. In section 2, we will discuss how to organize the port operation using IAV, and a decision-making framework for an IAV-based CT will be proposed in section 3. The concluding remarks will be made in Section 4.

2. IAV-based port operation

2.1. The properties of IAV

Driving mode

The IAV is an unmanned automatic vehicle, and no divers are needed. Under some circumstance where the external travelling environment of IAV is very complicated such as urban area, IAV can automatically follow a guide vehicle driven by a human being.

Assembling mode

The IAVs can be coupled together physically or virtually like a train. Normally, a number of IAVs can run like a train without the need of any physical connection. But when two IAVs coupled together to move a 40ft container, the physical connection is required due to safety requirements.

Containers stacking on the IAV

Each *IAV* can carry two stacked 20ft containers at one go. The two containers need to be put on a cassette as the IAV need the cassette to move the containers (Figure 3(a)). To move 40ft containers, two physically connected IAVs and a 40ft long cassette are needed (Figure 3(b)). In the practical port operation, the stacking modes can be very complicated. Figure 3(c-f) give more examples.

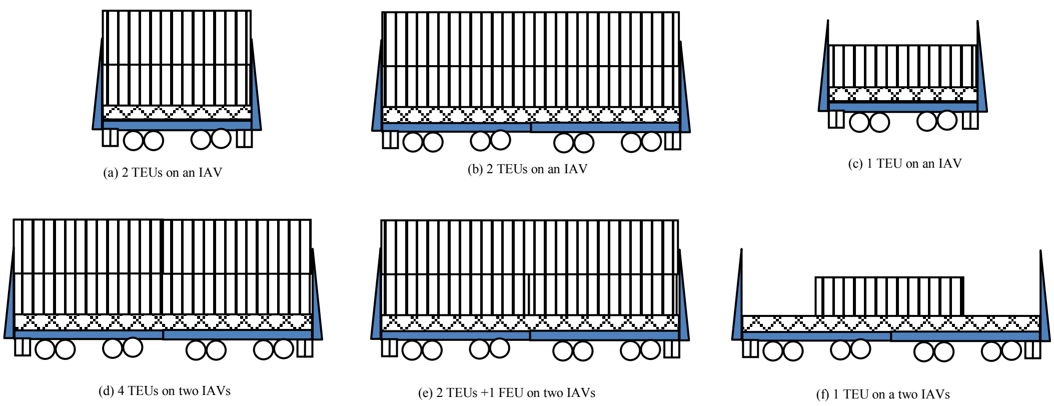


Figure 3: the stacking of containers on the IAV

Container picking-up and dropping-off by IAV

When an IAV tries to pick up a container on a cassette, it can stop exactly underneath the floor of a cassette automatically and fit himself into it, and then the IAV will lift the cassette off the ground by raising its own floor a little higher, and then move the containers to the designated location.

When the IAV arrives at the designated location, the IAV will reduce its height from its floor to the ground, so that the legs of cassette can land on the ground and the IAV can be separate from the cassette.

The above process of container picking-up and dropping-off is completed by IAV itself automatically without human involvement.

2.2. The QC operations

As QCs are expensive equipments in the CT, it is not economic to let QCs wait for IVs. Consequently, in the existing port operation, AGVs, trucks, SCs and RSs have to wait in the queue for the service of QC. Although this arrangement reduces the waiting time of QCs, the waiting of IVs still makes port operators incur considerable costs. In an IAV-based CT, the waiting costs can be dramatically reduced as it only needs the cheap cassettes to wait in the queue rather than the relatively expensive IVs.

In the port operation, the QCs normally only load or unload containers one bay after one bay, and they do not move along the length of vessel unless they change the container bay they are working on. This means the crane only move container along the width of vessel during the course of handling one bay of containers. Therefore, it would be desirable if the number of empty cassettes could be as many as possible along the width of vessel so that the possibility of QC and IAV waiting can be minimized. However, this number is subject to the width between the two rows of legs of QC. Furthermore, some space should be reserved for the travelling of IAVs. Taking all these factors into consideration, a plan for the utilization of the lanes beneath the QC is proposed as follows (Figure 4). In the figure, we assume that the QC can accommodate 5 lanes as this is the most common width of a QC being used in the current port operation.

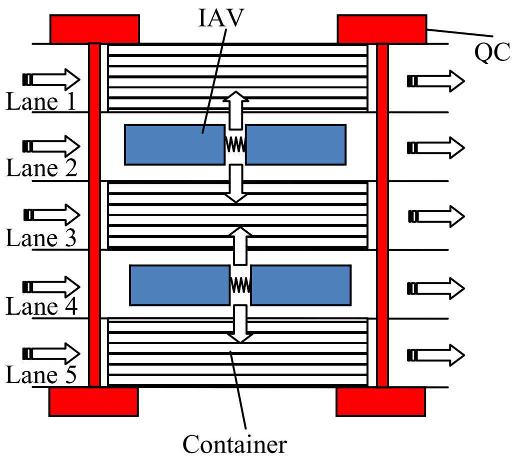


Figure 4: the allocation of lanes beneath the QC in an IAV-based CT

In Figure 4, the QC will move across the lanes, and drop off and pick up containers from the container stacking lanes; and the IAVs will travel on the lanes designated to them, and move the cassettes to or from the container stacking lanes.

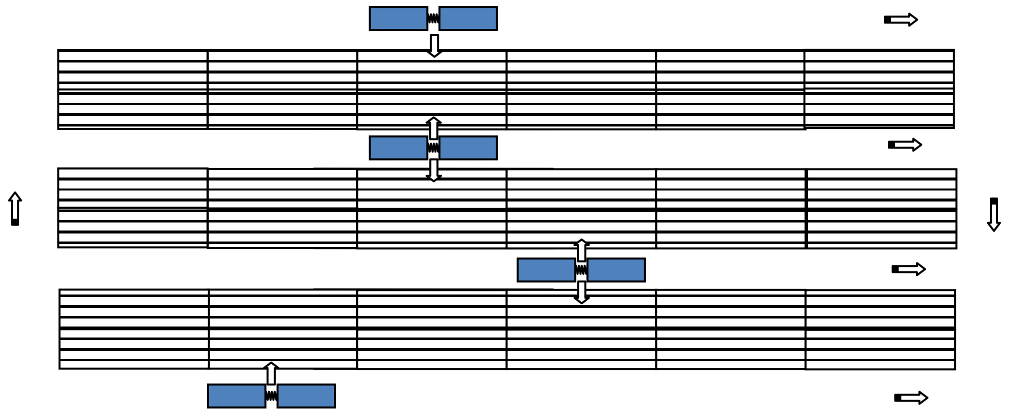
2.3. SY operation

In the CT where yard cranes such as Rubber Tyred Gantry Cranes (RTGCs) and Rail Mounted Gantry Cranes (RMGCs) are used, IAVs can cooperate well with these cranes without the need to change the layout of SY.

IAVs are more efficient to place and retrieve containers from the SY than the trucks as two coupled IAVs can carry two FEUs at one go and more IAVs can be assembled together like a train.

In the CT where SCs and RSs are used to move and stack containers, IAVs are able to act as the upgrade of these equipments as IAVs are expected to reduce the human labour costs and improve the efficiency of container movements. As IAVs have different methods to carry and lift containers, the layout of this sort of CT needs to be re-arranged. Basically, IAVs need a particular lane to move in/out containers. Figure 5 gives an example of container storage design layout. In this design, two rows of stacked can share one IAV lane. Within and around the SY, a one-way traffic organisation is proposed.

Figure 5: an initial design of SY in an IAV-based CT



3. The decision-making problems in an IAV-based CT

Besides influencing the workflow of port operation and layout design of CT, the introduction of IAVs to port operation also has significant impact on the decision-making issues and it might be inevitable to make some adaption to the methods being used in the current CTs to resolve the above problems. In a CT, there are a variety of decision-making issues, e.g., berth allocation, QCs allocation to vessels, space allocation, IVs dispatching, IVs routing, RTGC allocation to blocks in SY and IT allocation to QC. These issues have been studied for decades, and there are many research articles can be found in these fields. Stahlbock and Voβ (2008) and Steenken, Voβ and Stahlbock (2004) have done two comprehensive literature reviews for these studies.

Although the above decision-making issues have very close connection and should be treated as a whole to seek the optimal solution, most of previous studies normally break down the above problems into a number of smaller sequential decision-making problems. In other words, the above decisions are made one by one, and the output of one problem could be the input of the next problem.

In this study, we still follow the previous research road map, and decompose the decision-making issues in an IAV-based terminal into a number of smaller sequential decision-making issues. As this study mainly focuses on how to use IAVs in a CT, we will only consider the decision-making issues directly relating to IAVs.

3.1. Quay crane scheduling problem

Definition

This problem is to seek the sequence of containers for loading and discharging. The objective is to complete the loading and discharging tasks for the vessel as early as possible, and this is also referred to as makespan minimisation. This problem has been proved to be a NP-hard problem if the number of cranes allocated to the current container vessel is more than two (Lim, Rodrigues and Xu, 2007), and it is very difficult to obtain the optimal solution. Some recent studies (Lim, Rodrigues and Xu, 2007; Legato, Mazza and Trunfio, 2010) employ some meta-heuristic method such as simulated annealing to conduct an extensive search. In this study, we propose a number of simple heuristic rules as an initial solution to the problem in an IAV-based CT.

An initial solution

We suggest that the discharging operation is done prior to the loading operation, which is also the common practice in the existing port operation. For both the two operations, we need to balance the workload of each QC as it will not be economic if a few QCs are still working while the others have completed their work. In line with the consideration, the initial solution proposed in the study will centre on balancing the workload of each crane.

Assume that $B = \{1, 2, \dots, N_b\}$ is the set of container bays onboard a container vessel, where N_b is the total number of container bays; and $C = \{1, 2, \dots, N_{qc}\}$ the set of QCs available to handle the containers onboard the vessel, where N_{qc} is the total number of available cranes. For the container bays $a, b \in B$, $a < b$ indicates a is on the left of b and likewise for the C. In shipping practice, two adjacent cranes cannot work too close due to the safety consideration, and therefore the minimal safety distance between two adjacent cranes should be assured. Let l_i denote the number of containers to be loaded, d_i the number of containers to be discharged at the bay i ($i \in B$), we need to decide the initial position of the each crane u_i (i=1,2, ..., N_{qc}). The container holds between u_i and u_{i+1} (i=1,2, ..., N_{qc}) will be allocated to crane i, crane i will complete the loading/discharging tasks from left to right, and thereby the QCs can have the balanced work load. As mentioned above, we firstly consider how to allocate QCs for the container discharging tasks, and then for the container loading tasks.

The algorithm for container discharging is described as follows:

(1) Compute the average work load for each crane $\beta = \sum d_i / N_{qc}$;
(2) Let p_1, p_2 denote two positions, and initially be set to be the leftmost container bay where there are containers to be discharged;
(3) $p_2 := p_2 + 1$; if $p_2 > N_{qc}$, p_1 will be the initial work position for the last crane, *i.e.*, $u_{N_{qc}} = p_1$, and the algorithm stop; otherwise, go to the next step;
(4) Let β be the work load between p_1 and p_2, and then we have $\beta = \sum_{i=p1}^{p2} d_i$;
(5) If $\beta > \beta$, $p_2 - p_1 >$ then $u_i := p_1$, $p_1 := p_2$; otherwise, go to step (3)

The algorithm for container loading is very similar, and we just need to replace d_i with l_i in the above algorithm.

The above procedures determine the initial position of each crane, and these cranes will start from their initial positions, and load/discharge containers one bay by one bay from left to right sequentially.

As IAVs normally carry two or more than two containers at one go, the stacking consequence will be a new issue which is not considered in the previous study. A rule we suggest to tackle this issue is that the container reshuffling in SY should be minimised when the containers on the vessel are placed into the storage block. A heuristic rule for the lane layout shown in Figure 4 is given as follows:

1) Drop the container on the cassette which has least reshuffling number. If more than one cassettes have the least reshuffling number, go to next step;
2) Drop the container on the cassette which has the most containers onboard and can be filled up soonest;
3) If there is more than one cassette satisfying the above condition, drop the container on the cassette which is easy to be accessed by the IAV.

3.2. IAVs and Cassettes allocation to QC

Definition

This problem is to determine the number of IAVs and Cassettes allocated to a particular QC. The objective is to minimize the idle time of QCs, IAVs and Cassettes. It should be noted, however, the value of idle time of the equipments is not the same due to the different purchase price of the equipments.

An initial solution

The exact solution to the above problem involves the analysis of queuing network, and it is very difficult to solve it. Murty et al (2005) suggest that computer simulation should be a practical method, and they use brute-force search for the best fleet size of internal vehicles. In an IAV-based CT, this decision-making problem is more complicated as we have to consider the number of Cassettes, and the brute-force search might not be feasible. Some more intelligent search in the field of parametric optimisation via simulation might be needed (c.f. Gosavi, 2003).

3.3. Container storage allocation

Definition

This decision-making problem is to assign a space in the SY to the arriving containers, and its objective is to minimize the traffic congestion, the waiting time of IAVs and RTGC and container reshuffling in the SY.

An initial solution

Container storage allocation problem is notoriously hard due to its combinatorial and dynamic nature (Wan, Liu and Tsai, 2009). The main efforts recently are to decompose it into a few linear programming problems (Zhang et al, 2003) or to find some heuristic methods (Wan, Liu and Tsai, 2009; Murty et al., 2005). In this study, we propose a simple and easy-to-implement heuristics as an initial solution to this problem in the IAV-based CT. The heuristics are described as follows:

(1) Zoning the SY

In general, the purpose of SY is to provide a temporary space for inbound and outbound containers, and the particular area should be designated to each type of operation, thus the loading zone and unloading zone should be planned in a SY. Moreover, due to the uncertainty in the inbound and outbound containers flow, a buffer area between the loading and unloading zone is suggested to be set up. The buffer area can be used for either loading or unloading operation if there is no space for the containers in their designated zone. Thus, we can have three zones, and let $Z_l = \{1,2,\ldots, N_l\}$ denote the set of blocks in loading zone, $Z_u = \{1,2,\ldots, N_u\}$ unloading zone and $Z_b = \{1,2,\ldots, N_b\}$ the buffer zone, where, N_l, N_u, N_b represent the number of storage blocks, respectively. The value of N_l, N_u and N_b should be decided based on the statistical characteristics of the inbound and outbound container flow such as their average value and standard deviation.

(2) Allocating containers to the blocks

Assume that a number of containers come into the port, and we need to allocate storage space to them. Obviously, it is not desirable if all the containers are allocated to a single or a few blocks as this will increase the possibility of traffic congestion and the waiting time of IAVs or RTGCs at these blocks. A good allocation policy might be to evenly allocate containers among the blocks. In other words, we should allocate more containers to the blocks having bigger storage space. According to this principle, the possibility of allocating a container to block i ($i \in Z_l$, Z_u or Z_b) can be calculated as follows:

$$\alpha_i = \frac{C_i - s_i}{C_i} \%$$

Where, C_i is the physical capacity of storage block i;
s_i is the number of containers stored at block i;

When a container needs to be put in the storage stock, we first decide upon its zone according to the operation type, e.g., loading or unloading; then, we check each α_i in the corresponding zone, and allocate the container to the storage block i if it has the biggest value of α_i among the blocks satisfying the following condition.

$$\begin{cases} WT(i) < WT \\ Nr(i) < Nr \end{cases}$$

Where, $WT(i)$ is the expected time for waiting for service of RTGCs at the stock i;
WT is a pre-defined threshold control parameter for waiting time for RTGCs;
$Nr(i)$ is the minimum number of reshuffling containers;
Nr is a pre-defined threshold control parameter for the number of container reshuffling.

The above formulation implies that the container will be allocated to the stock which can let IAV wait for an acceptable time and the stack which accommodates the containers have an acceptable number of container reshuffling. WT and Nr are dependent on the port operator's tolerance of RTGCs waiting time and reshuffling number.

It should be noted that the buffer area should be considered to put into use if there are no space in loading or unloading zone. The space allocation in buffer area follows the same principle as above.

3.4. IAVs dispatching

Definition

IAVs dispatching involves the task allocation to IAVs with the objective function maximising the utilization rate of IAVs. In an IAV-based CT, the main task of IAVs is moving containers and cassettes between quay and SY. This vehicle dispatching issue is very complicated as there are many points of cargo picking-up and dropping-off including the cranes in the quay and the blocks in storage yard and at least two commodity including containers and cassettes are required to transported on the network. In this study, we will give an initial plan to dispatch vehicles in the IAV-based CT.

An initial solution

For the unloading operation, we assume that the start and end points of IAVs dispatching is QCs which these vehicles are designated to. Thus, we have the following decision-making procedures.

(1) Allocate a fleet of IAVs $V_i = \{1,2,\dots,N_{C_i}\}$to crane i (i∈B), where, crane i is a crane assigned to the unloading operation, $N_{C_i}$is the number of IAVs allocated to crane *i* and determined in section 3.2;
(2) Pick up a cassette full of containers, move towards the destination of the cassette designated at Section 3.3;
(3) Join or form a vehicle platoon on the way to the destination if possible;
(4) Break away from the vehicle platoon, and drop the containers at the designated position;
(5) Move the empty cassette back to the crane *i* if RTGCs are used in SY; or pick up a empty cassette from cassette storage place if no cranes in SY are used, and IAVs are used as a replacement of SCs or RSs;
(6) Return to the crane *i*;

For the loading operation, the start and end points of dispatching are the storage blocks within the SY if IAVs are used for the loading operation.

(1) Before the loading operation is conducted, we assume that the cranes have been allocated, and thus the number of IAVs can also be determined according to Section 3.2;
(2) Use the vehicles determined in step (1) to pick up the containers in the loading zone;
(3) Select the QC having the least waiting time to drop-off the containers and the cassette;
(4) Move the empty cassette to the SY if RTGCs are used; or move the empty cassette to the cassette storage yard if no yard cranes are used;
(5) Return to the SY

3.5. IAVs routing

Definition

In an IAV-based CT, there are at least three level problems relating to the IAVs routing: the highest level of IAV routing problem is the design of traffic network, e.g., one-way or two-way traffic, the capacity of a particular lane and the topological structure of traffic network; the middle level is how to route the traffic on the above network, its output is a sequence of nodes on the traffic network; and the lowest level is the control of individual control, e.g., determining a trajectory consisting of a set of consecutive coordinates to guide the IAVs in real time. The objective function of IAVs routing is to minimise the travel time of all vehicles. As the control of IAVs is beyond the scope of our study, we only consider the first two levels problem.

An initial solution

As for the high level problem of traffic network design, to reduce the complexity of traffic control and minimise the possibility of travelling conflicts, we propose a one-way traffic network as the initial plan in an IAV-based CT as shown in Figure 5. For the second level of problem, we suggest the shortest path problem in terms of distance is used as the initial plan.

4. Conclusion

It is a great challenge in both theory and practice to employ a new type of automatic vehicle like IAV in a container terminal, and we must carefully examine the cost-effectiveness, performance, safety, technical feasibility, etc. to the IAV-based CT. The study makes the first attempt to investigate the operation of IAV-based CT.

In this study, we firstly give an introduction on how the IAVs will operate in container terminal, and then propose a number of simple procedures to deal with the decision-making problem in a CT, e.g., quay crane scheduling problem, IAVs and cassettes allocation to QC, container storage allocation, IAVs dispatching and routing. The procedures have reasonably good performance and might be used in port operation directly or with some adaption. Meanwhile, they are also very useful to develop a dynamic simulator to test the feasibility of IAV.

There are some limitations in the study. A complete test of the decision-making methods should be carried out. However, we will consider this in the further study.

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A Disruption Management Model for Berth Scheduling Problem in Container Terminals

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Abstract

To deal with the unforeseen disruptions in container terminals, the disruption management problem of berth scheduling is studied. Firstly, a berth scheduling model considering the optimization of quay crane is developed. Then a disruption management model is developed to recover the berth schedule when unexpected events happen. To solve the disruption management model, a simulation optimization approach is proposed. In this method, simulation model is used to evaluate a given schedule; and optimization algorithm is used to search the optimal schedule. To improve the computation efficiency of simulation optimization model, an algorithm based on local rescheduling and genetic algorithm is designed. Finally, numerical experiments are provided to illustrate the validity of the proposed model and algorithms. Results indicate that local rescheduling based algorithm can improve the computation efficiency comparing to full rescheduling based algorithm. Moreover, the disruption management model considers the benefit of different parties, thus increases the scientific of disruption recovery schedule.

Keywords: Berth scheduling, disruption management, simulation optimization, container terminals

1. Introduction

With the development of container transport, the throughput of container terminals increases rapidly. To meet the increasing container volume, container terminals have to construct new berths, increase the equipments processed loading and unloading operations, or improve the operation efficiency. Meanwhile, container terminals are faced with bigger challenges to provide better services so as the vessel turn around time can be shortened. Therefore, how to improve the operation efficiency is one of the most important issues for container terminals.

Berths are important resources of container terminals and the good scheduling of berths can improve customers' satisfaction, increase throughput and lead to higher revenues of container terminals. The objective of the berth scheduling is to determine the berthing times and positions of containerships in container terminals, thus to minimize the penalty cost resulting from delays in the departures of ships and the additional handling costs resulting from non-optimal locations of ships in a container terminals.

Quay cranes (QCs) scheduling problem is another vital factor for efficient terminal operations. The scheduling of QCs significantly affects the operation efficiency of container terminals, and thus determines the makespan of a container vessel, which is the latest completion time of all operation tasks of the container vessel. QC operation rate is one of the most important indexes to measure the performance of operation system in container terminals. Moreover, berth allocation and QC scheduling are two inter-related problems, e.g. the change of QC-to-Vessel assignment influences the operation times of container vessels. Therefore, the integration solution of BAP and QCSP is needed.

Numerous studies have been conducted regarding the improvement of the efficiency of berth allocation and QC scheduling. And many models and algorithms are developed to optimize the berth allocation and QC scheduling.

However, during operation, the planned schedules often have to be revised because of disruptions caused by severe weather, equipment failures, technical problems and other unforeseen events. Once these disruptions happen, the initial plan may be infeasible, and modification of current or future schedule should be undertaken to minimize the negative impacts of the disruption, which is called disruption management.

This paper addresses the problem of recovering berth and QC schedule during irregular disruptions. The objective is to decrease the influence of unforeseen disruptions to operation system and decrease the addition cost resulting from disruptions. And this paper is organized as follows. In Section 2, a brief review of previous works is given. In Section 3, the problem of berth allocation is described, and models for simultaneous optimization of berth and QC schedule are developed. Models to tackle disruptions and recover the berth schedule are developed in section 4. A simulation optimization approach is proposed in section 5. A local rescheduling based algorithm is designed in section 6. Numerical examples are used to test the performance of the proposed method in Section 7. Conclusions are given in Section 8.

2. Literature review

Issues related to container terminal operations have gained attention and have been extensively studied recently due to the increased importance of container transport. And there have been a growing number of studies that deal with the berth allocation problem (BAP) as well as quay crane scheduling (QCSP).

Existing studies about BAP can be classified into discrete and continuous types. In the discrete case, the quay line is partitioned into a number of sections, called berths, where one vessel can be served at a time. Among them, Nishimura et al (2001) constructed a discrete assigning model in terms of public berths and designed a GA based algorithm to test the validity of the model. Imai (2003) further considered the docking privileges of different shipping company to assign the berth. Moreover, Kim et al. (2003) solved the discrete berth assignment model with simulated annealing and compared the results of simulated annealing with optimal solution methods.

In continuous cases, there is no berth concept, the quay line is considered as a whole entity and the ships are given a sector of quay line for berthing according to their lengths. Imai et al. (2005) have developed a continuous berth assignment model to minimize the total service times, and in 2007 they further studied the berth assignment problem in the context of indented berths and designed a genetic algorithm to solve the model. Wang et al. (2007) took berth assignment problem as a multi-stage decision making problem and solved their model with stochastic beam search algorithm.

The problem of QCSP was first studied by Daganzo (1989), he suggested an algorithm for determining the number of QCs assigned to ship-bays of multiple vessels. Kim and Park (2004) developed a mixed-integer programming model considering various constraints related to the operation of QCs, and proposed a heuristic search algorithm called greedy randomized adaptive search procedure to solve the problem. Lee et al. (2008) provided a mixed integer programming model for QC scheduling problem, the objective is to determine an operation sequence of holds for QCs assigned to a container vessel considering interference between QCs. And a genetic algorithm is proposed to obtain near optimal solutions. Tavakkoli et al. (2008) presented a mixed-integer programming model for the QC scheduling and assignment problem, and genetic algorithm was designed to solve the model. Goodchild A.V and Daganzo C.F (2006) described the double-cycling problem, and presented solution algorithms and simple formulae to determine reductions in the number of operations and operating time using the technique.

The simultaneous BAP and the QCSP was first considered by Park and Kim (2003). A MIP and a heuristic solution method based on a Lagrangean relaxation are proposed to determine the berthing positions, berthing times, and the QC assignments. Imai et al. (2008) developed a model for simultaneous berth and crane allocation problem, and the discrete BAP is considered in the model. A heuristic algorithm based on genetic algorithm was designed to find an approximate solution. Meisel, and Bierwirth (2009) studied the combined problem of berth allocation and QC assignment. To solve the problem a construction heuristic, local refinement procedures, and two meta-heuristics are presented. Liang et al. (2009) also developed a model for simultaneous berth and quay crane scheduling problem.

The objective of above studies is to optimize the berth and QC schedule before operations of vessels begin. However, during operation, the planned schedules often have to be revised because of irregular disruptions. Once these disruptions happen, the initial plan may be infeasible, and modification of current or future schedule should be undertaken to minimize the negative impacts of the disruption.

Recently, management of disruptions attracts more and more attentions, and models were developed to tackle the disruptions in supply chain, machine scheduling and airlines operation etc. Yu Gang (2004) developed disruption model for airline scheduling problem, and designed a system called Crew-Solver based on heuristics algorithms to solve the model. Oke et al. (2008) and Xiao et al. (2007) studied the coordination of supply chain management when disruptions happens, and proposed method to improve the robust of initial plan. Petrovic et al. (2006) and Qi et al. (2006) developed disruption model for flow shop problem and designed solution algorithms. Walker et al. (2005) developed an optimization model to resolve disruptions to an operating schedule in the rail industry.

To our knowledge, few literatures have been found in disruption management problem for berth scheduling. However, unforeseen disruptions often occur in container terminals, which may cause tremendous disruption, and thus decrease the operation efficiency and service level of container terminals. Moreover，comparing to above disruption management problems, difficulties of disruption management problem for berth allocation lies in the following aspects.

1) Operations in a container terminal include several inter-related sub-processes. Upon a vessel's arrival at the terminal, QCs unload containers from the vessel or load them onto the vessel, and yard trailers transport containers from quayside to storage yard and vice versa. At the storage yard, yard cranes perform the loading and unloading of yard trailers. Therefore, to obtain the recovery schedule, the relations between berth allocation and quay scheduling, and other sub-process should be considered.

2) Efficient algorithms are needed. Existing studies indicate that the scheduling problems of different sub-process such as berth allocation, QCs scheduling, and yard crane scheduling are NP-hard problem. Thus, the disruption management in container terminals is also an NP-hard problem. Furthermore, the characteristics of disruption management require the high speed and efficiency of solution algorithms. Therefore, efficient algorithm is one of the key problems for disruption management of berth allocation. Solution methods for disruption management model presently need to be improved.

3) In disruption management of berth allocation, the benefits of different parties should be balanced. Berth reallocation influences benefits of different parties such as shipping company, terminal, governments and yard trailer driver. Therefore, how to develop a model capable of balancing the benefits of these parties is difficult.

Moreover, the studies on disruption management are mainly focused on mathematical models. However, the disruption management in container terminals has the features of multi-objectives, uncertainty and complexity. It is difficult for mathematical models to tackle the numerous variables and constraints. Also it is difficult to measure or evaluate the disruptions and modification scheme precisely. Therefore, the scientificity of modification scheme for disruption can not be ensured.

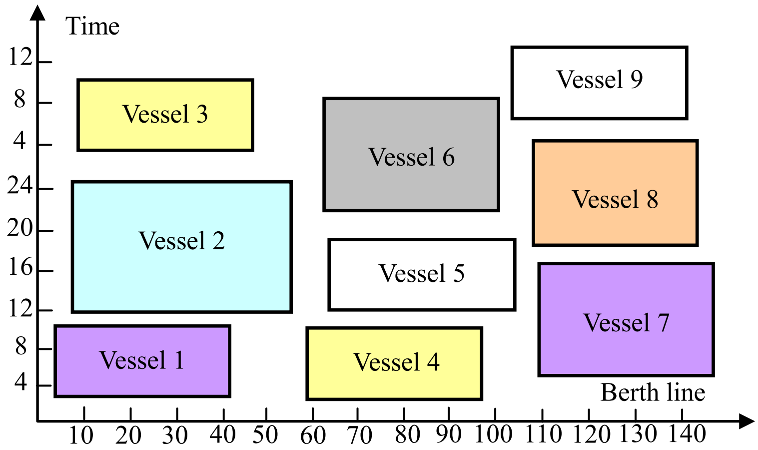
Therefore, in this paper, the problem of disruption recovery for berth allocation and QC scheduling is studied. The problem is formulated into a mix-integer programming model. And simulation is integrated with optimization algorithms to obtain the recovery schedule scientifically. To improve the computation efficiency, algorithms based on local rescheduling and genetic are designed. Finally, numerical tests are provided to illustrate the validity of the proposed model and algorithms.

3. Model for berth allocation

3.1 Problem descriptions

When scheduling berth, the berthing time and position of every ship must be determined. BAP consists of assigning a berthing position and a berthing time to each vessel within a given planning horizon. These decisions are made considering the different priorities, lengths, arriving and handling times of each vessel. As shown in Figure1, a solution of a BAP can be represented in a space-time diagram. The vertical axis represents the position on a quay line which is divided in segments of 10m length, and the horizontal one is the time axis which is divided in periods of 1 hour. The lower-left vertex of a rectangle represents the berthing position and the berthing time of a vessel. The objective of the BAP is to minimize the penalty cost resulting from delays in the departures of vessels and the additional handling costs resulting from non-optimal locations of vessels in container terminals

Figure 1: An example of berth scheduling



In the BAP model, the handling time of each vessel is usually assumed to be fixed and known in advance. However, QCs are scarce resource in container terminals, if several vessels berth simultaneously, the handling time of each vessel is influenced by QC assignment plan which is restricted by the total number of QCs. In addition, the number of QCs serving a vessel is often restricted by a minimum number and technically allowable maximum number.

For this reason, when determine the berth allocation plan, the assignment of QC should be considered. We call it simultaneous berth allocation and QC scheduling problem, (BACSP). This problem consist of two sub-problems: the first one is berth allocation and QC assignment problem which is to determine the berth allocation plan and the number of QCs assigned to each vessel, and the second one is QC scheduling problem which is to determine the QC routing according to the berth allocation and QC assignment plan.

Here, we use the model developed by Kim (2003), and extend it to model tackling disruption factors. The formulation of berth scheduling problem is based on the following denotations:

L the total length of a berth line;

N the number of ships;

a_i the estimated arrival time of ship i;

d_i the departure time required by ship i;

b_i the time required to finish the operation of ship i;

l_i the length of ship i;

p_i the best berthing location of ship i, in this location, the yard trailers have the least delivery cost;

x_i the berthing position of ship i;

y_i the berthing time of ship i;

c_{1i} the additional travel cost per unit distance for delivering the containers for ship i, resulting from non-optimal berthing location;

c_{2i} the penalty cost per unit time of ship i, resulting from the departure delayed beyond the required due time;

z_{ij}^x =1, if ship i is located to the left of ship j on the berth line, and 0 otherwise;

z_{ij}^y =1, if ship i is berthed before ship j in time, and 0, otherwise;

M a sufficient large constant.

Thus, the berth scheduling problem can be formulated as follows:

$$\text{Min} \sum_{i=1}^{N} \{c_{1i}|x_i - p_i| + c_{2i}(y_i + b_i - d_i)^+\} \tag{1}$$

s.t.

$$x_i + l_i \le L,\ \forall i \in N \tag{2}$$

$$x_i + l_i \le x_j + M(1 - z_{ij}^x), \forall i, j \in N, i \ne j \tag{3}$$

$$y_i + b_i \le y_j + M(1 - z_{ij}^y), \forall i, j \in N, i \ne j \tag{4}$$

$$z_{ij}^x + z_{ji}^x + z_{ij}^y + z_{ji}^y \ge 1, \forall i, j \in N, i \ne j \tag{5}$$

$$y_i \ge a_i,\ \forall i \in N \tag{6}$$

$$x_i \ge 0,\ \forall i \in N \tag{7}$$

$$z_{ij}^x, z_{ij}^y = 1, or 0,\ \forall i, j \in N, i \ne j \tag{8}$$

The objective function (1) is to minimize the delays in the departures of ships and the additional handling costs resulting from non-optimal locations of ships in a container terminal. Constraints (2) ensure that every ship must be berthed within the berth length. Constraints (3) denote the location relations between two ships, which are effective only when $z_{ij}^x = 1$. Constraints (4) denote the berthing time relations between two ships, which are effective only when $z_{ij}^y = 1$. Constraints (5) exclude the case where two ships are in conflict with each other with respect to the berthing time and the berthing position. Constraints (6) ensure that a ship cannot berth before it arrives at a container terminal.

3.2 Disruption management model for berth scheduling

Decision models used in disruption management typically take the form of a bi-criterion scheduling problem. The first criterion is the origin objective function, and the second is a measure of the deviation from the original schedule.

For berth scheduling problem, the deviation includes two parts. The first is the deviation of new schedule from original one, and the second is the additional travel cost resulting from new schedule.

Let $\bar{C}_i$ be the completion time of ship i in the original schedule (obtained by equation (1)-(8)), and $\bar{C}_i = y_i + b_i$. If no disruption occurs, ship i will finish processing at this time, so we can view $\bar{C}_i$ a special type of due date. If C_i is the real completion time in the new schedule when disruption happens, then the difference between C_i and $\bar{C}_i$ can be used to evaluate the deviation cost. In addition, the new schedule may induce the additional travel cost compared to original schedule.

Suppose that there are N' uncompleted ships left when disruption occurs. x_i', y_i' are the berthing position and berth time of ship i in the new schedule respectively, and $C_i = y_i' + b_i$. $z_{ij}^{x'}$ =1, if ship i is located to the left of ship j in the new schedule; and 0 otherwise. $z_{ij}^{y'}$ =1, if ship i is berthed before ship j in time in the new schedule; and 0, otherwise. T is the completion time of disruption event.

Thus, the disruption management model of berth scheduling can be formulated as:

$$\text{Min} \sum_{i=1}^{N'} \left\{ c_{1i} \left| x_i' - p_i \right| + c_{2i} \left| C_i - \bar{C}_i \right| \right\} \tag{9}$$

s.t.

$$x_i' + l_i \le L, \quad \forall i \in N' \tag{10}$$

$$x_i' + l_i \le x_j' + M(1 - z_{ij}^{x'}), \forall i, j \in N', i \ne j \tag{11}$$

$$y_i' + b_i \le y_j' + M(1 - z_{ij}^{y'}), \forall i, j \in N', i \ne j \tag{12}$$

$$z_{ij}^{x'} + z_{ji}^{x'} + z_{ij}^{y'} + z_{ij}^{y'} \ge 1, \forall i, j \in N', i \ne j \tag{13}$$

$$y_i' \ge a_i, y_i' \ge T, \forall i \in N' \tag{14}$$

$$x_i' \ge 0, \quad \forall i \in N' \tag{15}$$

$$z_{ij}^{x'}, z_{ij}^{y'} = 1, or 0, \quad \forall i, j \in N', i \ne j \tag{16}$$

The objective function is to minimize the deviation and the addition cost resulting from disruptions.

4. Simulation optimization approach

4.1 Framework of simulation optimization

It is well known that berth scheduling is a NP-hard problem. It is doomed unable to obtain optimal solutions for large-scale problems. Hence, heuristic algorithms are wildly used to obtain near-optimal solutions efficiently. However, because of the numerous constraints, it is difficult to evaluate a scheduling scheme in the process of heuristic algorithms, especially the calculation of $c_{1i} \left| x_i' - p_i \right|$.

Discrete event simulation has been a useful tool for evaluating the performance of such systems. However, simulation can only evaluate a given design, not provide more optimization function. Therefore, the integration of simulation and optimization is needed.

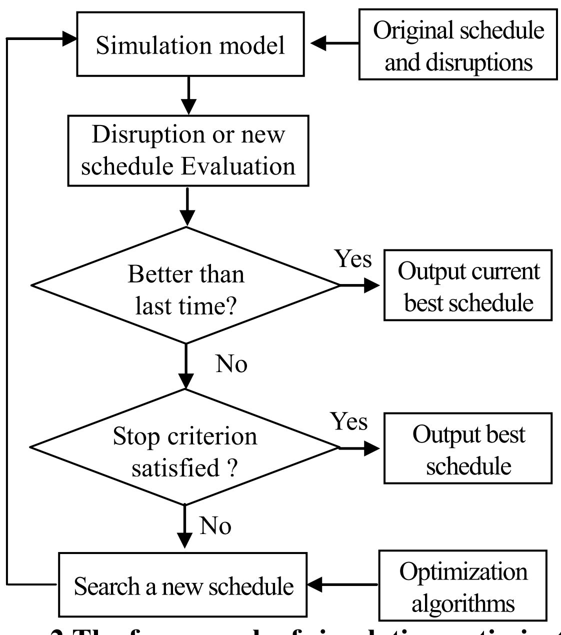


Figure.2 The framework of simulation optimization

As shown in Figure.2, the framework of simulation optimization modeling integrates a schedule simulation model and an optimization solver. It starts by activating the schedule simulation model to identify and assess the disruptions. The optimization solver is used to search a new schedule, and the schedule is evaluated by simulation model.

When the berth reschedule needs to be optimized after disruption happens, simulation model must be built first, and then the optimization algorithm is designed to optimize the parameters of simulation model. The setup of input and output variables, such as initial solution, constraints of decision variables, objective function, and repetition time of simulation in simulation model is done in optimization algorithm. As optimization algorithm running, it would create a set of feasible design variables, and transfer them to the simulation model by data interface; then the simulation model applies these variables to reconfigure the simulation parameters in real time, and run the simulation, then simulation results are returned to the optimization algorithm; according the results, the algorithm adjusts the direction of optimal solution searching and creates a new set of feasible solutions. The process would repeat until the stop criterion is satisfied. Finally, optimized design variables and best scheduling scheme are output.

4.2 Integration environment

An integration environment is needed to integrate simulation model and optimization algorithm. In this paper, Visual Basic is used as integration environment and Arena is used as simulation platform. Arena combines the simplification of high layer simulator and flexibility of simulation language. Also, it can integrate with Visual Basic and Visual C++, which enhances the modeling capability. The optimization algorithm is coded with Visual Basic6.0. The controlling of Arena simulation module is realized by Visual Basic, which can modify simulation parameter when Arena is operating, and control the running of Arena module. The process of integration is as follows:

Step 1: define an Arena application and activate it;
Step2: open an Arena project file, instantiate it in Visual Basic program;
Step3: find the required control module, instantiate and operate them in program, and return the results to Arena model;
Step4: run the Arena model;
Step5: deal with the results in Visual Basic program.

5. Simulation optimization algorithms

To improve the computation efficiency of simulation optimization, and thus provide online decision support for disruption management of berth scheduling, we design an algorithm integrating local rescheduling method with tabu searching.

The objective of disruption management is to find a new schedule which is optimal not only in terms of original objective, but minimization the deviation of updated schedule from original one. Therefore, disruption management does not simply optimize all future operations, and a good idea is to take the existing schedule into account to actually do local rescheduling.

Local rescheduling is based on the idea of responding to a disruption right there where it takes effect. Instead of trying to optimize the entire future immediately, it is first attempted to resolve problems locally (Kuster 2007).

To use local rescheduling in disruption management of berth scheduling, optimization starts within a relatively small time window first. And then the time window is extended until the entire future is considered.

Suppose t_c is the current time (i.e. the time when disruption is identified). t_e is the end of considered horizon. The considered time window is defined by a lower bound l_i and an upper bound u_i in each iteration

$i = \{1,...,n\}$. We set the lower bound t_c . The process of local rescheduling is as follows:

Step 1: initialize time window (t_c , u_0);

Step 2: if $i \le n$, go to step3, and step6, otherwise;

Step 3: update the upper bound by stepsize p_i , and $p_i = \frac{t_e - u_0}{n}$;

Step 4: optimize the reschedule using tabu search, $i = i + 1$;

Step 5: go to step2.

Step 6: end.

In step 4, tabu search algorithm (TS) is used. The basic TS guides the search to avoid getting trapped in local optima by moving from a solution to the best possible neighbor solution, even if it causes deterioration in the objective value. To prevent the search from cycling, attributes of recently visited solutions are memorized in a tabu list for a number of iterations (tabu duration). Neighbor solutions containing such an attribute are considered temporarily tabu or forbidden, unless they fulfill a so-called aspiration criterion.

Encoding and decoding of solutions: A solution is encoded by a sequence of ships. As shown in Fig.1, to decode a sequence of ships into a solution, rectangles of ships will be added into the time-berth plane one by one ensuring that the rectangles are not overlapped. Where (x_i, y_i) denotes the location of a ship in the sequence.

Initialization: A higher priority is given to a ship with lower values of p_i and d_i . The initial sequence of ships is in the increasing order of $p_i / L + d_i / \max\{d_i\}$.

Moves to obtain neighborhood: Pair exchanges, namely swapping the positions of two randomly selected elements, are used to obtain neighbors.

Tabu conditions and number of neighbors: To prevent a cycling of the solutions, a tabu list is used to save the last *m* (the size of tabu list) moves. The tabu condition is violated by the moves if the moves are in the tabu list. But on the other side, it is possible that a better solution is forbidden. To overcome this problem, aspiration criteria are used.

Depending on the size of problems to be solved, a suitable length of the tabu list is different Therefore, dynamic size for length of tabu list and number of neighbors is applied. Starting with the initial length of tabu list and number of neighbors, the parameters are adjusted automatically in the further procedure. If the is not any improvement after a certain of moves, the tabu list is increased; and if all moves are forbidden, the number of neighbors can also be increased.

The stopping criterion: When the best value of the objective function has not been changed during the previous five consecutive external loops or the total iterations are reached.

6. Numerical experiments

A numerical experiment is conducted to evaluate the validity of the proposed model and algorithms. Real data of a berth and size of ships are collected from a container terminal of Tianjin Port in China. Data for ships are collected from October November in 2007. The length of berth is 1200m. Different scenarios are designed according to the total considered horizon time and the number of ships (Table 1). The time of disruption happens when the operation of first ship are finished. Considering the practical situation in Tianjin port and taking the results of Kim (2003), c_{1i} and c_{2i} are set to be $10 l_i / 230$ USD and $2000 l_i / 230$ USD respectively. Using these data, two methods are compared:

1) *Local rescheduling with tabu search algorithm*, namely the algorithm described in Section4. The number of iterations n is set to 4 when $t_e \le 7\text{day}$; and 6, when $t_e > 7\text{day}$.

2) *Full rescheduling*: To optimize all future operations, and tabu search is used.

The computation Results are shown in Table 3.

Table 1 Results of different methods

Experiment scenarios		Local rescheduling		Full rescheduling	
t_e (days)	Number of ships	Objective value	Computation time(min)	Objective value	Computation time(min)
2	8	23	<1	23	<1
5	22	1546	<1	1535	4
7	34	1409	2	1409	21
10	41	2088	10	2057	42
12	52	2269	12	2232	75
14	65	2379	21	2345	214

From Table 3, we can find that comparing with full rescheduling, local rescheduling can improve the efficiency to obtain the new schedule coping with disruptions. The local rescheduling method performs particularly well if the considered problem is complex and if the time available to response to disruption is little. E.g. when the number of ships is 8, the difference of the two methods is small; and when the number of ships is 65, the solution computation of full rescheduling is longer than local rescheduling greatly. The characteristics of disruption management require the high speed and efficiency of solution algorithms, thus the local rescheduling based method is more suitable to disruption management problem.

In addition, in the optimization process, the simulation model can evaluate the influence of new schedule accurately, which can improve the scientificity of the new schedule.

7. Conclusions

In this paper, the disruption management problem of berth scheduling is studied. A simulation optimization approach is proposed to assess the influence of disruptions optimize the new berth schedule coping with disruptions. To improve the computation efficiency of simulation optimization model, an algorithm based on local rescheduling and tabu search is designed. Numerical experiments indicate that the algorithm based on local rescheduling and tabu search can improve the computation efficiency. And the simulation optimization method helps to reveal the evolution rule of disruptions and improve the accuracy and scientificity of the new schedule coping with disruptions.

In this paper, we only consider the disruption problem of berth scheduling. In fact, other operation resources in container terminals, especially the quay cranes should be considered when optimize the berth scheduling. This problem is open to further studies.

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Container Port Planning and Advanced Modeling Techniques

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Abstract

We present a general framework to support the operational decisions for port modeling using a combination of an optimization model and simulation techniques. Optimization models, in most cases, are deterministic and used for strategic or tactical decisions. Analytical performance models consider a dynamic and stochastic environment. They are used to investigate design or principal management decisions. These systems are represented as Markov chains or queuing models. The simulation model includes nonlinear and stochastic elements, while the optimization model represents a simplified version. Simulation techniques are used to analyze complex dynamic and stochastic situations and to understand issues of container port decision making.

A container port must be planned to satisfy prompt accommodation of ships with minimum waiting time in port, and with maximum use of berth facilities. Somewhere between these opposing objectives each container port must reach a compromise, the number of berths which will achieve the most economical transfer of cargo between ships and shore.

The increasing number of publications in the late decade indicates the importance of operations research models in the field of optimizing logistic operations at a container terminal. We attempt to provide a representative literature review concerning operations research models and applications in this important logistics field.

Keywords: Container port, Berth allocation, Problem classification, Simulation modeling

1. Introduction

Container ship operation usually begins with the ship's arrival to the port area. Depending on the state of congestion, the ship may or may not have to wait in the anchorage area. After berthing, the ship-berth link handling operation begins with preparing the ship for loading/unloading, and the QCs (quay cranes) and gangs are assigned for loading/unloading the containers. When these activities are complete, the ship may have to wait before it can leave the port.

The berth allocation problem (BAP) is defined as allocation of space along the quayside to incoming ships at a container terminal in order to minimize some objective function. According to Imai et al. (2005) three cases are notable: 1) the berthing area is partitioned into discrete berths, where each berth is occupied by at most one vessel at a time; 2) continuous case where multiple vessels can moor simultaneously at arbitrary location in a quay; 3) hybrid case is introduced when small ships may share a berth while large one may occupy more than one berth. The classification of literature has been made upon the algorithm and model implementation, thus forming the Operational research literature class, Artificial intelligence literature class and the specific heuristics class. Within this classification, an additional classification has been made upon spatial, as well as temporal attribute. In addition to this, we also review some specific features of each model.

The static variant considers vessels available for berthing at the port at the decision time. In this kind of models, vessel can be speeded up to reach the berth earlier than the expected arrival time or it waits at the port for berthing. The dynamic variant defines fix arrival times of vessels so vessel cannot berth before the expected arrival time. From a practical point of view, the total sum of shore to yard distances for all containers to be loaded and unloaded should be minimized.

This paper is organized as follows. In Section 2 we review the literature focused on operational research algorithms. Subsections 2.1 and 2.2 deals with the models in berth allocation problem based on artificial intelligence techniques and specific heuristics. In Subsection 2.3, literature based on some developed special heuristics is reviewed and this Subsection provides a new classification scheme based on previously mentioned classes. Literature review of container port operations planning by simulation models are given in Section 3. Finally, we conclude by summarizing the results and contributions of this paper in Section 4.

2. Operational research algorithms in berth allocation problem

Authors in (Bierwirth and Meisel, 2009) do not solve the berth allocation problem and the quay crane allocation problem simultaneously. They prefer to develop an efficient heuristic for the berth allocation problem and, then, in a subsequent study, to devise a decision support system where the quay crane allocation problem is solved considering non-linearities. Test instances are derived from analyses of real traffic and berth allocation data in port of Gioia Tauro. In real world examples a large number of constraints occur in dynamic berth allocation problem. This was a motivation for work (Hansen and Oquz, 2003) where authors presented an equivalent, more compact, formulation of dynamic berth allocation problem suitable for mixed integer programming. The minimum cost berth allocation problem has been introduced in (Hansen et al., 2008).

Proposed Variable Neighborhood Search heuristic is compared with Multi-Start, a Genetic Search algorithm and a Memetic Search algorithm. It appears that the use of systematic exploration of neighborhoods is superior to multiple restarts or use of a crossover operator. Hendriks et al. included due dates of vessels into a dynamic berth allocation problem (Hendriks et al., 2008). For periodically arriving container vessels predetermined time windows are defined. The model also incorporates crane capacity reservations for every vessel. The objective is to minimize the maximum crane capacity reserved for a period. Legato et al. 2008 proposed two phase approach to the quay crane deployment problem. They use outputs from model introduced in (Park and Kim, 2003), such as berthing position and berthing time as well as due time. After that, optimal number of cranes that must be assigned to each vessel for each time period is identified in the first phase. The heuristics in second phase is used to identify which cranes must be assigned to the vessel. Lim (1999) examines ship berthing problem represented as directed acyclic graph. This is a NP-complete problem hence near optimal solutions are generated by greedy algorithm and tabu search. A vertex in graph is assigned to every ship. The vertex weight is set to the length of the ship. If two ships have time overlap then there is an edge between them with weight calculated as the larger number of the two ships inter-ship clearance distances. Park and Kim (2003) have introduced a non-linear integer programming model that also considers quay crane assignments. The main assumption that allows integrating the berth allocation problem and the quay crane allocation problem is that handling times vary linearly with the number of quay cranes assigned to a vessel. The quay is represented as a continuous line. The objective function to minimize is the sum of penalty terms over all ships. The assumption is that an optimal berthing point is known. Whenever a different choice is made a penalty is applied. Penalty costs are incurred as well as to early ship arrival and late departure. The algorithm uses Lagrangean relaxation and a subgradient optimization technique.

2.1. Artificial Intelligence in berth allocation problem

Artificial Intelligence (AI) is a discipline of science developed by vision as having machines or software act more like humans. Genetic algorithm (GA) based heuristic is widely used in solving difficult problems and has a practical short computational time. Genetic algorithm produces answers near to optimal results. This heuristic work on the principle of evolving a population of trial solutions over several iterations, to adopt them to the fitness landscape expressed in the objective function. Imai et al. (2007) describes a linear model and a GA-based solution algorithm convenient for an indented terminal. Multiple small ships can be served by the same berth simultaneously. Integer linear program of the problem is presented. Solutions are compared with solutions in a conventional terminal of the same size. Mega ships are served faster but total serviced time of all ships is longer in intended terminals. Authors in (Imai et al. 2007a) solved a discrete berth structure by developing a genetic algorithm based heuristic also incorporating service priorities for vessels. They assume that each berth can serve one ship at a time and there are no restrictions where ship can be moored. Ship handling time is assumed dependent on the berth where it is assigned. Objective function minimizes the sum of waiting and handling times for every ship. In (Imai et al. 2001) objective is minimization of the total service time of ships in continuous berth allocation problem. Handling time of ship depends on the quay location assigned to it. Two stages heuristic is presented as a solution for this problem, by improving discrete case solution. Directions of edges are fixed in such manner that obtained new graph is directed acyclic graph with minimal longest path. The study (Imai et al. 2007b) deals with minimization of the total service time of ships and with minimization of the total of delay of ships from the expected departure time. A genetic algorithm is proposed in (Nishimura et al., 2001) for a nonlinear formulation of the discrete berth allocation problem. The approach allows simultaneous service for up to two vessels assigned to the same berth area if total vessel size does not exceed the size of the berth area. Ships cannot be always serviced at the assigned berth. Berthing is limited with some physical restrictions such as water depth.

Linear Programming model is used in (Briano and Bruzone, 2005) for improving berth assignment and a simulation model which represents the marine-side operations of a container terminal. All factors involved in the berthing process such as stochastic process of the incoming ships, sea conditions, and the consequent extra costs due to additional wharf occupation for improper dock schedule are considered in this model. All operations are divided in tasks. Every task requires the work specialization and the availability of the resources allowed doing this task. The objective function minimizes the penalty cost from the delay of the departure of vessels behind the requested departure time and the distance from best berthing position.

Up to now, there are only a few studies on such an integrated multi-agent approach, providing an optimized system including several agents (agents for ship, berth, yard, and gate and utility agents, for quay crane, gantry crane and transport). In papers (Henesey et al., 2003 and Henesey et al., 2006) authors described how container terminal entities can be implemented trough a multi agent system approach. The multi agent system presented in the paper is offering both a dynamic yard allocation and a dynamic berth allocation. The main goal of optimizing the capacity of the terminal is investigated by suggesting the use of a market based approach, in which agents are trading services. The berth agent is responsible for the allocation of resources at a dynamically changing part of the quay. The simulation tool, called SimPort, is a decentralized approach to simulating managers and entities in a container terminal. The results of the research indicate that the performance of a container terminal can be improved by using agent-based technologies. Multi-agent based simulation seems to offer container terminal management a suitable tool to improve productivity. Therefore, "integrated optimization" should be a field of increased investigation.

2.2. Specific heuristics in berth allocation problem

Dai et al. (2004) solve the static berth allocation planning problem as a rectangle packing problem with side constraints. The chosen objective function involves a delicate trade-off between the waiting time experienced and the deviation from preferred berthing space allocated. The packing algorithm must minimize the delays faced by vessels, with higher priority vessels receiving the promised level of services. Guan et al. represents a vessel as a job (Guan et al., 2002). The m parallel processors represent m cranes located along the berth, where the size of a job represents the number of cranes that will serve the vessel simultaneously. The objective of minimizing the total weighted completion time corresponds to the minimization of total weighted waiting time of the vessels.

In (Lim, 1998) the quay is represented as a continuous line. A heuristic solves the problem of deciding the berthing points given the berthing time of the ships, assuming constant handling times. This approach does not solve the general problem in which the berthing time is a decision variable and the handling time varies along the quay.

Meisel and Bierwirth (2006) considered the integration of the berth allocation problem and the crane allocation problem. Objective function that aims at a reduction of quay cranes idle times is introduced. The problem was solved heuristically by a priority-rule based method.

2.3. Literature classification

We attempt to provide a representative literature review concerning operations research models and applications in this important logistics field. The classification of literature has been made upon the algorithm and model implementation, thus forming the Operational research literature class, Artificial intelligence literature class and the specific heuristics class. Within this classification, an additional classification has been made upon spatial, as well as temporal attribute. In addition to this, we also review some specific features of each model. This classification is summarized in the Table 1.

Most models given thus far aim at the minimization and optimization of the port stay time of vessels. A frequently addressed issue is the berthing position different from the desired one. An optimized berth allocation is especially important in case of ship delays when a new berthing place needs to be allocated.

Table 1: BAP literature classification

Classification	*Solution method*	*Spatial attribute*	*Temporal attribute*	*Characteristics*	*Papers*
Operational research techniques	Tabu search	Discrete	Dynamic, due	The BAP and the QCAP are not solved simultaneously	Cordey et al., 2005
	Mixed Integer Programming	Discrete	Dynamic	Exact solution of berth allocation problems of a realistic size	Hansen and Oguz, 2003
	Variable neighborhood search	Discrete	Dynamic	A compact reformulation for the dynamic BAP is provided	Hansen et al, 2008
	MILP	Continuous	Dynamic, due	Construction of a window-based periodic berth plan is established	Hendriks et al., 2008
	Integer Programming	Continuous	Dynamic, due	- vessel has a maximum number of cranes that can be assigned - vessel has a minimum number of cranes that must be assigned	Legato et al., 2008
	Non-linear integer program	Continuous	Static	- number of quay cranes assigned to a vessel linearly determines handling times - BAP and the QCAP integration	Park and Kim, 2003
	Greedy algorithm, Tabu search	Continuous, draft	Dynamic	Graph representation of a BAP	Lim 1999
	Packing algorithm	Hybrid	Dynamic	Areas where certain vessels have already been moored are recognized as “forbidden” regions	Dai et al., 2004
Artifical inteligence techiques	Genetic Algorithm	Hybrid	Dynamic	Short string chromosome representation	Imai et al., 2007a
	Genetic Algorithm	Discrete	Dynamic	Service priorities for vessels	Imai et al., 2001
	Genetic Algorithm	Continuous	Dynamic	Handling time depends on the quay location where the ship is moored	Imai et al., 2005
	Subgradient optimization, Lagrangian relaxation, Genetic Algorithm	Discrete	Dynamic	The berth allocation ignores the FCFS rule	Imai et al., 2007b

	Non-linear integer program, Genetic Algorithm	Hybrid, draft	Dynamic	Chromosomes are represented as character strings	Nishimura et al, 2001
	Multi-agent system	Continuous	Dynamic	All CT entities are represented as agents	Henesy et al., 2003 and 2006
	Linear Programming, Symulation	Continuous	Dynamic	Decision support system is implemented	Briano and Bruzzone, 2005
Heuristic	Heuristic H	Continuous	Static	M processors with agreeable job processing times and job sizes	Guan et al., 2002
	Priority-rule based heuristic	Continuous	Dynamic	Integration of the BAP and the CAP	Meisel and Bierwirth, 2006
	Graph based heuristic	Continuous	Dynamic	Concise graph representation of the problem is proposed	Lim, 1998

3. Container port operations planning by simulation models: Literature review

Simulation models have been used extensively in the planning and analysis of operating processes at a container terminal. Many different simulation models regarding terminal operation, especially anchorage-ship-berth link, terminal design, container yard optimization planning, YC (yard crane) deployment, container handling and storage operations in a yard and others, have been developed in papers which are given Table 2. These models are coded in different simulation languages, as it can be seen in Table 2. In addition, Kozan (1997) gives a review on recent analytical and simulation models. Yamada *et al.* (2003) presented a mathematical model with the queuing theory for determining optimal container handling systems so that the total cost incurred in a container terminal is minimized. A simulation model was also developed to investigate the performance of the mathematical model.

It should also be pointed out, as shown in Table 2, that there are a few overview concepts of container port operation literature given by Vis and Koster (2003), Steenken et al. (2004), Stahlbock, and Voß (2008), Günther and Kim (2006) and Kim (2005). Good surveys of container port operation have been done by these papers.

Table 2: Literature overview of container port operation planning by simulation models

Considered problems	*Approaches*	*References*
Simulation of ports and container terminals (CT)	PORTSIM Modsim III Object oriented programming, C++ ARENA, SLX Visual SLAM AweSim Witness software Taylor II GPSS/H Extend-version 3.2.2 Scenario generator Java	Nevins et al. 1998; Gambradella et al. 1998 and 2001; Yun and Choi 1999; Tahar and Hussain 2000; Merkuryev et al. 1998 and 2000; Lee et al. 2003; Park et al. 2006-2008; Dragović et al. 2009 Legato and Mazza 2001; Nam et al. 2002; Ng and Wong 2006; Shabayek and Yeung 2002; Martinez et al. 2003; Kia et al. 2001; Pachakis and Kiremidjian 2002; Dragović et al. 2005 - 2008; Sgouridis et al. 2003;

	Generic simulation model Discrete event simulation	Hartmann 2004; Bielli et al. 2006; Otjes et al. 2006; Dahal et al. 2004;Canonaco et al. 2008; Petering & Murty 2009; Petering et al. 2009.
Overview concept and surveys of recent research on CT	Quantitative models for various decision problems in CT; Logistics processes and operations in CT – optimization methods; Operations research at container terminals: a literature update; CT and terminal operations; Models and methods for operations in CT.	Vis and Koster 2003; Steenken et al. 2004; Stahlbock and Voß 2008; Günther and Kim 2006; Kim 2005.

Tugcu (1983) used a port simulation model to aid investment planning for the Istanbul seaport. El Sheikh et al. (1987) developed a simulation model to help the planning of future berth requirements of a third-world port. Chung, Randhawa, and McDowell (1988) proposed a method that uses buffer space to reduce container loading times and optimize equipment utilization, and a simulation was developed to justify their method. Silberholz, Golden, and Baker (1991) employed simulation to study the impact of work crew schedules on container port productivity. Hassan (1993) presented a simulation to be used as a decision support tool for evaluating and improving port activities. Ballis and Abacoumkin (1996) developed a simulation with animation to simulate the operational activities of a container terminal with straddle carriers. Ramani (1996) developed a simulation to support the logistics planning of seaports. The simulation provided estimates of port performance indicators such as berth occupancy, ship output and ship turnaround times for various strategies. Merkuryev et al. (1998) used simulation to improve logistics processes at Riga Harbour Container Terminal. Merkuryeva et al. (2000) considered simulation of containers processed at the Baltic Container Terminal in Riga as a basic simulation research, and then its complementing by a metamodelling study is discussed.

Nevins et al. (1998) simulated the operations of a seaport, and provided detailed statistics on seaport throughput and resource utilization. Gambardella, Rizzoli, and Zaffalon (1998) developed models of an intermodal container terminal to aid container allocation in the terminal yard, resource allocation and operations scheduling. Thiers and Janssens (1998) used a port simulation model to investigate the hindrance of a river quay. Bruzzone and Signorile (1998) employed genetic algorithms and simulation to make strategic decisions about resource allocation and terminal organization. Yun and Choi (1999) proposed a container terminal simulation model using an object-oriented approach. Gambradela et al. (2001) presented a solution to the problems of resource allocation and scheduling of loading and unloading operations in a container terminal. Legato and Mazza (2001) focused on the berth and allocation of berths to arriving ships with queueing network based on the model which is simulated by Visual SLAM software in various scenarios.

Their model was tested with data from Gioia Tauro container terminal. Key issues of the application of modeling and simulation for the management of the Malaysian Kelang container terminal are discussed in paper by Tahar and Hussain (2000). Nam et al. (2002) examined the optimal size of the Gamman Container Terminal in Pusan, in terms of berths and quay cranes using the simulation analyses which were performed in four scenarios, representing different operational patterns. Shabayek and Yeung developed simulation model employing the Witness program to analyze the Hong Kong's Kwai Chung container terminal performance. It is shown to provide good results in predicting the actual operation system of the terminal. Kia et al. (2002) investigated the role of computer simulation in evaluating the container terminal performance in relation to its handling techniques and their impact on the capacity of terminal. Pachakis and Kiremidjian (2003) presented a ship traffic modeling methodology based on statistical analysis of container ship traffic and cargo data obtained from a port in the United States. Sgouridies et al. (2003) focused on the simulated handling of incoming containers. Results on the service level, i.e., service times, utilization factor, and queues, are generated for analysis. Demirici (2003) developed simulation model to analyze port operations and was run especially for investment planning. This paper discussed the simulation model results of Trabzon port. Simulator calibration and validation were also presented in the paper at the Casablanca container terminal. van Renzburg et al. (2005) described a computer simulation model of ocean container carrier operations. Their simulation is called SimSea. Ali Alattar et al. (2006) simulated different condition to find out the queue of containers at the port and also analyses the effect of increase in the facilities at the port to reduce this queue. Ng and Wong (2006) developed a simulation model for studying the impact of the vessel-traffic interference in Hong Kong's terminal basin on its container terminals' capacities.

Due to the cost and complexity involved in container terminal and ship operations, the simulation models have been used extensively to understand the behaviour and test different strategies in the container terminal systems and the modeling, planning and analysis of container terminals, e.g. see (Bielli et al., 2006; Canonaco et al., 2008; Dahal et al., 2003; Dragović et al., 2005 – 2009; Lee et al., 2003; Park et al., 2006 – 2008; Petering et al., 2009; Petering and Murty, 2009 and Petering 2009. Bielli et al. (2006) proposed simulation model which can improve ports efficiency and they gave the architecture components that are implemented with Java. Simulator calibration and validation were also presented in the paper at the Casablanca container terminal. Canonaco et al. (2008) focused on the optimal management of container discharge/loading at any given berthing point, within a real maritime terminal. Due to its complexity, discrete-event simulation appears as the most appropriate approach to model solution. Dahal et al. (2003) developed a genetic algorithm based approach to provide an optimization capability to the port simulation tool. Two case studies based on real world port systems are presented and the results are discussed. Dragović et al. (2005 – 2009) gave the simulation and analytical models results for ship berth link of the Pusan East Container Terminal (PECT).

They developed simulation models which can be used by the port management to improve different operations included in the process of ship service at the ship-berth link. Dragović et al. (2005b) developed simulation models of ship-berth link with priority service in container port. The ship berth-link performance for five alternative strategies was evaluated, and system behavior observed. The results revealed that simulation modeling is a very effective method to examine the impact of introducing priority, for certain class of ships, on the ship-berth link performance at PECT. In order to determine the performance evaluation of ship-berth-container yard link in port Dragović et al. (2006 – 2008) proposed two models based on simulation and queueing theory, respectively. Numerical results and computational experiments were reported to evaluate the efficiency of the models for PECT. In these papers authors addressed the problem of how to optimize the balance between the shipowners who request quick service of their ships and economic use of allocated resources at container terminal where the cost structure of terminal plays a significant role. The authors provided a tractable algorithm to obtain high-quality solutions. The above works study the optimizing problem in a container terminal and focus on the computational algorithm. Different from them, the papers (Dragović et al. 2009a and 2009b) studied the integration of container berth and yard simulation planning and modelling wit more attention on the close form analysis about cost strategy in a container terminal as well as optimal throughput calculation. Lee et al. (2003) presented the modelling and analysis of the dynamics of business processes and interaction between business entities in a supply chain with multiple objectives. The simulation approach serves two purposes: to model a supply-chain network in quantity approach and to evaluate its supply-chain performance based on proposed strategies. Results on the service level, i.e., service times, utilization factor, and queues, are generated for analysis. Park et al. (2006 – 2008) developed simulation models to calculate optimal throughput of a quay by port type and determine terminal performance. It is shown to provide good results in predicting the actual terminal operations system of the Korean container port.

Petering et al. (2009) developed a real-time yard crane control system and show that a terminal's long-run average quay crane rate depends on the portion of this system that dispatches yard cranes in the storage area in real time. Petering and Murty (2009) investigated how two parameters - (1) the length of the storage blocks in a terminal's container yard and (2) the system that deploys yard cranes among blocks in the same zone - affect the overall, long-run performance of a seaport container terminal as measured in terms of GCR (i.e. average quay crane work rate). Toward this end, the authors constructed a discrete event simulation model of terminal operations that was designed to reproduce the multi-objective, stochastic, real-time environment at a multiple-berth facility. Petering (2009) investigated how the width of the storage blocks in a terminal's container yard affects the overall, long-run performance of a container terminal as measured in terms of GCR. To understand this relationship, he discussed container yard operations in more detail.

All the previous studies assumed that the objective simulation models are developed in different environment, and that optimal solutions can be obtained. However, in container terminals, there are many complicated constraints to be satisfied, and so, finding an optimal solution itself is a difficult problem. This is why simulation models of dynamic transfer operations based on real-time positioning are applied to the many deployment problems in container terminals.

4. Conclusions

To our knowledge, our work is the first one to study the integration of container planning operations using a combination of an optimization model and simulation techniques. We hope that the managerial insights obtained by studying this problem can help container terminal operators understand more about the integration of container berth and yard with optimal throughput calculation in container terminal and shed light on more practical problems.

The contribution of this paper to the existing literature is the following. First, we present the operational research algorithms in berth allocation problem integration, could provide an acceptable solution for the terminal links involved. Second, we analysed some models in berth allocation problem based on artificial intelligence techniques and specific heuristics. Third, we provide a new classification scheme based on previously mentioned classes of models. Fourth, we explained literature review of container port operations planning by simulation models.

The importance of planning operations at container terminals becomes more and more obvious. An increasing number of theoretically and practically oriented papers during the last decade can be observed. Lately, there has been a tendency to move from relatively theoretical publications to more practical ones and even apply them in real terminals. A prerequisite for such applications is an increased availability of modern information and communications technology. Comprehensive surveys of container port operation planning have been done by these papers. The past few years have been an increasing interest in combinatorial optimization models and their solution techniques. One of the driving forces behind this area has been new developments in container terminal modeling, especially in dynamic logistic systems and wide area maritime networks.

Finally, one can conclude that all of these main port links have been adequately analyzed and modeled by using different simulation approaches. Various operations research models and methods in the field of optimizing main port link planning are applied more and more in world terminals.

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Quayside Container Cranes: Development and Automation

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Abstract

Quayside container cranes (QCs) have had a dramatic development in the period from 1959 to 2009 in depending on the generation of ship. For these reasons, faster serving of ships at berths can be reached by: generally increase the QC efficiency; increase the QC rate by lifting two loaded containers simultaneously; and the new technical solutions.

The fact that the QCs should be quicker, larger and more efficient, force both the manufacturer and terminal operator to incorporate to the equipment some automation for the repetitive process of handling containers. For the years many authors have been researching and developing ways to make QCs transfer containers faster and more safely through computerized anti-sway and automatic controls. Automation continues to evolve and will continue to improve productivity of QCs. Automation is also another important aspect of QC becoming a conglomerate of sophisticated elements of high added value consisting of specialized software and hardware. The behavior of the QC with antisway device is completely different from that the QCs without it. The outline of the classification of existing QCs due to their degree of automation is shown in this study.

Keywords: Quayside crane, QC development, QC automation

1. Introduction

The port container terminal continues to expand. New, more productive QCs are needed. New wharves must be designed to carry the new QCs and allow for uninterrupted use of the quay. For years the design team members - the mechanical, structural, automation, and electrical engineers have worked together to produce economical design that meets operational demands and can be efficiently fabricated and erected. The QC is not only part of the terminal system, but is also a system in its own right. As always, the best (optimum) design requires balance. The cost and benefits of each alternative should be considered in concert. For each crane purchase, the owner will need to evaluate each design and then choose the design which best suits the site and all-round operational needs. Also, the ability to economically upgrade existing QCs within a short time is a key to an effective modification program.

The analysis of the past and state of the art of QCs may help us to predict the future trends in their development. New QCs should be designed that are big and fast enough to keep up with the demands of new larger ships. Some expected performances of future QCs are as follows: the QC rail gage to as much as 45.72 m; lift above rail up to 47.55 m; outreach above 65 m (increase of the outreach will follow the increase in the size of ships because current New Standard Maersk crane orders provide for ships with 22 containers on deck while ships with 23 containers on deck are referred to as Suezmax, and with 24 containers across as Malacca Max); trolley travel speed from 250 to 300 m/min, or even more (in 2002 ZPMC made fundamental improvement on the trolley starting up, braking and travelling, and the trolley speed has successfully reached 350 m/min, instead of previous 240 m/min); types of trolley systems, RTT and MOT have beneficial site-specific applications, and are viable.

The paper gives the state-of-the-art of development and automation of QCs, as the biggest investments in the port terminal system (Dragovic et al., 2010). The automation techniques increase the productivity of the QCs, and consequently increase the port terminal efficiency, as an integral part of logistic network (Davis Rudolf III, 2007). The paper also shows a short survey of some most important and recent researches in control of QCs, and main principles of operation of antisway currently existing devices.

This paper is organized as follows. Section 2 presents a brief description of evolution of QCs industry. Section 3 gives the development of mechanical and structural design of QCs. Development of mechanical design of trolley is presented in Section 4. Section 5 provides QC automation with basic facts on the automation. Basic principles of anti-sway systems operation are given in Section 6. The final Section gives concluding remarks.

2. Evolution of QCs industry

At these early 1960s a crane container purchaser could call up a PACECO (at that time a US company) representative in any part of the world and order QCs. Around the same time, European manufacturers entered the market, offering improved and standard design, good quality and competitive prices. The Japanese entry into the container crane industry in the late 1960s presented some opportunities and, for the first time, some challenges for the purchasers. Japanese consumer and industrial products were introduced to the world market at significantly lower prices. The first reaction in the Western world was “No such thing as a free lunch – you will pay for it one way or another” (Bhimani and Jordan, 2001). But, some large shipping lines saw opportunity in the new competition and decided to give the Japanese a try. The Japanese provided good quality cranes, and within a short time they were in the same category as the Americans and Europeans. With the growth of the economy and domestic demand increasing, Japanese cranes ceased to be a bargain. The concept of purchasing cranes with the “Tailor-Made” specification was born. The “Tailor-Made” philosophy requires the detailed performance specifications and very competitive bids. A larger number of cranes brings economy of scale and favors this concept. Tailor-made cranes require high expertise, whether in-house or through outside consultants (Bhimani and Jordan, 2001).

Korean QCs manufacturers were next with the lower-priced cranes, starting from 1970s. Now, at the beginning of 21st Century the Chinese manufacturer ZPMC, Shangai, has made the most significant impact on the QCs industry, and may further increase its share of the world market during the coming years. The actual situation is that PACECO could no longer compete with the overseas suppliers, some European suppliers have merged or quit manufacturing QCs, and the Japanese suppliers retracted from the international market and remained focused on their protected domestic market. To compete in the current market, established cranes builders have shifted fabrication and assembly to remote plants with cheaper labor, purchased electrical components and integrated them in-house, used standardized components and reduced profit margins. The use of standardized components favors the “Off-the-Shelf” approach in design of QCs. The aim of this strategy is to emulate the early purchasing strategy of issuing a brief technical outline and inviting proposals from two or more crane suppliers (Bhimani and Jordan, 2001).

3. Development of design of QCs

The basic structural form of QCs (A-frame) remains practically unchangeable compared with the first structure built in 1959. The A-frame gantry crane takes its name from it’s “A”-shaped noticeable when observed from the bridge. On 7 January 1959 the world’s first container crane was put into service at the Encinal Terminals in Alameda, California, Figure 1 (Zrnić and Hoffmann 2009). Of course some modifications are done. The basic structural shape of QCs can be divided into two groups:

- Conventional or modified conventional cranes, Figure 4 (Morris and Mc Carthy, 2001);
- Low profile cranes, Figure 5 (Bhimani, 2003).

Conventional QCs are used for servicing the following ships:

1. **Panamax ships:** III-generation ships with a beam of less than 32.3 m (width of Panama Canal) – their structure was developed from end of 1960s up to early 1980s, and they operate with up to 13 containers abeam on deck and with maximum capacity of 4,700/4,900 TEU (Twenty Equivalent Unit);

2. **Post-Panamax ships:** IV-generation ships, developed from 1984, whose beam is greater than the width of the Panama Canal – they operate with up to 20 containers abeam on deck and with a maximum capacity of 7,000 TEU;
3. **Mega ships or Jumbo ships:** Ships of the most recent generation, pioneered in the last years of the 1990s, they operate with more than 20 containers abeam on deck and with a capacity of more than 7,000 TEU.

In the meantime, to keep up with the growth of container traffic, container ships and QCs are getting bigger and bigger. During the first 48 years since the first QC was designed, the size of QCs and lifting capacity has almost tripled, Figures 2 and 3 (Verschoof 2002; Zrnić and Hoffmann 2004; Zrnić and Hoffmann 2009). Figure 9 presents growth of QCs, 1959-1995, while Figure 3 shows comparison between the first QC (1959) and MalaccaMax QC (2003).

Figure 1: First QC

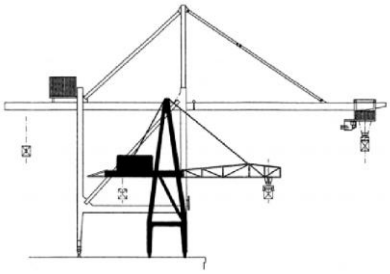


Figure 2: Growth of QCs

Figure 3: Comparison between QCs

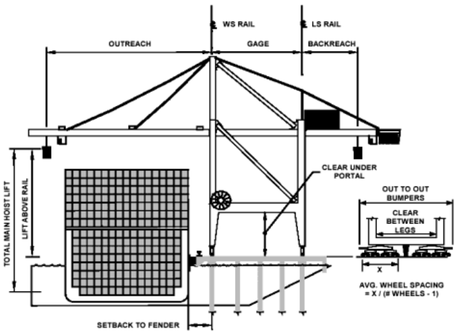


Figure 4: Conventional QC
Source: Morris and Mc Carthy, 2001

Figure 5: Low profile QC
Source: Bhimani, 2003

4. Development of mechanical design of trolley

The selection of a crane's trolley system type is significant for the structure of crane, for wheel loads, and for maintenance considerations. The trolley can be rope towed (RTT) or machinery type (MOT). A hybrid of the two systems, commonly known as a fleet-through machinery trolley (or semi-rope trolley, Jordan, 1998; Zrnic and Petkovic, 2002), was adopted by some manufacturers. For the fleet-through machinery trolley the main hoist machinery is placed on the gantry frame, but the trolley is self-driven. Since the machinery in the machinery house tow the trolley and hoist the load by a system of wire ropes, this system is called a RTT system. The main hoist ropes run from the machinery house to the landside of the crane, through the trolley and head block, and usually dead end at the waterside tip of the boom, Figure 11 (Bhimani and Hoite, 1998).

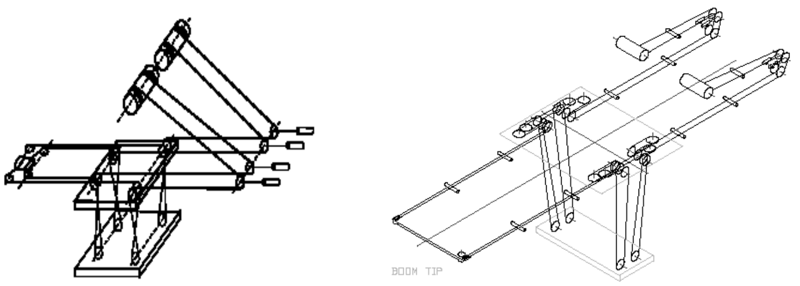


Figure 6: Main hoist reeving, RTT system
Source: Bhimani and Hoite, 1998

The trolley tow ropes run from the machinery house to the sheaves at the landside of the crane, through the trolley to the tip of the boom, and back to the house, Figure 7. This arrangement allows the trolley to be shallow and lightweight, permitting greater lift height and smaller loads on the crane structure and wharf (Morris and Mc Carthy, 2001).

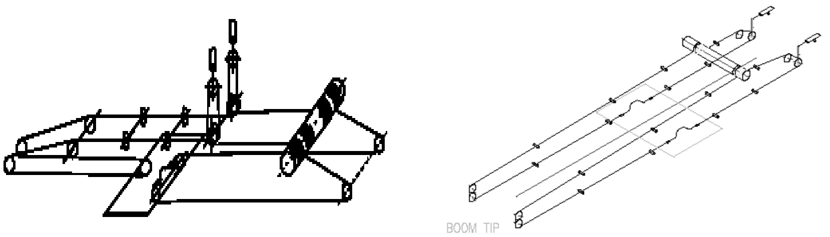


Figure 7: Trolley reeving, RTT system
Source: Bhimani and Hoite, 1998

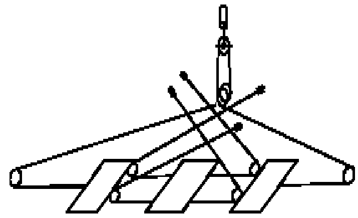


Figure 8: Catenary trolley
Source: Bhimani and Hoite, 1998

With the RTT design, there was concern that the rope would stretch and that catenary effect would reduce productivity. The auxiliary catenary trolley is the typical solution for reducing the catenary effect due to greater outreach of modern cranes and longer trolley travel, Figure 8. But even with the catenary trolley, the long runway will result in a significant catenary effect [3].

A machinery trolley (Figure 9, Jordan, 2001) has the trolley and main hoist machinery on board. No trolley drive ropes are required, and the main hoist ropes (Figure 10) are shorter than for a rope-towed trolley (Morris and Mc Carthy, 2001).

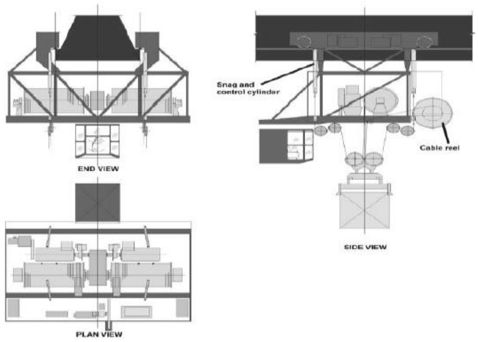


Figure 9: Construction of MOT
Source: Jordan, 2001

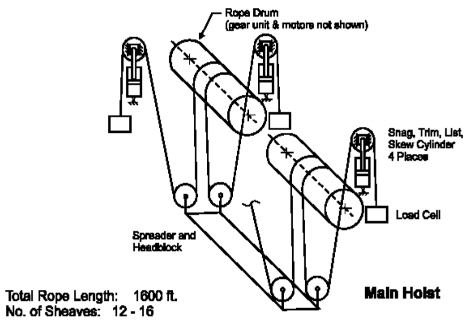


Figure 10: Reeving diagram for MOT
Source: Bhimani and Hoite, 1998

For the structural design, weight is the main difference between the two types of trolleys. The weight of the rope-towed trolley is approximately one-third that of a machinery trolley. The main disadvantage of the machinery trolley is the increase in crane weight and wheel loads on the wharf.

Why was the MOT system chosen? 1) Depending on the design, approximately 1,650 m of wire rope is eliminated from the main hoist, trolley drive, and catenary trolley; 2) Approximately 36 sheaves of various sizes are eliminated; 3) Hydraulic rope tensioning devices are eliminated; 4) The spare parts inventory is reduced; 5) The intensity of maintenance is reduced; 6) Up-time reliability is increased because of the reduced number of crane components; 7) Wire rope lubrication is reduced.

Table 1 presents a comparison of both mechanical systems.

Table 1: Comparison of mechanical systems of trolley

	Rope-towed Trolley RTT	**Machinery On Trolley MOT**	**Advantage**
Reeving Assemblies	Main Hoist, Trolley Drive Catenary Trolley Drive	Main Hoist	MOT
Trolley Positioning	Movement due to trolley travel rope stretch	Movement due to skidding	MOT
Festoon	Spreader power only	Power for main hoist (including trim, list, skew, and snag device), trolley drive, and spreader	RTT
Trolley Accelerations	0,6 m/s^2	0,6 m/s^2	---
Rope Lubricant	Exposed to environment. Oil spillage on ground.	Enclosed, spillage contained	MOT

Source: Morris and Mc Carthy, 2001; Zrnic and Petkovic, 2002

5. Automation of QCs

More current QCs control systems depend on the skill of the operators to put the load in the right place, quickly and safely. Full crane automation, from ship to shore, may be the answer to greater crane speeds and productivity demands (Zrnic, 2001). The higher operating speeds make the control task more difficult [27]. This is difficult to achieve for several reasons: accuracy will be required to automatically pick a container from a ship, Figure 11, and set it on a truck on the quay, Figure 4; the new container cranes have increasing degrees of automation that increase crane productivity (Zrnic, 2001). The realization of automation for the cranes at container terminal has been delayed compared with indoor service cranes caused by various problems at the outdoors environment.

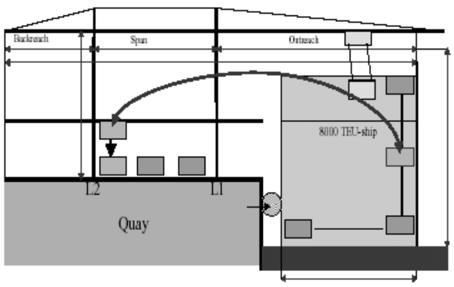


Figure 11: Schematical drawing of crane operation
Source: Klaasens et al., 1999

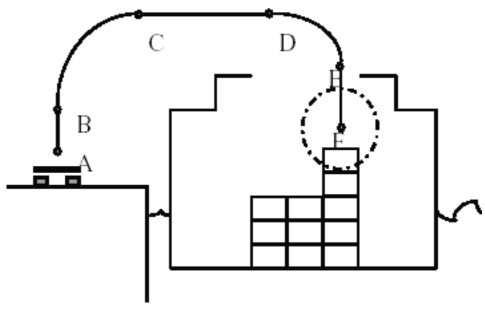


Figure 12: A "desired" trajectory of container
Source: Kimiaghalam, 1999

For the QCs, the main objection to achieving the full automation is that relative position of the ship to the crane could not be surely recognized due to the ship's rolling motion.

5.1. Basic facts on the automation of QCs

The fact that the QCs should be quicker, larger and more efficient, force both the manufacturer and terminal operator to incorporate to the equipment some automation for the repetitive process of handling containers.

Automation is also another important aspect of the container crane becoming a conglomerate of sophisticated elements of high added value consisting of specialized software and hardware (Sandman, 2001). Productivity is highly improved by automation because the crane operator sits in the cabin during a long periods of time just looking down and moving containers from one side to the other, and the repetitive task becomes so routine that it products discomfort and fatigue (Sandman, 2001). The results are also boredom that easily turns into the cause of accidents, thus including delays in the handling of loads. The basic common types of semi-automated and automated cranes are (Ioannou et al., 2001): QCs with Anti-Sway Systems; QCs with Automatic Positioning Systems and QCs with Automatic and Smart Spreaders.

QCs with Anti-Sway Systems

The pressure on the port terminal by the shipping companies to release vessels as fast as possible is used by port operators to specify that the cranes shall be supplied with an antisway system. Antisway systems are now common in newer QCs and most specifications for container cranes around the world contain requirements for computer antisway (Overton et al., 2000). These cranes are equipped with special control systems for killing sway. Most antisway systems can be installed without requiring major modifications of the crane. The behavior of the crane with antisway device is completely different from that the cranes without it or with the antisway system off (Sandman, 2001). An industrial computer reads the operator's speed and position commands from the control stick and sends appropriate modified commands to the motor drive to control sway while allowing the operator to maintain manual control. The computer measures the acceleration and deceleration of the trolley to match the pendulum period, so that the crane catches the load with no sway at the end of the move. Automatic moves to position the spreader are handled in a similar way. Antisway systems can be either feedforward or feedback, where feedforward means that no independent measurements of load sway are required. Such feedforward systems, by definition, cannot remove sway caused by external forces because the computer has no way of determining the magnitude or phase of the sway. However, such systems reliably limit sway to less than 15 centimetres. For finer control, some methods of measuring the position and velocity of the spreader are required. But the pure feedback systems have not proven effective in practice (Overton et al., 2000). Anti-sway devices are not without controversy. Most crane operators at commercial ports around the world are highly skilled and take great pride in their ability to work productively. Some types of anti-sway devices are disruptive to the crane operator in that the devices take control away from the crane operator, sometimes unexpectedly. In these cases the crane operator would be trying to make a move and the anti-sway device would kick in causing the load to move differently than the operator expected. The perception to the crane operator is that something is wrong with the crane controls. Trained operators usually switched the antisaway system off because they are more efficient when operating the crane without using it, but beginner operators prefer to use it. It is not uncommon for the anti-sway devices to be permanently disabled in order to satisfy the crane operator. It is possible that, given enough time and patience, the crane operator would become used to the feel of the anti-sway control system, because, even very skilled operators, when the task become routine for extended period of time, prefers to use antisway device, in order to relax from repetitive operations and therefore concentrate on other activities of the container handling tasks. The outline of the classification of existing quay cranes (three different types, according to (Ioannou et al., 2001), due to their degree of automation is shown in Figure 13.

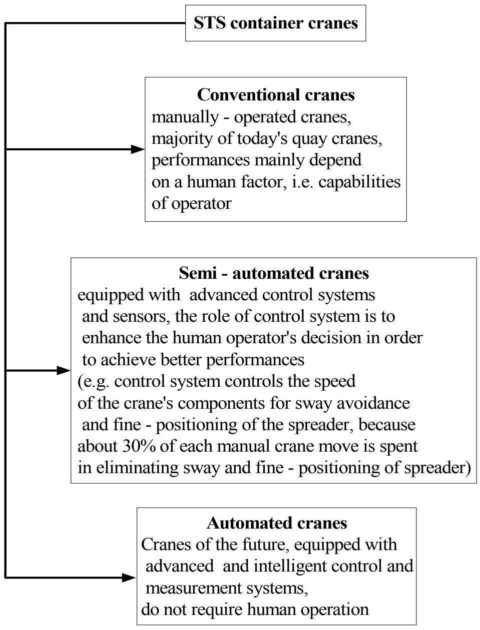


Figure 13: Classification of QCs by their degree of automation

Source: Zrnić et al. 2003a,b; Zrnić et al. 2005

QCs with Automatic Positioning Systems (APS)

One of the main causes of delays during container loading/unloading is the positioning of the chassis so that container and chassis properly mate or the positioning of the container so that the flippers on the spreader bar can mate precisely. The current positioning technique involves the cooperation of the hostler or crane operator with human spotters who communicate with each other with hand and voice signals. A technology called automatic positioning systems (APS) has been introduced which minimizes this positioning difficulty (Ioannou et al., 2001). Manufacturers Wagner and August Design have demonstrated systems that measure the relative position of chassis and container beneath cranes. Manufacturer Matson and others have used vision systems to position straddle carriers beneath cranes. The automatic positioning systems are equipped with sensors such as cameras and machine vision systems with specially designed software. In the August Design system, the machine vision processes the images provided by the cameras and locates the twist locks on the chassis. Using this information a control signal is transmitted to the crane or hostler operator using either LED displays or other means of communication. The control signals transmitted provide the crane operator with information on how to move and do the alignment.

QCs with automatic and smart spreaders

Another technique for reducing the positioning difficulty of the spreader bar is the so-called automatic spreader. Automatic spreaders are equipped with electro-hydraulic controls for automatic rotation of the twist locks by 90 degrees for locking the spreader into the container. The most advanced technology in this area is the Bromma Smart Spreader used for loading/unloading two twenty-foot containers simultaneously (Ioannou et al., 2001). Seven sensors located at the center of the specially designed spreader are used to detect the existence of any gap between the containers. Using the information provided by the sensors, the spreader expands or retracts accordingly. Special attention is given for impact avoidance. The automatic positioning system automatically adjusts the length positioning of the spreader in the event of an impact. If a particularly hard impact causes the telescopic ends of the spreader to be pushed in or out, the spreader will automatically expand or retract to return the spreader to its original position.

6. Basic principles of anti-sway systems operation

Before analyzing the problem further is presented a simplified description of the sway problem. A large STS container crane with Rope Towed Trolley system is presented in Figure 14. The first simplication of the trolley system is presented in Figure 15. For analyzing sway problem is often used a simplified crane model consisting of a weight suspended on a long string. This final simplification is presented in Figure 16. Such a system acts very much like a pure pendulum. This approximation is frequently used, although the period of container sway is not exactly accure. The exact expression for period of sway is presented in (Georgijevic and Milosavljevic, 1994). In a frictionless environment, once the weight is offset from the vertical, it will swing back to a point just as far on the other side and keep doing that forever. The length of time it takes for the weight to get back to the same position on every cycle is called the pendulum period. The period is dependent only on the length of the pendulum and has nothing to do with how much weight is attached. In the real world, there is always some air friction on the string and the weight, so the heavier the weight, the more it acts like a frictionless pendulum. If the weight is stationary and the top of the cable (called the fulcrum) starts to move, then sway occurs also. If the fulcrum now stops suddenly, then there will be residual sway. Unless there is significant friction or something else to stop it, it will keep swaying for a long time. With well-timed fulcrum movements, it is possible to reduce this residual sway but it takes time. When an actual crane is operated, the unavoidable movements of the trolley and the container lead to sway and the operator has to trade off speed and fine positioning with sway (Ioannou et al., 2001).

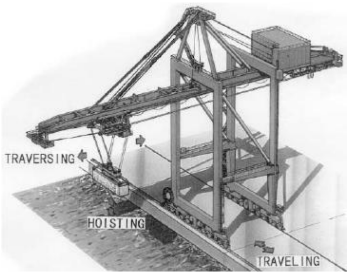


Figure 14: An outline of QCs in operation
(Source: Masoud and Nayfeh, 2003)

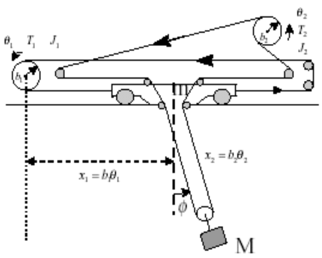


Figure 15: First simplification of trolley model
Source: Kimiaghalam, 1999

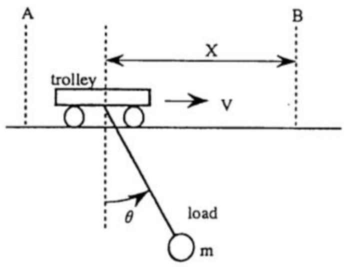


Figure 16: Final simplification of trolley model
Source: Itoh et al., 1993

The most existing QCs use the simplest "bang – bang" control technique that will be discussed in further text. If the motion of the fulcrum is controlled properly, then the sway can be eliminated from the accelerations at both ends. In this case the fulcrum is first accelerated to half the speed and, one-half period later, it is accelerated to full speed, Figure 17 (the three lines, respectively from the top are: trolley speed reference, trolley speed reference via speed pattern system, and sway angle). If this is done precisely, then the weight will be hanging straight down below the fulcrum, Figure 18 (Ioannou et al., 2001). Stopping sway is just the reverse procedure: slow to half speed and then wait one-half pendulum period before stopping. So, the acceleration is in two pulses, allowing the load to catch up with the trolley. The deceleration is also in two pulses, letting the load get first ahead of the trolley and then the trolley catches up with the load. The load is being lowered rapidly at the end of the move (Ioannou et al., 2001).

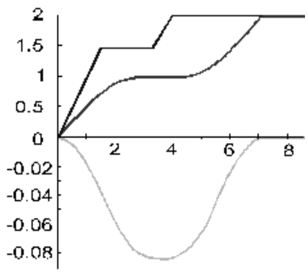


Figure 17: Speed reference pattern

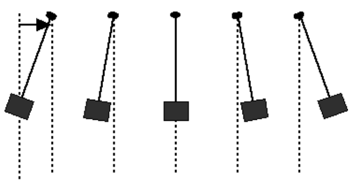


Figure 18: The bang-bang sway problem

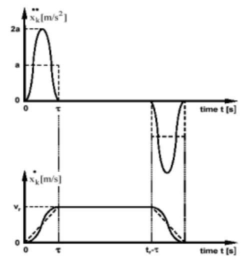
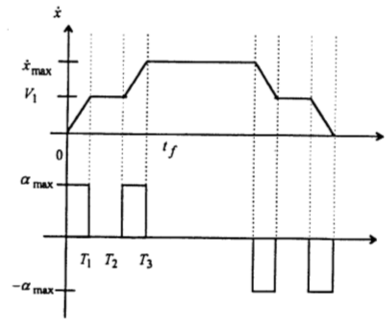


Figure 19: The modification of standard trapezoidal velocity pattern

However an actual crane is not as simple as pendulum. The actual crane dynamics is highly nonlinear, and due to the effect of human operator quite unpredictable. This has three implications: 1) Due to the system nonlinearities and operator interference the antisway system may not improve, and even in some cases worsen the crane performances; 2) In many cases the use of antisway systems has a negative effect on productivity, which lead the operators to switch the antisway off; 3) From a mathematical point of view, simple control strategies, as “bang – bang”, may lead to instabilities or poor performance when applied to complicated nonlinear systems.

For mentioned reasons it is necessary to reshape the standard trapezoidal velocity pattern (Zrnic and Petkovic, 2003). The traversing time of the trolley must be reduced as much as possible and the swing of the spreader must be stopped at the end point. For these requirements, usually the traversing interval is divided into three parts such as accelerating interval, the constant speed interval, and the decelerating interval (Kim et al., 1996). The modification of trapezoidal velocity pattern is presented in Figure 19.

A comparison of most suitable velocity patterns are gives in Figures 20 and 21.



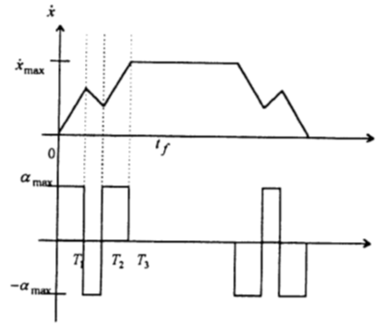


Figure 20: The stepped velocity pattern **Figure 21: The notched velocity pattern**

Source: Itoh et al., 1993; Hong et al., 1997

Finally, in the container terminals the requirement of faster cargo handling leads higher speeds and higher accelerations in the motion of the crane. For example, some of these values for large container cranes are given in Table 2.

Table 2: Speed and acceleration performances of large STS container cranes

Mode	Speed	Acceleration times	Deceleration times
Hoisting with rated load	70 m/min	2,0 s	1,5 s
Hoisting with 40 t container	100 m/min	2,0 s	1,5 s
Hoisting with spreader only	180 m/min	4,0 s	3,0 s
Trolley drive	250 m/min	5,0 s	5,0 s

Source: Zrnic and Petkovic, 2002

7. Conclusions

An effective crane must be designed to suit the present and future needs of the end user. But if today’s crane is built large enough to serve tomorrow’s ships using future technology, the crane will not perform well on today’s ship with today’s technology. For years design team members - mechanical, structural, automation, and electrical engineers have worked together to produce economical design that meet operational demands and that can be efficiently fabricated and erected. As always, the “best” (“optimum”) design requires balance. The cost and benefits of each alternative should be considered in respect of the specific case.

The QCs have had a dramatic development in the period from 1959 to 2009 in depending on the generation of container ship. This increase in size must be met with sufficient crane capacity, because as the ships get longer their time becomes more precious and berth time is unproductive time. The longer container ships use today up to five or six container crane simultaneously. For these reasons, faster servicing of container ships at berths can be reached by: generally increase the crane efficiency; increase the crane rate by lifting two loaded containers simultaneously; the new technical solutions, for example, introduce a dock system where one can load and unload the container ship from both sides. Any port wants to be at the forefront of terminal operations and container handling should be able to reduce to a minimum turnaround time that the ship is docked in the berth for servicing, i.e. unloading and loading. The crane itself is only one of the terminal components (elementary subsystem) that control production. Productivity of QCs is always the critical component of port terminal productivity. In the next decades, the QC productivity may become the limiting component of the terminal production. Some improvements in performances and new technical concepts increase the production incrementally (5-20%), other improvements make a quantum jump (25-40%).

The development of efficient, automated, high-technology loading/ unloading equipment has the potential of considerably improving the performance of terminal operations. Advances in QCs technologies, as the major part and the biggest investment (capital costs for container cranes are 70% of total costs in ports – basic price of QCs in seaports is 5-7 millions $, with modern electronic and advanced control systems approaches 11 millions $) of the cargo storage and retrieval system have a significant effect on the efficiency of port terminal operations once properly implemented.

The construction industry is relatively still slow in implementing advanced technology to improve safety. Current practice requires that control of the QCs' dynamic behavior is the responsibility of a skilled operator. The operator applies corrective measures based on experience when any undesirable swaying is detected. The absence of automated sensing and control not only leave room for accidents arising because of human error and/or delayed response of the operator, but also can greatly reduced the productivity of the cranes' operation, also as the productivity of a whole port terminal representing a complex system, which most important and most expensive part is a QC. Container loading automation investments will continue to increase efficiency of ports, supplemented by improved infrastructure for storing and transferring containers on the landside. Precise control of the spreader and load is only possible using mathematically correct algorithms, and properly implemented sensor systems. We can expect some others more sophisticated control solutions in future researches.

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A Framework for Estimating Economies of Agglomeration and Supply Chain Network Effects in Maritime Clusters

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Abstract

Maritime clusters have been the subject of a variety of research studies, such as cost savings and supply chain network effects. Most of the attempts at estimating cost savings and network effects rely on customer service questionnaires, benchmarking analysis, and more esoteric approaches such as data envelopment analysis. Some studies focus on only one industry. Others provide case studies, which are of limited applicability to other ports. In this paper, the advantages of maritime clusters will be developed through an analysis of possible economies of agglomeration and supply chain network effects that may be present in maritime clusters. The literature on both economies of agglomeration and supply chain network effects is very rich, but the applicability to maritime clusters is in the early stages of development. Based on this literature and its application to maritime clusters, a framework for estimating these effects will be developed. This framework utilizes a gravity model formulation to estimate these effects. Alternatively, a production function formulation is developed to estimate these effects. The paper will develop measures of these effects and recommend a methodology for collecting data to be utilized in the models, using the Panama Canal as an example.

Clusters of Economic Activity

In his classic work on clusters of economic activity, Porter (1998, 2000) defines clusters as "…. geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition." (1998, p. 78) Porter goes on to say that clusters affect competition in three ways: increasing the productivity of companies based in the area; driving the direction and pace of innovation, and stimulating the formation of new businesses, which expands and strengthens the cluster itself. "A cluster allows each member to benefit as if it had greater scale or as if it had joined with others formally-without requiring it to sacrifice its flexibility."(1998, p. 80)

Clusters affect productivity, in Porter's view through better access to a pool of employees and suppliers, access to specialized market, technical, and competitive information, and complementarities which are linkages among cluster members that results in a whole greater than the sum of its parts. Also, public spending for specialized infrastructure or educational programs can enhance a company's productivity.

Motoyama (2008) discusses the shortcomings of cluster theory. He argues that one limitation of the cluster theory is its notion of regional competitiveness and specialization. It is not yet clear how regions compete or gain competitiveness. A second limitation of the theory involves identifying the geographical boundary of a cluster.

More fundamentally, there are problems in analyzing the interconnectedness within a cluster. While input–output tables are used ". . . but determining the threshold for a decent or high level of interconnectedness among identified subindustrial sectors is a subjective process. Virtually all-industrial sectors have some form of transactions with one another; having a transaction is merely a satisfactory condition to identify a strong linkage. Furthermore, input–output tables capture only monetary transactions, not the critical part of interconnectedness: firm rivalry and collaboration, Marshallian externalities, and knowledge spillovers." (Motoyama, 2008, p. 358) Montana and Nenide (2008) develop a 10-point "cohesion score" using input-output tables and location quotients to determine this level of interconnectedness.

In order to address the issue of identifying clusters of economic activity, Hill and Brennan (2000) develop a method that combines cluster analysis with discriminant analysis, using variables derived from economic base theory and measures of productivity, to identify the industries in which a region has its greatest competitive advantage. "These industries are called driver industries because they drive the region's economy." (p. 65) They link driver industries to supplier and customer industries with information from a region-specific input-output model to form industry clusters.

Economies of Agglomeration

One way to look at clusters of economic activity is that these result in economies of agglomeration and supply chain network effects. Without these economies and network effects, clusters would not have a competitive advantage over businesses that are not in a cluster.

The classic approach to measuring economies of agglomeration is reflected in the work of Uchida and Nelson (2009). They argue that there are three indicators of economies of agglomeration in urban economics. These are population size, population density, and travel time. They state that population size is that of large city(ies) that can be regarded as the focal point(s) of an urban area, and travel time is to the nearest large city. They state that for a location to take part in agglomeration economies, it must have both a relatively high population density, which is a proxy for market thickness, and be reasonably near the large city center, a proxy for market access and lower transportation costs.

An alternative view of agglomeration economies is expressed by the work of Melo, Graham and Noland (2009). They conducted a meta analysis of 34 studies which included 729 separate estimates of agglomeration economies. They note that more recent studies have used a "market potential" type of measure of these economies "…that is not restricted to geographic boundaries, and allows the effects of agglomeration externalities to be realized over space and diminish with increased distance." (p. 335) Older literature on economies of agglomeration used urban size within certain geographic boundaries to attempt to measure these economies. The authors find that: "Estimates obtained from models using a market potential type measure appear to have higher elasticities of urban economies than studies using measures of total urban size and employment density." (p. 336)

Cluster theory is also important to understanding economies of agglomeration. Porter (2000) states that many treatments of agglomeration economies rest on cost minimization due to proximity to inputs or proximity to markets. "These explanations, however, have been undercut by the globalization of markets, technology, and supply sources; easier mobility; and lower transportation and communication costs. Today, the nature of economies of agglomeration has shifted toward the cluster level and away from either narrower industries or urban areas per se." (p. 21)

Network Effects

Maritime networks are defined by Mangan, Lalwani and Fynes (2008) as a set of links and nodes. They define transport services as links in supply chains and transport infrastructure as nodes in supply chains. "Maritime transport (comprising ports as nodes and shipping services as links) is the dominant mode for international freight movements and is thus crucial to international trade and a vital component of many supply chains." (p. 35)

Goyal (2007) shows how networks can explain the direction and pace of innovations among firms engaged in collaborative research. The firms are nodes connected by collaboration agreements (links) to other firms. Networks built upon empirical data show the emergence of a typical core-periphery structure, in which there is a core with firms having a high degree of interaction and a periphery with firms having a low level of interaction with other firms. This core-periphery structure reveals the way in which competing firms are collaborating and how is the pattern of innovation diffusion.

Song and Panayides (2008) argue that ports play an important role as members of a supply chain. “In this role, the port is considered as part of a cluster of organizations in which different logistics and transport operators are involved in bringing value to the final consumers.” (p. 75) They go on to say: “In order for ports to fulfill their performance goals as well as those of the supply chain, they must be capable of attaining objectives of the supply chain and not merely objectives of efficiency. The items conceptualized to be critical to terminal competitiveness in the supply chain era include issues of cost advantage (price), quality, reliability, customization and responsiveness to customers’ needs. Such items are increasingly regarded as critical in the measurement of contemporary container terminal performance.” (p. 78)

The authors found a positive relationship between value-added services and port pricing. “The positive relationship suggests that provision of value added services justifies the higher charges because the port is perceived to be offering prices that are competitive since it is offering services that add value to the users, unlike competitors who may charge less but not offer the same added value.” (p. 82)

Meixell and Gargeya (2000) conducted a review of the supply chain design literature. They note that much of the emphasis in supply chain management has been on cost reduction, but performance in real-world supply chains has multiple attributes. These include reliability, responsiveness, flexibility, cost, and assets. Additional benefits are reported by Handfield (1994) who mentions improving quality, meeting schedule requirements, reducing cost, accessing new technologies, and broadening the supply base.

Supply chain collaborations were investigated by Zacharia, Nix, and Lusch (2009). They argue that competitive advantage is obtained from the value created by a network of firms. Their paper indicates the level at which firms engage in a collaboration with a supply chain partner is directly affected by the level of interdependence of knowledge and process and their level of understanding about their partner. “The more interdependent the firms are, and the more insight they have into each other’s processes, products, culture, and business goals, the more intensely they will engage. Higher levels of collaboration will lead to improvements in both operational and relational outcomes, which in turn will lead to better business performance.” (p. 103)

Port Clusters and Economies of Agglomeration and Supply Chain Network Effects

The literature on port clusters and economies of agglomeration and network effects implies that port clusters achieve a variety of economies. These are economies of agglomeration, which result from cluster economies; economies of scope typically provided by 3rd Party Logistics Providers (3PLs); and economies of density, which result in lower costs through greater volume of activity and make specialists feasible. Network effects result in a variety of customer service benefits including lower order cycle time, smaller inventories, fewer stockouts, etc.

The question remains as to how to measure these effects. These are all intertwined in the port cluster and any attempt to separate and measure these would be very difficult, if not impossible. Our approach is to develop two different models of these effects. The models result in indices of cluster economies and network effects. The indices can be used to measure these effects over time for one port, or to compare ports at one point in time. The two approaches are a gravity model approach and a production function approach.

A Gravity Model Formulation

The gravity model has been used in many applications over the years. These include estimating the number of trips between city pairs, measuring the potential for intercity bus service, and estimating the change in accessibility as transportation facilities are built. In this paper, the gravity model will be used to develop an index of port cluster economies and network effects.

To develop an index, the gravity model is turned into a scoring function of the potential for interaction. This will be illustrated assuming the model is used to estimate the potential for interaction between two places. One formulation of the gravity model is:
where:

Tij = number of trips between places i and j, respectively
Ai = measure of attractiveness of place i
Aj = measure of attractiveness of place j
dij= distance between places i and j
G = a constant of proportionality

A scoring function can then be developed as:
where Sij is the interactivity potential between place i and place j.

$$S_{ij} = \frac{T_{ij}}{G} = \frac{A_i \cdot A_j}{d^2{}_{ij}} \tag{1}$$

If population is used as an attraction, the model says that city pairs i and j would have a higher score and thus greater potential demand for transportation service, the larger the populations of the two cities and the closer they are to each other.

The identification of potential markets can be accomplished by scoring the interactivity potential between the pairs of places above using the following gravity-type formula:

$$S_{ij} = \frac{P_i \cdot P_j}{d^2{}_{ij}} \tag{2}$$

where,

Pi and Pj are the (total) populations of the two places i and j, respectively
dij is the distance between the two places, and
Sij is the interactivity potential between place i and place j.

The rationale for this approach is that the level of demand for transportation services between two places, would be proportional to the population masses of the terminal places and inversely proportional to the squared distance between the places. Note that in traditional demand forecasting, properly estimated population and distance functions would be used.

This approach can be used to measure the interactivity between businesses. Instead of population, substitute sales or employment. But, this needs to be adjusted by the input-output coefficient to reflect the level of inter-connectiveness between the two businesses. Businesses which have a low level of inter-connectiveness will not experience as much of a supply chain network effect as those which have a high level.
So:

$$S_{ij} = \frac{B_i \cdot B_j \cdot c_{ij}}{d_{ij}^2} \tag{3}$$

where,

B_i and B_j are the (total) sales or employment of the two businesses *i* and *j*, respectively
d_{ij} is the distance between the two businesses,
c_{ij} is the input-output coefficient between businesses i and j
and
S_{ij} is the interactivity potential between business *i* and business *j*.
n is the number of businesses in the cluster

For all businesses in the cluster we can sum up all the scores to get:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{B_i \cdot B_j \cdot c_{ij}}{d_{ij}^2} \quad (4)$$

This formulation specifically takes distance into account in the estimation of economies of agglomeration and supply chain network effects. Businesses that are closer together in a cluster would exhibit a higher score than if these were further apart. Since much of logistics is movement of goods, having cluster participants in close proximity would reduce costs as compared to clusters in which goods must be shipped longer distances. Thus, if the cluster is spread out over long distances, then agglomeration effects would be less.

As more businesses are added to the cluster, the scoring function increases, reflecting the concept that economies of agglomeration increase, the larger the cluster. This formulation also incorporates supply chain network effects, through the use of the input-output coefficients. The larger these coefficients, the greater the network effects, since the interaction between businesses is greater.

While this model takes both agglomeration and network effects into account, it is not possible to separate the two. Both effects are imbedded in a cluster. The net effect is measured by this model, which is the degree to which a cluster reduces costs and increases effectiveness of its businesses. This model is easily implementable using secondary data sources from an economic census, map distances and input-output table results.

An Alternative Production Function Formulation

An alternative formulation to reflect agglomeration economies is through the use of a production function. This formulation focuses on economies of agglomeration by estimating the impact of the number of firms on productivity of workers. Let
Qi = GDP or production (in physical units) in sector i
E(.) = efficiency function ,
Li = labor in sector i
Ki = capital in sector i

Thus, the production function can be written as

$$Q_i = E(.)\, F(L_i, K_i) \quad (5)$$

If we focus on the production per unit of capital in sector i as qi, we get

$$q_i = E(.)\, F(L_i / K_i) \quad (6)$$

Qi would be a measure of the productivity per unit of capital as a function of the number of workers per unit of capital. As E() is represents the efficiency of the production process, we can use this function to portrait agglomeration economies. We can think about E() as a function of the number of firms in the sector i and a vector of other relevant variables denoted X.

$$q_i = E(n_i \ , X_i)\, F(L_i / K_i) \quad (7)$$

Hence, the productivity is a function of the number of firms, labor per unit of capital and a vector X.

$$q_i = \ f(n_i \ , L_i / K_i, X_i) \quad (8)$$

This last expression can be estimated econometrically in a log form where the coefficients are elasticities.

$$\ln q_i = \ \beta_0 + \beta_1 \ln n_i \ + \beta_2 \ln L_i / K_i + \beta_3 \ln X_i \quad (9)$$

The agglomeration effects would be reflected on the impact of the number of firms upon the productivity of sector i.

Application to the Panama Canal Cluster

In 2006, the Panama Canal Authority developed a study[1] that examined the impact of the Canal on the Republic of Panama. The report provides a wealth of information on the economy of Panama, and the Canal and its related activities. The study discusses Direct, Indirect, Induced and Parallel components of the Cluster. Direct components are the foreign exchange contributions of the Canal, indirect are those derived from the provision of additional services to transiting vessels, and induced are those activities located in Panama as a result of the existence of the Canal, but depending on international and regional markets for their growth. Parallel activities are other related economic activities, which do not depend or were induced by the Canal. The cluster components are shown in Table 1.

Table 1: Cluster Components

Direct	Indirect	Induced	Parallel
Canal Operation	Shipping Lines Shipping Agencies Ship Chandlers Ship Repair and Maintenance Launch and Pilot Services Dredging	Ports Colon Free Zone Canal Tourism Logistics Management Railway Export Processing Zones Intermodal Services Cruiseship Tourism Container Repair Land Transportation	Air Hub Colon Free Zone Merchant Marine Telecommunications City of Knowledge Legal Services Ship Grading and Classification Maritime Court Public Services Financial Intermediation Education and Training Insurance

Source: ACP Study of the Panama Canal Economic Impact on the Republic of Panama.

Indirect Activities

The indirect activities are mainly shipping agencies, bunker fuel and lubricant sales, ship chandlering and ship repairs and maintenance. Another component that began recently is the establishment of local offices of international shipping companies.

Shipping Agencies primarily provide all the services needed locally by the shipping lines utilizing the Canal. These include services needed by the ships as well as by their crews. **Bunker Fuel and Lubricant Sales** is the sale of fuel and lubricants to transiting vessels. **Ship Chandlerling** includes mainly food, liquor, cigarettes, some CFTZ goods such as TV's and cameras as well as hardware, tools, spare parts, safety equipment, clothing, shoes, medicines and others to transiting vessels.

Ship Repair and Maintenance is performed at the dry docks next to the Balboa port. These provide dry dock, wet-dock, floating repair, maintenance services and spare part shopping services. There are also other two smaller repair service companies at the main Atlantic and Pacific ports. **Shipping Lines Offices** are those of main shipping lines which have established offices in Panama. Maersk, Evergreen, COSCO, P & O Nedloyd, APL, China Shipping, CLS, Seaboard and Crowley are examples. **Launch and Pilotage Services** are provided by ACP for vessels transiting the Canal. There are also pilotage services needed by ships docking in the ports. The service is basically guidance and advice to enter and exit the ports. This service is provided by 4 private companies.

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[1] ACP study with Intracorp and Asesores Estratégicos, Impacto Económico del Canal de Panamá en el ámbito Nacional, 2006

Dredging Operations are mostly done by the ACP Dredging Division. Sometimes the ACP contracts private dredging companies to complement their normal operation.

Induced Activities

The Colon Free Trade Zone (CFTZ) is a well established and mature commercial activity with 2,200 businesses of which 1,600 are active residents and 600 are representative offices. There are four operational **Container Ports** at the entrances to the Canal: MIT, Colon Container Terminal and Cristobal on the Atlantic side and Balboa on the Pacific side. Besides loading and unloading containers, they provide lighthouse and buoy services, tugboats, cargo insurance, services to crew, storage, cargo consolidation and deconsolidation, water, garbage disposal, fumigation and security services, refrigerated container services, container repair services, sale of food and spare parts (through concessions) **Container Repair Services** have grown with the high volume of container transshipments taking place at the ports adjacent to the Canal. **The Panama Railroad** was the first transcontinental railroad in the hemisphere built in 1855. It connects the Atlantic ports of Cristobal, MIT and Colon Container Port with the Balboa Panama Port on the Pacific side. It offers both cargo and passenger services. **Trucking Services** involves the overland movement of cargo to and from the CFTZ, the seaports, airports and the railroad. **Export Processing Zones (EPZ)** are special locations that provide tax and administrative incentives for manufacturing and assembly companies that produce mainly for foreign markets. **Logistics Management Services** design and manage cargo transportation systems, reorganize, deconsolidate and consolidate cargo for their clients, and provide temporary inventory services while the cargo is being transported. They take charge of cargo movement from the origin to final destination adding value along the way. **Canal Tourism consists** of different components: regular tourists that visit the Canal locks, cruise ship tourists that visit the Canal area and ecological and cultural tourists who are attracted by Panama's rich biodiversity and historic sites.

Table 2. Sector Production (year 2001)

Sector	Total Production
	Millions of Dollars
Canal	$ 868,504
Colon Free Trade Zone	$ 5,606,172
Tourism	$ 48,000
Bunkering & Shipping Agencies	$ 175,014
Shipping companies	$ 3,838
Ship Chandlers	$ 15,782
Ports	$ 172,300

Since **Parallel Activities** do not depend or are induced by the presence of the Canal, and have very little linkage to the above-mentioned activities, these will not be examined in this paper.

Data Analysis

The ACP Economic Impact Study report provides a variety of information that was used to estimate agglomeration and network effects. The report provides estimates of total production for sectors of the Panamanian economy in 2001. The information was obtained from the 2001 Economic Census. To simplify the analysis, seven sectors were chosen for detailed analysis. These are the Canal, the Colon Free Trade Zone, Tourism, Bunkering & Shipping Agencies, Shipping Companies, Ship Chandlers and Ports. Total production for each of these sectors is shown in Table 2.

The same report developed a set of Input-Output coefficients for the components of the cluster by first building an intersectorial relations map. The map was developed from a questionnaire sent to maritime and maritime related businesses. Detailed interviews were then conducted with representative businesses. A qualitative classification of the degree of linkage among the cluster activities was then developed. These relationships were then used to develop the input-output coefficients, which encompass the direct and indirect effects of changes in individual cluster components.

The input-output coefficients were modified slightly to better fit into the framework for this paper. Coefficients were developed for more detail than what is needed in this approach. For example, tourism was divided into cruise ship tourism and canal tourism. These were combined into one sector called tourism. Second, the input-output coefficients show the direct and indirect effects of changes in one component on another. One cluster component is a dependent variable and the other is an explanatory variable. The coefficient shows how changes in the explanatory variable affect the dependent.

But, in this analysis, we are interested in the total level of interconnectedness between two cluster components. What was done is to simply add the coefficients of the two activities to obtain one measure of connectivity between two cluster activities. This resulted in the matrix of combined coefficients shown in Table 3. Some non-zero items appear on the diagonal since some of the activities were combined.

Table 3. Matrix of Combined I-O Coefficients

	Canal	Colon FTZ	Tourism	Bunkering & Ship. Agencies	Shipping Cos.	Ship Chandlers	Ports
Canal	0						
Colon Free Trade Zone	0.02	0					
Tourism	0.03	0.03	0.7				
Bunkering & Shipping Agencies	1.09	0.05	0.01	0.04			
Shipping companies	0.4	0.2	0	0.02	0		
Ship Chandlers	0.4	0.01	0	0.05	0	0	
Ports	0.18	0.25	0.03	0.5	0.21	0.5	0

The next step in the process was to estimate distances between cluster components. The Panama Canal is about 50 miles long, from the port at Balboa on the Pacific side to Colon on the Caribbean side. What was done is to crudely estimate distances. Many of the activities occur on both sides of the Canal. So, for these activities, half the distance of the Canal was assumed. For some, the components are in the same general area. A five mile distance was assumed. Finally, a one mile distance was assumed for some activities and for the component itself, to avoid division by zero.

Gravity Model Results

The gravity model results are shown in Table 4. Sector production estimates were expressed in hundreds of millions of dollars. The results below the diagonal in the table were duplicated above the diagonal, in order to gauge the importance of each of the cluster components. The results show that the ports are the most important component, accounting for over 46% of the total estimate of cluster economies and network effects. The second most important component is the Canal itself. The logic is that the ports have many inter-relationships with other cluster activities that the Canal may not have. The third most important element is the Colon Free Trade Zone, accounting for 15% of the model estimate. While the FTZ is important, this analysis indicates that its linkages with other cluster activities need to be strengthened.

Table 4. Gravity Model Results

	Canal	Colon FTZ	Tourism	Bunkering & Ship. Agencies	Shipping Cos.	Ship Chandlers	Ports
Canal	-	15,581	200	26,509	9,728	877	2,693,578
Colon Free Trade Zone	15,581	-	861	196,232	17,213	3,539	965,943
Tourism	200	861	6,451	13	-	-	992
Bunkering & Shipping Agencies	26,509	196,232	13	4,901	54	552	60,310
Shipping companies	9,728	17,213	-	54	-	-	555
Ship Chandlers	877	3,539	-	552	-	-	5,438
Ports	2,693,578	965,943	992	60,310	555	5,438	-
Total	2,746,473	1,199,369	8,518	288,571	27,550	10,407	3,726,818
% of Total	34.30%	14.98%	0.11%	3.60%	0.34%	0.13%	46.54%

Of particular interest are the activities within an individual cluster component. These marginal effects within a component provide important information about the strength and importance of relationships among individual activities. The marginal effects are estimated using the following formula:

$$\sum_{i=1}^{n} \frac{B_i \cdot B_j \cdot c_{ij}}{d_{ij}^2} \qquad (10)$$

In the table, the Canal has the most important linkage with the ports, with the interaction with the ports accounting for 98% of the total estimate of Canal contribution to cluster economies and network effects. The most important linkage that the FTZ has, is with the ports, accounting for 80% of the variation. Since the tourism component is the combination of cruise ship tourism and canal tourism, it is not surprising that the most important element is tourism itself. The linkage between bunkering and shipping agencies and the Colon Free Trade Zone, accounts for 68% of the total for this element, with the ports also providing an important linkage. Finally chandlers are most closely linked to the ports and the FTZ, with the each accounting for 52% and 34% of the cluster relationship with that component.

Conclusions

The gravity model provides an estimate of maritime cluster economies of agglomeration and supply chain network effects. Estimates over time will help to understand the growth of these effects. The model helps to provide an understanding of which components are most important to the cluster and which activities are most closely linked. The model allows us to essentially peer inside the cluster to understand the inner workings of linkages among the cluster elements. This information can play an important role in shaping public policy regarding cluster development and enhancement.

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A Model on Port Basin Choice with Russian Container Trade

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Abstract

For the economic and financial evaluation of port investment projects it is important to understand the relations between port demand and the price of using a port. That is, the demand function of a port's services needs to be known. The objective of this paper is to establish such a demand choice function for the Russian container port services per maritime basin, which is derived from the coefficients of the Multinomial Logit Model estimated with regression analysis.

The statistical analysis is carried out for Russian maritime container imports and exports for the years 2006 and 2007. The results of the statistical analysis show that variables such as inland and maritime transport costs and time are statistically significant and explain about half the variation in market shares. The shape of the demand function indicates that the choice elasticity of the demand is low compared to those measured in other studies on container port choice with respect to West Europe, Spain and the United States. A number of explanations are given for the low elasticity.

Keywords: Port competition, container routing choice, logit model, Russian container trade

1. Introduction

For the economic and financial evaluation of port investment projects it is important to understand the relations between port demand and the costs of using a port. That is, the demand function of a port's services needs to be known. The objective of this paper is to establish such a demand choice function for Russian container port services per maritime basin, which is derived from the coefficients of a Multi-Nomial Logit (MNL) Model estimated with regression analysis.

The objective of this study is to get insight in the choice of port basin for Russian containerised imports and exports in 2006 and 2007 on the basis of generalised transport costs by applying routing choice models. A routing is defined here as the chain linking maritime transport, port transfer in Russia (or in a neighbouring country) and inland transport to the final destination in Russia.

The study concerns the choice of routings involving a maritime component and does not include land-based routings such as those connecting Russia with large parts of Europe and Asia. This omission does not impact the results of our analysis, as a convenient property of the MNL model is that it satisfies the axiom of independence of irrelevant alternatives, so that the outcome is not affected by the fact that some choice options are not included.

Section 2 presents the background and setting of the port choice issue and its basis in maritime economic literature. It refers to findings by Veldman and Bückmann (2003), Malchow and Kanafani (2001) and (2004), Tiwari et al. (2003), Blonigen and Wilson (2006), Garcia-Alonso and Sanchez-Soriano (2009), Anderson et al. (2009) and Veldman et al. (2010). Section 3 gives a description of the MNL model, the port basin choice situation and the variables to be tested. Section 4 describes the data used for the statistical analysis. Section 5 gives the results of the logit models tested with regression analysis. The impact of routing cost changes on market volumes is given in section. Finally follow, the interpretation of statistical results and conclusions in Section 6.

2. Routing choice options

In general importers and exporters or their representatives, such as logistic service providers, will choose the seaport of import or export on the basis of least generalised cost. These costs include sea-freight, port charges, inland transport costs, terminal handling costs and the trader's internal costs associated with quality of service. The quality of service includes transit time and frequency of service and all other aspects that result in a cost for importers and exporters, such as reliability of service, risks of theft and damage to cargo and stock carrying costs.

A Russian trader located in, for instance, Moscow and importing from the Far East may choose between three basic routings:
1) Baltic basin routing: the ocean route via the Suez Canal and the Baltic Sea ports.
2) Black Sea basin routing: the ocean route via the Suez Canal and the Russian Black Sea ports
3) Far East basin routing: the Trans-Siberian (Transsib) route via the Far Eastern ports

Overland routing options such as via Mongolia, Kazakhstan and China also exist, but are disregarded in this paper.

Within the Baltic or Northwest basin the following ports are involved:

- Russian ports: Saint-Petersburg, Kaliningrad, and Northern basin ports: Arkhangelsk, Murmansk
- Baltic states ports: Ventspils, Riga, Klaipeda and Tallinn
- Finnish ports: Hamina, Hanko, Helsinki and Kotka

The Baltic basin routing requires the use of a mainline ship from for instance the Far East to a transhipment port in West Europe, feeder transport to one of the Baltic ports and inland transport by rail or road to the inland destination in Russia. There are various variants with respect to the choice of transhipment port in the North Sea port region (Rotterdam, Antwerp or Hamburg), the choice of feeder port in the Baltic Sea region and subsequent rail or road transport.

Within the Black Sea or South basin the following ports play a role:

- Russian ports: Novorossiysk and smaller ports such as Rostov on the Don
- Ukrainian ports: Odessa and Ilyichevsk

The Black Sea routing requires the use of a mainline ship from the Far East to a transhipment port in the Mediterranean region, feeder transport to the ports in the Black Sea and inland transport by rail or road to the inland destination in Russia. There are various variants with respect to the choice of transhipment port in the Mediterranean or Black Sea (Port Said, Piraeus or Constantza), feeder ports in the Black Sea region and subsequent rail or road transport.

In the Black Sea the mainliners make direct calls at ports such as Odessa, Ilyichevsk and Constanza, so that they are directly connected with the Far East, thereby avoiding transhipment. Novorossiysk has not been receiving regular direct calls until 2009. Trade volumes through this port appear becoming large enough to support direct calls[1]. It may be expected that this will lead to a reduction in the freight rates and transit times for ocean transport between Russia and the Far East and an increase in the competitive position of the Black Sea routing vis-à-vis the Baltic basin routing.

[1] At present ZIM as partner of the Grand Alliance calls directly at Novorossiysk on its East Med Express Service (EMX)

Within the Far East basin the ports of Vladivostok and Vostochny are the main international ports. Port such as Nakhodka, Vanino, Petropavlovsk Kamchatsky and Sakhalin play a regional role. There is an important volume of domestic (cabotage) trade between the two main ports and the regional ports. The two main ports have direct connections with the Korean and Japanese ports with shipping lines such as Chao Yang, FESCO and Magistral operating ships ranging from 450 TEU to 1,200 TEU. With respect to the overseas distances and the size of ships employed shipping between Russia and the Far East is comparable to feeder shipping in the Baltic and in the Eastern Mediterranean.

The Transsib railway link offers the advantage of shorter transit time, especially with block trains. An advantage also is that the freight rate is not subject to the market fluctuations of the sea freight.

Chinese imports are also routed over land via the border check points of Zabaikalsk (China), Lokot (Kazakhstan) and Naushki (Mongolia). As noted the choice of these land routings against maritime routings is not included in this paper.

The Far East basin routing requires short sea shipping transport from the ports in the Far East, to one of the Russian Far East ports and inland transport by the Transsib rail connection or by road for the nearby Primorye region. The total volume of containers carried via the Transib[2] was 424,000 TEU in 2006 and 620,000 TEU in 2007. The volumes carried on the Russia – China link were 148,000 TEU and 163,000 TEU respectively.

Table 1: Container throughput by basin (1000 TEU)

Year	2006	2007
Totals per basin		
Northwest	1,648	1,984
South	247	371
Far East	546	650
All basins	**2,441**	**3,005**
Percentages per basin		
% Northwest	68%	66%
% South	10%	12%
% Far East	22%	22%
Total including. foreign ports	**63%**	**62%**
Volumes through foreign ports		
Finland	350	399
Baltic States	275	383
Ukraine	38	40
Total foreign ports	**663**	**822**
Transit via Transsib	15	11
Total	**3,089**	**3,816**

Source: SeaNews

3. The Port Basin Choice Model

3.1. Models on Port Choice

Choice between transport options with respect to surface transport has been receiving a great amount of attention for decades and subsequent research has lead to extensive model development and related practical applications and commercial software. Similar research in the maritime field started much later.

Research on demand choice models involving maritime transport, based on revealed preference data, started with modal split studies, such as by Winston (1981), where maritime transport was part of a logistic chain.

[2] According to data from the International Coordinating Council on Trans-Siberian Transportation and Russian Railways statistics published in Gudok newspaper

The focus on port choice started with Malchow and Kanafani (2001), who tested the factors determining port choice in the US by applying a MNL model for US exports using discrete disaggregate data. The availability of combined trade, vessel and freight rate data in the US offers a rich source of information making it possible to combine detail on cargo, port of origin and destination, ship type, size and shipping route. Malchow and Kanafani (2004) elaborated this work and showed how the predicted market share for a port varies with type of commodity and carrier.

Tiwari et al. (2003) used a discrete choice model where shippers choose among combinations of shipping line and port and make decisions based on shipper and port characteristics. The situation concerns the Chinese foreign trade. Veldman and Bückmann (2003) tested port choice models for the continental and overseas hinterland of West European container ports using aggregate container flows, where they did not distinguish type of cargo, type of container (loaded or empty) and direction of trade were disregarded. Port access costs, hinterland transport costs by mode and proxy variables for quality of service proved to be significant.

Blonigen and Wilson (2006a) used the same rich source of US maritime statistics as Malchow and Kanafani (2004) to test port choice for US imports using aggregate data. The level of aggregation was low resulting in a multitude of information on cargo type, trade partner and port in the US and abroad. Given these enormous of amount of data, nearly 100,000 observations, the models tested could include port efficiency data based on Blonigen and Wilson (2006b), which measured port efficiency for a great number of US and foreign ports. Anderson et al. (2009) went into more detail with 470,766 observations derived from the same statistical source on container import shipments and tested models with a great number of variables, without using port efficiency data as done by Blonigen and Wilson (2006a).

Garcia-Alonso and Sanchez-Soriano (2009) studied the inter-port container traffic distribution (for imports and exports) among the biggest Spanish ports using logit models, concluding that the distance between port and the gravity point of the province of destination of the cargo is a relevant variable in the port selection process. Veldman et al. (2010) studied port choice for the Spanish container trades in a similar way as applied in this paper.

3.2. Model Specification

3.2.1. The Logit Model

The choice of port basin concerns the routings of Russian imports or exports between the gravity point of the inland region of import or export and the gravity point of the overseas trade region. The logit model expresses the probability that an importer or exporter trading between one of the Russian regions "i" and one of the overseas trade partners "j", chooses port "k" from a set of possible ports. Per combination of inland region and trade partner region the probability of choosing a routing via one of the available routings (including each a port), can be expressed as:

$$P_{ijk}(p = k \mid p = 1 \ldots P) = \frac{e^{-Uijk}}{\sum_{p=1}^{p=P} e^{-U_{ijp}}} \qquad (1)$$

where:

P_{ijk}: probability of choosing port k from all possible ports p = 1..P, for province i = 1..I and trade partner j= 1…J;

U_{ijk}: the 'utility' attached to the routing via port k for trade between i and j;

i, j and p indices

The probability P_{ijk} can be interpreted as the market share of a port k in the total of all ports serving the trade between province "i" and trade partner "j", for either imports or exports. The probability P_{ijk} can be set equal to the observed market share of volume F_{ijk} of routing k in the trade between i and j.

3.2.2. The Utility Function

The value, which a trader attaches to routing k is measured in the utility function, which can be expressed as a (linear) combination of all aspects impacting the choice between alternative ports. One of the models tested is:

$$U_{ijk} = a_0^k + a_1 CL_{ik} + a_2 CM_{jk} + a_3 TL_{ik} + a_4 TM_{jk} + a_5 Q_k \qquad (2)$$

where:
CL_{ik}: inland transport costs between region i and port k;
CM_{jk}: maritime transport cost between trade partner j and port k;
TL_{ik}: inland transport time between region i and port k;
TM_{jk}: maritime transport time between trade partner j and port k;
Q_k: quality of service aspects for i, j and port k.

The explanatory variables CL_{ik}, $CM_{jk,}$ TL_{ik} , TM_{jk} and Q_k are referred to as attributes. α_0, α_1 to α_5 are the coefficients of the utility function. An alternative version of equation (2) includes the variable of the C_{ijk}, which is the sum of CL_{ik} and CM_{jk} and T_{ijk}, which is the sum of TL_{ik} and TM_{jk} replaces these two, and another version includes a dummy variables for the ports other than the base port.

3.2.3. Market Share of a Container Routing

The relative position of one port against the other for trade pair i-j is expressed by the ratio of the probability that an importer (or exporter) chooses a routing via port k against the probability that he chooses routing p. By subsequently substituting k and p in equation (1) and dividing the resulting probabilities, the ratio becomes:

$$P_{ijk} / P_{ijp} = e^{-U_{ijk}} / e^{-U_{ijp}} = e^{U_{ijp} - U_{ijk}} \qquad (3)$$

The probability of the ratios becomes a function of the differences of their attributes, which is a convenient form. If instead of differences a ratio form would apply (this applies to the situation where its is assumed that the utility function has a multiplicative instead of a linear form) the absolute level of the attribute values would have to be known and thereby of information on all shackles of the transport chain. Oum (1989) states that with the ratio form the choice of base routing n affects the empirical results, including own and cross elasticities of the demand.

By taking the logarithm of equation 3 the model becomes convenient for estimation with regression analysis:

$$\begin{aligned} Ln(P_{ijk} / P_{ijp}) &= U_{ijp} - U_{ijk} = \alpha_0 + \alpha_1 (CL_{ip} - CL_{ik}) + \alpha_2 (CM_{jp} - CM_{jk}) + \alpha_3 (TL_{ip} - TL_{ik}) \\ &+ \alpha_4 (TM_{jp} - TM_{jk}) + \alpha_5 (Q_p - Q_k) \end{aligned} \qquad (4)$$

where $\alpha_0 = \alpha^k_0 - \alpha^p_0$.

Note that there are variants of equation (3) and (4) including total cost and total time variables and a dummy variable for the port basins.

4. Data for statistical analysis

4.1Introduction

To test the logit model we use information on container flows between Russian hinterland regions and trading partner or, in short, foreland regions. This information is available from data files provided by the Russian customs authority for containerised imports and exports in 2006 and 2007 (Russian Customs 2006 and 2007). The dataset gives the containerised flows in tons between about 80 administrative entities such as oblasts and krais in Russia and 140 trading partner countries combined with broad information on the border crossing.

The Russian trading partner regions were aggregated into 8 regions, which nearly coincide with the 7 national districts. Considering the large size of the port basins it is not useful to split the regions into smaller entities. The foreign trade partners were aggregated into 10 coastal areas suitable for the testing of a routing choice model. Trade with neighbouring regions in Europe and Asia where overland transport is likely, is omitted. Also omitted are trades with countries where maritime trade is complicated by a port basin choice at the foreland end of the trade, such as North America.

Information on border crossings concerned the three maritime basins, the total of railway connections with Asia and a category "other" that included transport by land and a category "unknown".

4.2 Composition of container trade

In 2006 the total volume of containerised international trade according to Customs 2006 and 2007 was 19.7 million tons, of which 13.8 million tons import and 6.0 million tons export. The volume reportedly routed via the three maritime basins was 89% of the total. Of this 89%, 72% was passing the Northwest Basin, 12% the South Basin and 16% the Far East Basin. See table 2.

The trade volumes of 2007 were considerably higher with 23.3 million tons, of which 16.6 million tons of imports and 6.7 million tons of exports. The information contains a large share of the category" unknown", so that only 22% was reported to be passing through one of the three basins. Of this 22%, 68% was passing the Northwest Basin, 11% the South Basin and 21% the Far East Basin.

The total volume of containers routed through the three maritime basins in 2006 according to customs statistics (17.7 million tons) can be converted into TEUs assuming a ratio of 10 tons per TEU: this leads to 1.8 million TEU. Port statistics for 2006 give a total of 2.9 million TEU, which is a difference of 38%. For 2007, this gap is considerably bigger.

The shares of maritime regions according to the two sources show some differences too. Port statistics show a higher share for the Northwest ports: in 2006 77% against 72% in customs statistics and for 2007 the difference is 76% against 68%.

Table 2: Russian container trade volume by category (in 1000 tons)

Data 2006			
	volume	shares in subtotal	shares in grand total
Border category			
Baltic	12,729	72%	
South	2,069	12%	
Far East	2,831	16%	
subtotal	17,629	100%	89%
Other categories			
Asian rail	408	19%	
unknown	1,707	81%	
subtotal	2,115	100%	11%
Grand total	**19,744**		**100%**
Data 2007			
	volume	shares in subtotal	shares in total
Border category			
Baltic	3,474	68%	
South	570	11%	
Far East	1,084	21%	
subtotal	5,127	100%	22%
Other categories			
Asian rail	271	1%	
unknown	17,874	99%	

subtotal	18,145	100%	78%
Grand total	**23,273**		**100%**

Source: Compiled from Russian Customs data (2006, 2007)

The origin and destination of container trades are dominated by the Northwest and Central region, which together generate nearly 70% of total containerised imports and exports. The other 6 regions have much smaller shares of up to 8%. See table 3.

Table 3: Russian container trade volumes by hinterland region (in 1000 tons)

Hinterland region	2006				2007			
	import	export	total	shares	import	export	total	shares
1 Northwest	6,289	1,934	8,223	42%	7,150	2,193	9,344	40%
2 Central	5,025	366	5,391	27%	6,199	429	6,628	28%
3 South	804	120	924	5%	1,067	106	1,174	5%
4 Southeast	279	1,204	1,484	8%	443	1,123	1,565	7%
5 Ural	146	664	810	4%	209	871	1,080	5%
6 West Siberia	218	588	806	4%	281	764	1,044	4%
7 East Siberia	58	961	1,019	5%	83	1,046	1,129	5%
8 Far East	849	144	993	5%	1,064	139	1,203	5%
9 Unspecified	86	8	94	0%	98	8	105	0%
Total	**13,756**	**5,988**	**19,744**	**100%**	**16,594**	**6,678**	**23,273**	**100%**

Source: Compiled from Russian Customs data (2006, 2007)

The volume of container trade by foreland region is lower than for the hinterland regions as not all information of trade partner regions is known, as explained before. Containerised trade with Northwest Europe and East Asia appears to dominate.

Table 4: Russian container trade volumes by foreland region (in 1000 tons)

Foreland region	2006				2007			
	import	export	total	shares	import	export	total	shares
1 Northwest Europe	3,766	1,246	5,012	32%	3,783	1,153	4,935	27%
2 West Mediterranean	645	203	848	5%	721	202	923	5%
3 East Mediterranean	668	608	1,276	8%	790	652	1,441	8%
4 South Am. East Coast	1,060	81	1,140	7%	1,196	104	1,300	7%
5 Arabian Sea Area	551	523	1,073	7%	522	1,314	1,836	10%
6 Southeast Asia	863	213	1,077	7%	866	266	1,132	6%
7 Oceania	141	6	147	1%	101	11	112	1%
8 East Asia	2,604	935	3,539	22%	3,995	912	4,907	27%
9 Korea	961	150	1,111	7%	1,050	141	1,191	6%
10 Japan	121	529	650	4%	161	498	659	4%
Total selected regions	11,380	4,493	15,874	100%	13,183	5,253	18,436	100%
Other regions	2,376	1,495	3,870	-	3,411	1,425	4,837	-
Total	**13,756**	**5,988**	**19,744**	**-**	**16,594**	**6,678**	**23,273**	**-**

Source: Compiled from Russian Customs data (2006, 2007)

The volume of flows for which the combined information on hinterland, foreland region and maritime routing is known is considerably lower. This applies for imports in 2007 in particular. See table 5. This means that the data used for the statistical analysis concerns a sample, rather than the full set.

Table 5: Russian container trade volumes by port basin (in 1000 tons)

Summary	2006			2007		
	import	export	total	import	export	total
Northwest basin	7,158	2,813	9,971	48	2,680	2,728
South basin	1,201	567	1,769	51	413	464

Far East basin	1,635	880	2,515	16	958	975
Total	**9,994**	**4,261**	**14,255**	**115**	**4,052**	**4,167**

Source: Compiled from Russian Customs data (2006, 2007)

4.3 Explanatory variables for logit model

Inland transport costs concern the costs between the major seaports of the port basin and the gravity points of the hinterland regions. The major seaports are Saint Petersburg for the Northwest, Novorossiysk for the South and Vostochny for the Far East port basin. The gravity points of the hinterlands regions are assessed on the basis of the centrality of the major cities in combination with the volume generated by the oblasts, krais or other entities involved. These are given in Annex 1.

Inland transport costs depend on the mode of transport used and the distance involved. Railway transport costs are calculated with RailTariff software based on 40 ft containers, which dominate the container trade and are shipped in full train loads. Returns of empty containers are included. The resulting container freight rates appear to vary from USD 0.57 to 2.57 per 40 ft kilometer.

The road tariffs are based on quotations by freight forwarders. Returns of empty containers are included. Container freight rates show some variation per container-kilometer and appear to vary from USD 1.27 to 1.59 per 40 ft kilometre. This is considerably less variation than as found at the railways.

Data used for road distances is based on Autotransinfo.ru, a Russian route planner software. The distances chosen concern the quickest route, which may be a longer distance than the shortest route.

For the assessment of inland transport costs it is assumed that for distances of up to 1000 km (based on the distances by road) road transport is used and that for the longer distances rail transport is used.

Road transport time is based on the time according to the route planner and railway transport time is derived from the railway software package. To allow for congestion and uncertainties with planning the resulting time is multiplied by a factor 1.3 and a fixed amount of two days is added for time spent in port for loading or unloading and clearance of cargoes.

The Transsib routings provide a shortcut between land and sea dominated routes thereby allowing for a trade-off between land and maritime transport. Therefore transit time is included as an explanatory variable.

Maritime transport costs of Russian containerised trades are available from private port studies (2007) and (2008), Drewry (2007) and Lloyd's Register/Fairplay (2007). Data from a private port study (2008) show that there is little difference between freight rates for the Russian trades with East Asia through Novorossiysk or Saint Petersburg. Drewry (2007) shows that freight rates for eastbound (return) cargoes to East Asia are about on third of the freight rates for westbound cargoes.

The transit time between the foreign port of origin (or destination) and the corresponding Russian port varies with the position of the ports within the itinerary of the liner service. This pattern becomes complex, if a shipment requires a combined main line and feeder service. Transit time also varies with the position of the ports in the inbound and outbound itinerary. In this study it is assumed that the transit time is equal to half the roundtrip time. Information on the roundtrip time is compiled from Drewry (2007).

5. Results of regression analysis

The models are tested with data sets of imports and exports for 2006 and 2007. The models include two variants: a variant with separate maritime and inland cost and time variables and a dummy variable for the South region (coming at 5 variables) and a variant with the totals of inland and maritime costs and time (coming at 3 variables).

The models with separate inland and maritime costs and time variables show varying results for the 4 data sets. The maritime cost variable is statistically significant for all data sets with t-values ranging from -3.54 to -6.25, while the value of the estimated coefficients varies between -0.002 and -0.003. In three of the four cases the inland cost variable is not significant with the exception of the data set of exports in 2007. The time variables perform poor, with the exception of the inland time variable for the data set of imports.

The value of the constant is negative and differs significantly from zero with t-values of up to -4. This means that for the base case alternative, i.e. the alternative of the Northwest basin, the market share as explained by the explanatory variables has to be adapted in a downward manner. This implies that the market share of Northwest routings is higher than is explained by the time, cost and dummy variables. The dummy variable for the South basin shows a mixed pattern with a positive sign for imports and a negative one for exports suggesting that for imports the market shares have to be adapted upward and for imports in a downward manner.

The models with inland time and cost variables added show significant estimated values for the costs for all datasets with t-values ranging from -7.1 to -9.3. The time variables show only significant values for the data sets of 2006.

The dummy variable for the South basin routing shows a significant negative value for exports and is insignificant for imports.

The r-square value ranges 0.44 to 0.58 for the four data sets and the two variants indicating that about half the variation of the market shares is explained by the model.

Table 6: Results of regression analysis on logit models

Variables	Imports 2006		Exports 2006		Imports 2007		Exports 2007	
	coefficient	t-value	coefficient	t-value	coefficient	t-value	coefficient	t-value
Separate cost and time variables								
Constant	-5.03	-4.06	-3.05	-3.54	-1.796	1.23	-2.04	-2.44
Maritime costs	-0.002	-5.21	-0.003	-6.25	-0.002	-3.54	-0.003	-5.80
Inland costs	0.001	0.99	-0.000015	-0.01	0.0021	1.59	-0.0024	-2.06
Maritime time	-0.036	-1.56	-0.022	-1.00	0.00413	0.14	-0.012	-0.52
Inland time	-0.675	-2.24	-0.488	-1.73	-0.987	-2.91	0.0156	0.58
Dummy south	2.13	1.56	-3.40	-3.36	1.462	0.858	-2.701	-2.71
Adj. R Square	0.44	-	0.57		0.58	-	0.51	
Total cost and time variables								
Constant	-2.81	-4.05	-2.152	0.083	-2.19	-2.54	-1.50	-1.86
Total costs	-0.0014	-7.06	-0.002	-9.29	-0.0019	-8.15	-0.0018	-8.65
Total time	-0.052	-2.33	-0.046	-2.21	0.001	0.03	-0.034	-1.59
Dummy south	0.064	0.066	-4.14	-4.12	1.38	1.11	-3.126	-3.16
Adj. R Square	0.42	-	0.55	-	0.55	-	0.51	-
No of observ.	150	-	144	-	91	-	143	-

Source: Authors' analysis

6. Interpretation of Results and Conclusions

The models tested measure the relation between market share ratios and cost and time differences according to model (4). The values of r-square indicate, that about half of the variation of market shares is explained by the model. An important part of the relation may be explained by other factors which are not included in the model, such as quality of service aspects. An important factor is the role of capacity limitations posed by ports and hinterland infrastructure, which leads to high congestion costs in 2006 and 2007. See Containerisation International Monthly Special Issue on Russia issue. The impact of strategic considerations of traders, keeping routing options open in order to minimize the risk of disruptions in their supply chains, may be an important factor too. The precise impact of these factors on the outcome of the model is not known.

For interventions in ports, such as investments in infrastructure, superstructure or pricing, it is important to know how such measures impact the market share of a port. The impact of an increase in costs per TEU of all containerised cargoes routed through a port can be assessed by systematically increasing the cost of the routings passing the port compared to the cost of all other routings. An example is given for the South basin ports. By increasing or decreasing the costs of the container trades routed via the ports of the South basin compared to the other port basins, containers are rerouted and the South Basin ports' market share will decrease or increase.

The impact of cost changes on the market share of a routing is simulated for both imports and exports using the coefficient of total costs as given in Table 4. We take equation (4) as starting point and include a term of the total cost differences C. As a result of an increase in total costs of, say, imports of 2006 of ΔC = USD 1, the term α1 (C_{iip}-C_{iik}) changes with an amount of α_1x 1 = α_1 = -0.0014. For values of ΔC = USD 2 the changes are 2 x 0.0014 = -0.0028, and so on for ΔTC = 3, 4 etcetera. Instead of taking the market ratios according to the model, i.e. P_{ijk}/P_{ijp}, we use the observed market ratios as starting point, i.e. F_{ijk}/F_{ijp}, where F_{ijk} and F_{ijp} are the actual trade flows as used for the regression analysis.

We calculate the market share of the South basin port for variations of ΔC ranging from USD -500 per 40 ft container to USD +500 per 40 ft container. The percentage changes in the volume of cargoes routed through the South ports vary as given in Figure 2, which represents the demand choice function for the South ports. The figure shows that a decrease in routing cost of USD 300 will result in an increase of the throughput volume varying from 9% to 14% for imports and 25% to 26% of the containerised exports. It should be noted that this order of magnitude of cost decreases is realistic for the South ports, in case they succeed in attracting mainline services replacing the feeder line services from trade regions east of the Suez Canal. Given the strong increase in trade volumes this may be expected to take place soon.

The demand choice elasticity is a measure of the responsiveness of demand to changes in the price of a routing. The elasticity is defined as (δd/d)/(δc/c), where d is demand and c the price leading to demand level c, while δd and δc refer to infinitesimal small changes. The values of the demand choice elasticity of imports and exports appear to range from -0.02 to -0.06. This implies that the choice of port basin is not sensitive to changes in port costs.

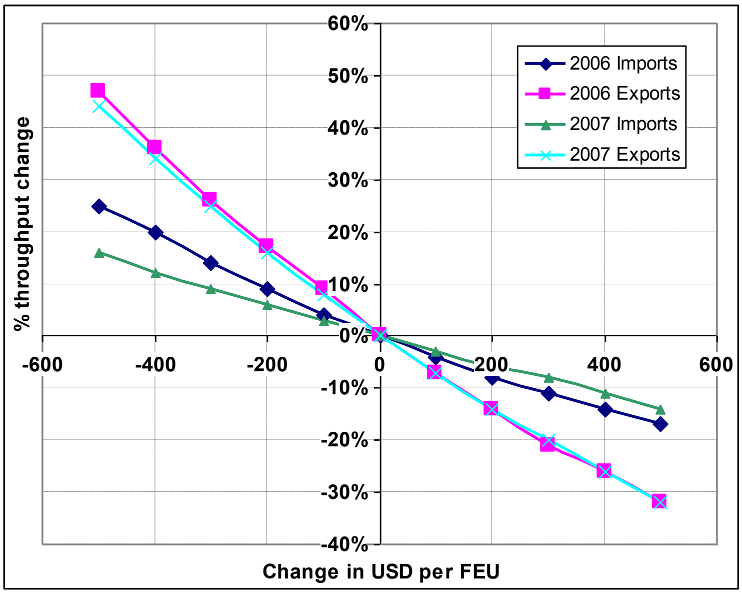

Figure 2: Change in throughput of the Southern basin ports for variations of ΔTC

Source: author's calculations

The impact of port costs on the choice of routings using ports can be compared with the result of other studies. Veldman and Bückmann (2003) studied ports choice for container flows between 33 hinterland areas and the container hub-ports of Antwerp, Rotterdam, Bremen and Hamburg along the West European North Sea coast. As shipping lines of all major trade routes call at these ports in a similar way the maritime costs per port for a particular route differ little, so that differences in routing costs are caused mainly by differences in the costs of hinterland transport. Results of simulations show a port choice elasticity value of -1.44. This is considerably higher than as measured for the Russian port basins.

Blonigen and Wilson (2006) tested a logit model for US imports of containerised cargoes and report a value of the average port choice elasticity of -1.5. Anderson et al. (2009) tested a logit model for US containerised imports for 10 ports and measured elasticity values ranging from -0.28 for the port of Houston to -2.11 for the port of Oakland. Veldman et al. (2010) tested port choice models for Spanish containerised trade and measured elasticity values of -0.20 for exports and -0.21 for imports.

Compared with these studies it can be stated that the elasticity values measured for the South ports basin of the Russian container trades are low. Possible explanations could be:

- the importance of costs of congestion and informal payments reducing the role of direct transport costs,
- the variation of the routing costs between the routing options for ports within a port basin,
- the strategic considerations to keep options open, and
- the lack of competition between the routing options and, more important, between the links of the routings.

Point 3 requires some explanation. Under full competition of all markets of the elements of the routing chains, there is competition between individual ports, inland transport modes and maritime routes. All the elements can be combined easily into a routing chain. If the linkage of elements requires more effort and thereby costs, the decision-maker has to concentrate on his integral costs of the total chain of a shipment. The variation of the costs of this compared to the costs of the individual elements (the costs of calling at a container port in case of the assessment of a port choice elasticity) is little and the thereby the value of the port choice elasticity. It is clear that this requires more research.

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Port Spatial Development and Theory of Constraints

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Abstract

Ports in different regions look for further developments to improve their ports to compete with others and deal with the demand of sea transport. A common way to deal with the increasing demand of sea transport and competing with adjacent ports is to expand the port. Due to the lack of structural guidance on this concentration-deconcentration issue, this paper aims at proposing a decision framework to determine whether a port development should be at the original site or a new site. In particular, a port spatial development model is developed based on Bird's Anyport Model and the Theory of Constraints (TOC). A framework of decision making is further formulated by considering major constraints (geographical, economic, and supporting constraints). In a systematic manner, the framework includes four steps for making decisions of port spatial development: port planning, site consideration, analysis, and decision making. Using Taiwan's Keelung and Taipei ports as case studies, the paper investigates the conditions in deciding whether port development would spatially concentrate or de-concentrate. The case studies suggest that the framework developed in this paper provides guidance for port spatial development decisions. The decision framework is readily expanded and modified to include other important constraints on port development.

Keywords: Port development, Theory of constraints, Ports, Concentrated, Taiwan

1. Introduction

Ports in different regions accomplish further developments to improve their ports to compete with others and deal with the demand of sea transport. Some ports aim to have the world's top container port throughput. Hong Kong and Singapore ports have competed with each other over decades. As China develops, ports in China have become strong competitors to them. In 2008, the world's busiest port was Singapore which handled 29.9 million TEUs, followed by Shanghai port 28 million TEUs, Hong Kong 24.3 million TEUs, Shenzhen 21.4 million TEUs, and Pusan 13.4 million TEUs. In order to be leading ports and provide better services, ports, such as Singapore and Hong Kong, maintain the high quality of port infrastructure and improve their port services from time to time.

Some ports will cooperate with other ports to enhance competition and improve their quality of services and infrastructure. Ningbo port and Zhoushan port in China are combined to enhance competitiveness. This cooperation maximises the location advantages, obtains benefits via sharing resources and complements the development each other. Hong Kong and Shenzhen also cooperate to develop the ports in the Pearl River Delta. As China develops, the Chinese market becomes more important. Shenzhen has two major ports, one is Yantian port to the east of Shenzhen, and the other is Shekou port to the west. The cooperation between Shenzhen and Hong Kong ports is Hong Kong's investment in Shenzhen and the Pearl River Delta port terminals. For example, a Hong Kong company, Hutchison-Whampoa, helped develop the Yantian container port to work closely with regions to coordinate inter-port links (Gallagher, 2002).

However, the usual way to deal with the increasing demand of sea transport and compete against competitors is to expand the port in the original site. For instance, in 1998 Shekou port in Shenzhen had only 2 berths to handle containerships and 200,000 m^2 of terminal facilities. But in 2008, the port expanded to have 7 berths and 1,060,800 m^2 of terminal facilities. The port of Los Angeles in the USA had 18 berths and 3,190,000 m^2 of terminal facilities in 1998. However, after the port development, this increased to 29 berths and 6,477,336 m^2 of terminal facilities in 2008.

The above indicate that port development is an important strategy for ports against competitors and to meet the demand of sea transport. Ports are required to look for a location to further develop their port. The location can be an area near to its original site or at another site. This paper aims to find out how and why the further port development will or will not be separated from the original site.

2. Literature Review

Port development has been studied in the past and there are many studies on the relationship between a port and a city. A well-known theory is the Anyport Model, which was developed by Bird (1963) to describe how port infrastructures evolve in time and space (also see Rodrigue, 1998). There are three major stages in a port development process: setting, expansion and specialisation. In the setting stage, the port development is strongly dependent on geographical considerations. In the expansion stage, industrial growth impacts on port activities. For instance, quays are expanded to handle the growing amounts of freight and passengers as well as larger ships. Port-related activities will also be expanded to include industrial activities. This expansion mainly occurs downstream. In the specialisation stage, the port development will involve the construction of specialised piers to handle freight, such as containers, ores, and coal. Some ports will move away from their original setting to increase their handling capacities. The expansion area is usually adjacent to downtown areas. The original developed site may become obsolete and be abandoned.

There is an extension to the Anyport Model by Notteboom and Rodrigue (2005), who commented that the model does not explain the recent rise of seaport terminals that primarily act as transshipment hubs in extensive maritime hub-and-spoke, collection, and distribution networks, and it also does not include the inland dimension as a driving factor in port development dynamics. Therefore, Notteboom and Rodrigue (2005) introduced the fourth stage in port development – Regionalisation, where *"inland distribution becomes of foremost importance in port competition, favoring the emergence of transport corridors and logistics poles. The port itself was not the chief motivator for and instigator of regionalization. Regionalization resulted from logistics decisions and subsequent actions of shippers and third party logistics providers"* (Notteboom and Rodrigue, 2005, p.311).

Apart from that, Ducruet (2007) studied how port-cities integrate land and sea networks, port and urban functions, logistics activities, and intermodal potentials. It was found that the closer the ports are to the hinterland, the less their port-city equilibrium is realised, given the concentration of flows and the indirect dependence on inland markets. Wang and Olivier (2007) studied the relationship of different global supply chains (GSCs) with port development. They mentioned 6 requirements for ports and shipping: 1) type of cargo, 2) volume, 3) flexibility in using alternative ports or terminals, 4) environment considerations, 5) vertical integration including port facilities, and 6) horizontal clustering in space.

However, firstly, there is no study whether the port expansion should be developed at the original port site or not (Issue 1). Secondly, it has not explained when developing a port at the original port site or another one, which constraints affect the port spatial development (Issue 2). Ng and Pallis (2007), who studied the impact of political culture on the differentiation of port strategies in addressing proximity, pointed out that the political culture must partly affect port strategies and development. Ng and Pallis (2007) also provided a framework for analysing the port management reforms and governance, such as considering the original port structure and strategies with the environment. This framework provided an idea and insight on analysing the relationship between the site and the environment in a port development.

In order to further address the above two issues and study the port spatial development, Taiwan is selected as a case study in this paper.

3. Methodology

3.1. Research Question and Propositions

This paper tries to find out how and why the port development will be separated from the original port site based on the Anyport Model by considering the constraints, which may affect the decision of this port spatial development. The research questions and propositions are as follows:

Research question: How and why will the port development be separated from the original port site?

> *Proposition 1: If there is no constraint against the development at the original site, then the port will be developed at the original site.*
>
> *Proposition 2: If there is a significant constraint against the development at the original site, then the port will be developed at another site.*

In order to examine the above propositions, the Theory of Constraints (TOC) will be used to analyse the constraints affecting the decisions of the port spatial development.

3.2. Theory of Constraints

TOC is a management methodology, which provides a thinking process for decision makers or managers. Many companies of all sizes in the world use TOC. The managers use TOC to understand their businesses and obtain a sense of control, and then they are able to take the correct actions, because TOC provides a consistent framework for diagnosing problems (see Mabin, Forgeson and Green, 2001). The TOC methodology contains a wide range of concepts, principles and tools. It enables different industries to apply it as long as they want to improve their performance (e.g. Lockamy and Spencer 1998). Mabin, Forgeson and Green (2001) studied TOC in a common area for different kinds of companies. They put TOC assisting with the change management, since there are similar situations in both topics, where resistance is involved. When a company wants to change, there is resistance to make the change difficult; TOC can be a tool and thinking framework to find out the constraints and solutions.

Some scholars also applied TOC in the events of supply chains. Rahman (2002) pointed out that the TOC provides a thinking process approach in developing strategies in supply chains. It not only helps to identify critical success factors in supply chain management, such as supply based management, communication, and trust among channel participants, but also to understand causal relationships between these constraints. Simatupang, Wright and Sridharan (2004) applied the TOC approach to overcome difficulties in realising the potential benefits of supply chain collaboration. The supply chain members used the framework of TOC to find out the potential benefits of supply chain collaboration. Since the managers were required to achieve the overall goal, which was to increase throughput and at the same time reduce inventory and operating expense, the managers had to quickly identify and remove the constraints and ensure that their company could continue to meet changing customer requirements accurately. Therefore, collaborative replenishment policy and collaborative performance metrics had been used to overcome the constraints.

As TOC is a useful tool to assist decision making and a powerful management methodology to find out the constraint and causal relationships, this paper uses TOC to develop the framework to determine the constraints affecting the port spatial development.

3.3. Evaporating Clouds Method of TOC

"*Evaporating Clouds method is used to model the assumptions that block the creation of a breakthrough solution*" (Stein, 1997, p.50). In this evaporating clouds method, there should be at least two different routes to achieve a desired objective. In order to achieve the objective, there are at least two different, yet necessary, conditions which are required to be met. Therefore, defining problems is to define requirements. A compromise must exist, and it is shared by the requirements. In order to satisfy the requirements, there is a requirement to do prerequisites which may conflict each other. That means two prerequisite exist, where the conflict arises. The evaporating cloud, which contains the above ideas, is shown in Figure 1 (Goldratt, 1990). More detailed discussion on the evaporating clouds method can be found in Goldratt (1990).

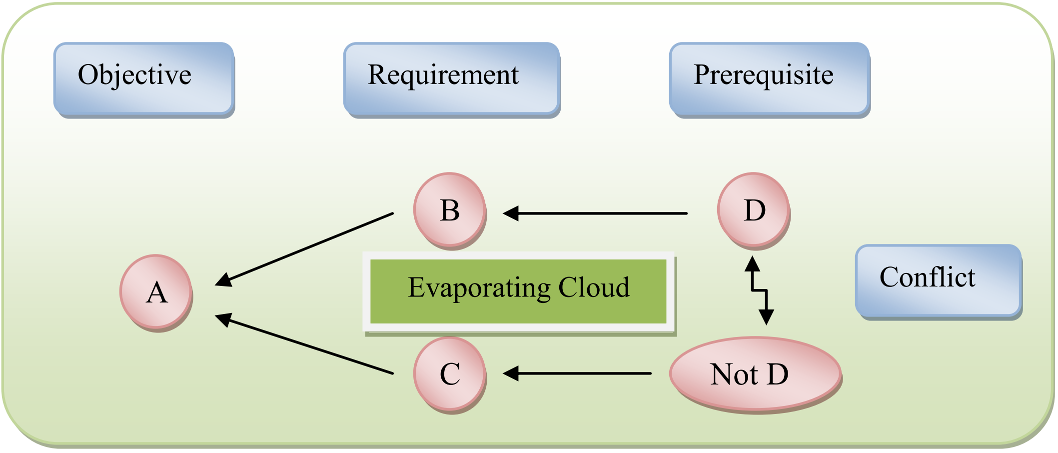

Figure 1 Evaporating Cloud

4. Port Spatial Development Model

4.1. Port Spatial Development

Many countries have formulated their own plan of port development. Some ports are developed in similar spatial settings, but some are not. There are 2 major different types of port spatial development in Taiwan Keelung port and Kaohsiung port. It is an interesting situation for a detailed study to find out the reasons why the port develops in a packed manner (original site) or a loose manner (another site).

Using the ports in Taiwan as a case, port spatial developments can be classified as two types – (1) concentrated port development and (2) deconcentrated port development.

- Concentrated port development means a port's expansion and development remains at or near the original site.
- Deconcentrated port development means a port's expansion and development is moved to a new location while still retaining the original site.

Keelung port in Taiwan is treated as a deconcentrated port development because it includes Keelung main port (main port), Taipei port and Su Ao port (sub-ports). On the other hand, the development of Keelung main port, Taipei port, or Su Ao port can be treated as a concentrated port development when only considering one single port. Kaohsiung port is treated as a concentrated port development because all terminals are developed in a packed area.

According to the Anyport Model (Notteboom and Rodrigue, 2005), the port infrastructures evolve in the site over different stages, which are the setting stage, the expansion stage, and the specialisation stage. However, referring to Taiwan Keelung port, the further port development could not evolve at the original site. When Keelung port was planning to expand its port in order to meet the demand of sea transport, there were alternatives as to whether the expansion was located near to the original site (Keelung main port) or the expansion was located at another site (Taipei port). Therefore, a decision maker was required to consider whether to separate the development from the original site or not (Figure 2).

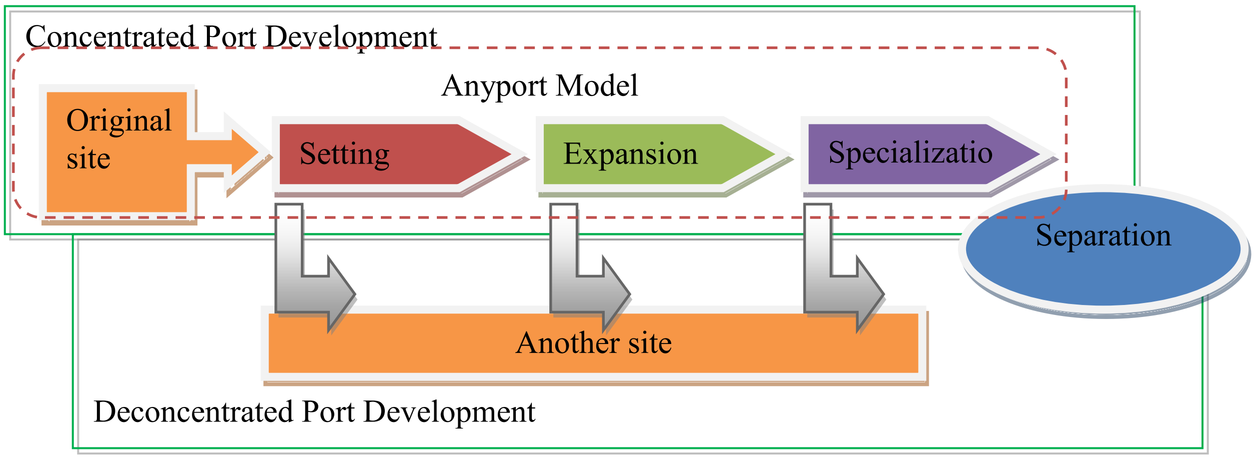

Figure 2 Port spatial development model

In the earlier stage, Keelung port was considering to further expand its port near to the original main site. A possible expansion area was in the western area of the original main site. However, this project was held and is pending. The port has found another site as a sub-port of Keelung port to further develop their port activities and functions. This site is known as Taipei port, which is isolated from Keelung main port but near Taoyuan and Taipei cities.

This case shows that during the expansion stage of the Anyport Model, the Keelung main port was not further expanded at the original site but looked to develop at another site. This separation makes the Keelung main port development move from the concentrated port development mode to the deconcentrated mode.

The problem is whether a planner should choose the concentrated mode (development at the original site) or the deconcentrated mode (development at another site)? The original site, where the port planner chooses, is fit to the original environment. Under this environment, another site is unfit to be developed. When the environment is changing, such as increasing cargo volume and vessel size, the port is required to further develop; therefore, the planner needs to consider whether the original site or another site is fit to the new environment.

Then, another problem is incurred. A planner needs a framework to assist his decision systematically. The paper will use the TOC tool to develop a decision framework for port spatial development.

4.2. TOC Analysis for Port Spatial Development

This paper uses the Theory of Constraint (TOC) to develop the framework about the decision of port development. That means using TOC to determine whether the further development should separate from the original site.

Firstly, there is a requirement to identify which constraints affect the decision of port spatial development or cause this conflict to occur. Secondly, the evaporating clouds method is used to find out the possible solutions of each constraint, and then the best solution can be selected from all constraints.

Loo and Hook (2002) discussed that the container terminal area in Hong Kong remained at the same location because of the delay in building the ninth Container Terminal since 1993 while Hong Kong's container volume continued to grow from 1993 to 2000. It implies that a port development is not only affected by one single constraint. This paper selects the major constraints, which should be considered for the port spatial development. The constraints (Table 1) can be classified as three core constraints, which are geographical constraint, economic constraint, and supporting constraint.

Table 1 Constraints of Port Spatial Development

Core Constraints	Sub-Constraints	Elements
Geographical constraint	Landside	Earthquake area
		Development spare
	Airside	Bad weather
	Seaside	Water depth
Economic constraint	Cargo sources	Hinterland
		Transshipment
	Cargo volume	Trend
Supporting constraint	Supporting package	Transportation
		Human resource
	Green production	Environmental impact
	Government planning	Control power
	Port operation	Terminal operators

For the geographical constraint, there is a requirement to consider landside, airside, and seaside sub-constraints. For the landside, the natural conditions, such as hill or earthquake area, may limit the port development. For example, if there is a hill near the port, it may restrict the building of a new facility. In the airside, the weather conditions, especially typhoons, can affect navigation. During a strong typhoon, bad weather is not favourable for navigation, vessels are restricted to enter, leave, or move within ports. In the seaside, the vessel size has been continually increasing in recent years, and more container ships are built to be over 10,000 TEUs vessels. It is preferable if an area has a deep water depth, as this can allow larger vessels to move in or out. Perhaps technology will become advanced; the area of natural advantages is not easy to discard.

In the economic constraint, if increasing trades occur near the port or in its hinterland, this can imply and assume that the cargo volume will be increased. The demand of requiring sea transport will increase, given that the trades will lead to the product flows via sea transport instead of air or road transport. Therefore, it is believed that a port planner will expand terminals near to this original site in order to capture the potential profit from sea transport. Thus, there are two sub-constraints in this economic constraint. One sub-constraint is cargo sources; whether an area will have cargoes is dependent on its connectivity to the cargo sources. The cargoes can come from the hinterland or other countries. Another sub-constraint is cargo volume. If the amount of cargo is not large enough to support the expansion, it is better not to expand the port. To check whether there is sufficient cargo volume for a port development or not, a planner can forecast the future cargo volume. For example, forecast can be conducted by using regression analysis on the past data of gross domestic product (GDP) and port throughput.

The supporting constraint includes four sub-constraints – supporting package, green production, government planning, and port operation. The supporting package is required near a potential developed area because the operation of the terminals cannot be run without infrastructural connection and man power. Another sub-constraint is the green production sub-constraint; if the development can produce a green effect, it is often preferred. Otherwise, a planner should choose another site, which has smaller environmental impact on human beings and nature. A high control from the government on port operation can also be a sub-constraint to develop a site.

These constraints with the elements can be the constraints of developing and expanding a port.

5. Results and Discussion

After completing the evaporating clouds for different constraints, in order to find out which way of port development is better for the planner to choose, this paper assigns marks to different situations for the constraints under the port development:

- Situation 1: if there is no way to solve the constraints to achieve the objective of port development, then the planner does not prefer this development; no marks go to the constraint.
- Situation 2: if the constraint can be solved by taking major mitigation measures, it will be relatively better than Situation 1; one mark is given for the factor.
- Situation 3: if the constraint can be solved without taking major mitigation measures, the planner prefers to choose this development; two marks are allowed for the factor.
- Situation 4: if the constraint can be solved with significant benefits, the planner mostly prefers this development; three marks are assigned for the factor.

While the details are not reported here, the result is summarised in Table 2. There are higher marks (18 marks) for deconcentrated port development as more objectives can be achieved by geographical, economic, and supporting constraints in Taipei port, compared to the marks for concentrated port develop in the Keelung port expansion area (14 marks). This result is supported by the fact that the Taipei port site has been chosen for development.

Table 2 Case of Port Spatial Development

Constraints of port spatial development	Objectives	Concentrated port development - Keelung Port expansion area	Deconcentrated port development - Taipei Port
Geographical Constraints	Allow large vessel to access	1	2
	Space for building terminals	1	1
	Similar or less risk in navigation & port operation	2	2
Economic Constraints	Closer to cargo sources	2	3
	Cargo growth	2	2
Supporting Constraints	Access to market	1	2
	Minimising environmental impact	1	2
	Man power for daily operation	2	2
	Flexibility in decision making	2	2
Results		14	18

Remarks:
0 mark = The constraint is unsolvable against the objective.
1 mark = The constraint can be solved with major mitigation measures.
2 marks = The constraint can be solved without major mitigation measures.
3 marks = The constraint can be solved with significant benefits.

Therefore, a planner can use TOC to design whether the further port development should be developed at the original site, or should be separately developed at another site in the different stages of the Anyport Model – Setting, Expansion, and Specialisation stages. By combining the idea of the Anyport Model and TOC, a port spatial development model is formed as in Figure 2.

In this port spatial development model, if in the setting stage, the TOC analysis shows that development at another site is better than at the original site, and then there is a separation, which means the port will move to another site for the development. The deconcentrated port development should be resulted. Otherwise, there will be a concentrated port development that means a planner will continually do the development at the original site until the expansion stage is reached, and the planner is required to make the decision of port spatial development again with using TOC. After the expansion stage, the decision making process will be taken again in the specialisation stage.

To assist the port spatial development model, there are four steps for making a decision on port spatial development (Figure 29). The four steps are: (1) port planning, (2) site consideration, (3) analysis, and (4) decision making.

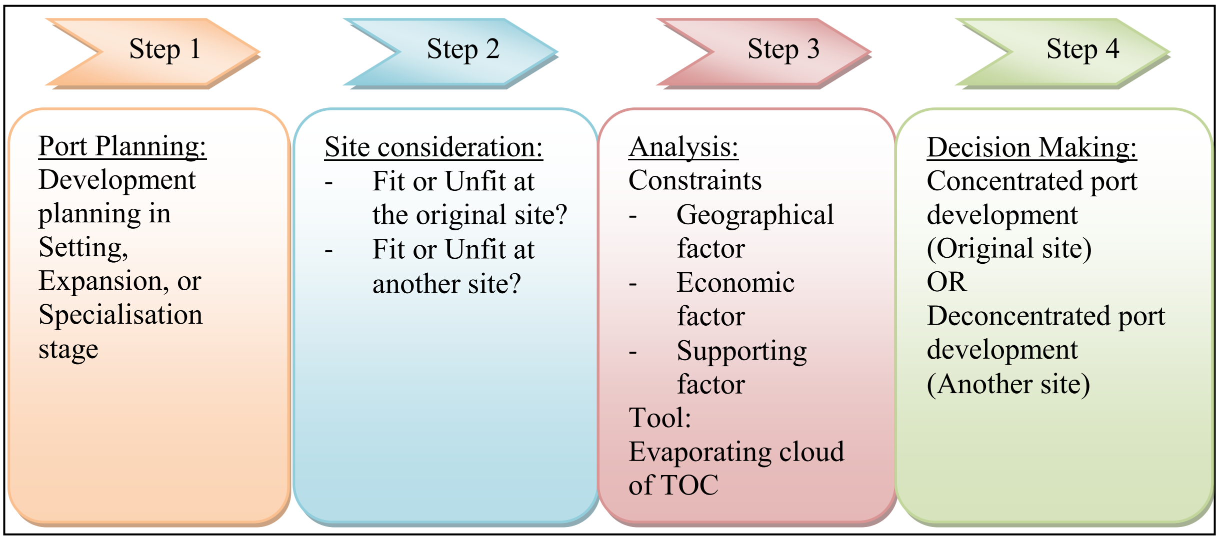

Figure 3 Decision Framework of Port Spatial Development

In Step 1, a port planner is seeking a port development. This can be in the setting, expansion, or specialisation stage in the Anyport Model. In Step 2, the port planner will consider whether the development is suitable to be completed at the original site or another site, so that the planner is required to find one more site as another site in this step. After having the options, in Step 3, the planner should indentify what geographical, economic, and supporting constraints there are. These constraints are constraints that affect the decision of port spatial development. Then, the port planner can use evaporating clouds of TOC to do the analysis. Step 4 is decision making. After the analysis, the output provides the information to make the decision. The planner can base the decision on the results from the TOC analysis to choose a concentrated port development (development at the original site) or deconcentrated port development (development at another site).

6. Conclusions

Ports look for further development sites from time to time in order to deal with the increasing demand of sea transport and become more competitive. The port spatial developments are classified in two types: concentrated port development mode and deconcentrated port development mode. In the case of studying the Keelung port and Kaohsiung port in Taiwan, Keelung port (including Keelung main port, Taipei port, and Su Ao port) in Taiwan is treated as a deconcentrated port development. The Keeling port has taken the concentrated port development mode when only considering one single port. Kaohsiung port has taken the concentrated port development mode. This paper has developed a framework of port spatial development to determine whether a planner should choose concentrated or deconcentrated port development, as well as how a planner can make this decision.

Under the Taiwan case, Keelung port has two port development plans. One is to further expand its port near to the original main site. Another is to find another site as a sub-port of Keelung port. The Theory of Constraint (TOC) has been used to deal with the identified problems. The TOC is used to test whether a planner should separate the further port development from the original site or not. The major constraints affecting the decision of port spatial development are included as three core constraints, which are geographical constraint, economic constraint, and supporting constraint. The evaporating cloud method has been used to study the constraints in order to find out the possible solutions, and then to select the best one. After analysing the constraints, the paper identifies that there are higher marks (18 marks) for a deconcentrated port development at Taipei port because more objectives can be achieved by the geographical, economic, and supporting constraints, and with the concentrated port development – the Keelung port expansion area obtained lower marks (14 marks).This result is supported by the fact that the Taipei port is chosen to be developed and the project of Keelung port expansion is on hold.

This paper not only shows that a planner can use TOC to design whether the further port development should be developed at the original site or another site, but also develop a framework, including the port spatial development model and four steps for making a decision on port spatial development, which is based on an idea for the Anyport Model and TOC. Under this framework, in different stages of the Anyport Model – Setting, Expansion, and Specialisation stages, the port development will be separated to develop at another site if the TOC analysis shows that the development at another site is better than at the original site.

As a result, the research question (How and why will the port development be separated from the original port location?) is answered by Proposition 1 (If there is no constraint against the development at the original site, then the port will be developed at the original site.) or Proposition 2 (If there is a significant constraint against the development at the original site, then the port will be developed at another site.).

Acknowledgements

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Group Pricing Models for Liner Shipping Revenue Management

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Abstract

Revenue management (RM), also known as yield management (YM), is a process of understanding, anticipating, and influencing consumer behavior in order to maximize revenue by allocating the right inventory to the right customers at the right price, at the right place, at the right time from resource-constrained companies, and the most important factor is the right price. There were many pricing mechanisms in the past research, and points to which special attention should be paid is group pricing, which is the tactic of offering different prices to different groups of customers for exactly the same product. In the competitive liner shipping market, liner carriers should realize the customer value to analyze what the reasonable price is for the different types of shippers. The elasticity and willingness to pay are two important factors for customer value analysis. In this paper, we analyze the shippers' response to price variation by these two factors and formulate four types of price response functions to categorize shippers into several groups by the two factors. Each group has the different characteristics to pricing, so we apply the recency, frequency, and monetary (RFM) analysis to analyze each group. This paper integrates price response functions with RFM analysis to develop group pricing models, which can be used to support pricing decision making for liner carriers.

Keywords: Liner Shipping, Revenue Management, Pricing, Group Pricing

1. Introduction

Liner shipping provides a service which follows a sailing schedule with one regular fleet on a regular route calling at regular port terminals, and it loads mostly containers such as dry cargo containers, reefer containers, etc. The liner shipping of shipment constitutes one third of the shipping industry, but the value accounts for about seventy percentage of the shipping industry. Due to the low price elasticity of demand and low customer switching costs, overcapacity has led to a price war in this industry. Agents, personnel in charge of pricing and sales representatives reduce the prices on the spot market to attract needed cargo tonnage, called predatory pricing which is defined as follows: "when the price of the product is lower than other products by very much in order to expel other products from the market. (Morrison, 2004)" Most liner companies focus on short-term revenue improvement by trying to control load factors. An increase in capacity utilization is usually viewed as a remedy for declining yields. A downward spiral of lower and lower yields is triggered by lowering prices to generate more demand. Clearly, pricing and revenue are directly linked: price multiply by lifts is revenue, which means that price determines revenue. Assuming that we are acting in a very simple market model, there are principally two ways to react in the market: either we change the price and cope with the reaction in terms of more or less demand by adjusting the capacity availability; or we influence the capacity availability and have to assess the necessary reaction in terms of prices. Most carriers simply use the low-rate policy to assure space utilization. This resulted in the space supply increase and lower rates (Ting and Tzeng, 2004). From a practical point of view, the sales process is that salespeople get the reserve price (i.e. the lowest price ceiling) offered by the pricing department at the head quarters or branch offices to seduce cargo. Under the pressure of supply- demand imbalance, the sales department mostly sells the space at the reserve price. Although this price is not less than the reserve price that carriers can accept, the space could be sold at a higher price to earn more revenue. This possible revenue loss is the consumer surplus, which is the difference between what consumers are willing and able to pay for the product and the price that they actually do pay. It will have a negative influence on the market. For this reason, the sales department must realize what the reasonable price consumers are willing to pay is, and the price must be higher than the marginal cost.

Revenue management (RM), also known as yield management (YM), is a process of understanding, anticipating, and influencing consumer behavior in order to maximize revenue by allocating the right inventory to the right customers at the right price, at the right place, at the right time from resource-constrained companies, and the most important factor is the right price. There were many pricing mechanisms in the past research, and points to which special attention should be paid is group pricing, which is the tactic of offering different prices to different groups of customers for exactly the same product. The idea is to offer a lower price to customers with a low willingness to pay and a higher price to those with a high willingness to pay (Phillips, 2005). Compared to the uniform pricing, it does not only make more revenue and profit for carriers but reduce the customer surplus shown as in Figure 1, which can achieve much more economic effectiveness in the market.

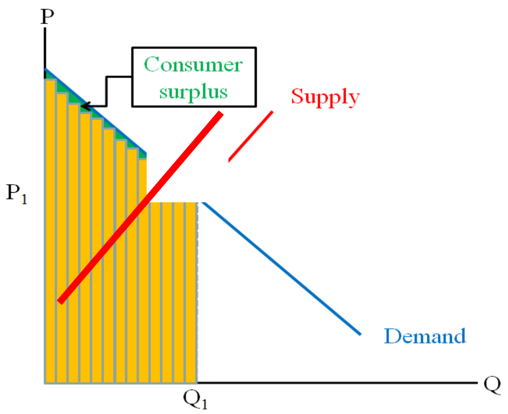


Figure 1: Consumer Surplus with Group Pricing

As for the previous studies and applications regarding pricing and revenue management, Ting and Tzeng (2004) proposed a conceptual liner shipping revenue management (LSRM) model. The LSRM is concerned with the integrated operation of long-term customer management, cost management, route planning and ship scheduling, as well as short-term cargo demand forecasting, container inventory control, slot allocation, pricing and dynamic space control. There are two major components: (i) long-term planning, which can assist with longer term customer management, cost management, market monitoring, service route planning and ship scheduling; and (ii) short-term operations, which can assist with voyage revenue optimization in terms of demand forecasting, slot allocation, pricing, container inventory control and dynamic space control. Ideally, such a system should be integrated with freight revenue, cost, container inventory database and accounting systems. There are many different kinds of pricing mechanisms used in the different industries in the previous research. We reviewed the pricing mechanisms including basic pricing mechanisms and dynamic pricing mechanisms. The basic pricing strategy can be divided into five mechanisms which include maximum profit pricing, average cost pricing, cost-plus pricing, demand oriented pricing, and competition oriented pricing. Firstly, maximum profit pricing which will happen in a monopoly, exists when a specific individual or enterprise has sufficient control over a particular product or service to significantly determine the terms in which other individuals shall have access to it (Friedman, 2002); secondly, average cost pricing is breakeven, and the government usually uses it as a tool to regulate the prices a monopolist may charge for social welfare; thirdly, cost-plus pricing, open-book pricing, is used primarily because it is easy to calculate and requires little information, and the price is the actual cost of the service plus a markup or profit margin; fourthly, demand-oriented pricing, demand-based pricing, is the method of establishing the price for a product or service based on the level of demand - a higher price can be charged when the demand is strong, a lower price when it is weak; finally, competition oriented pricing is the strategy whereby prices are set based on what a firm's competitors are charging competitive advantage. Pricing mechanisms research and a list of the industries in which it has been undertaken are shown in Table 1.

Table 1: Pricing Mechanisms Research and Applications

Applied industries	Issues and problems	References
Airline	Seat inventory control	Littlewood (1972), Belobaba (1987), Belobaba (1989)
	Airfare pricing	Ples and Rietveld (2004),Vowel (2006)
Ferry	Pricing	Jørgensen et al. (2004)
Airport landing fee	Pricing	Morrison (1982), Martĺn-Cejas (1997)
Liner shipping	Pricing	Brook and Button (1996)
Perishable product	Pricing	Anjos et al. (2005), Feng and Xiao (2006), Zheng and Chen (2006)
Retailer	Pricing	Sung and Lee (2000)

In the competitive liner shipping market, liner carriers should realize the customer value to analyze what the reasonable price is for the different types of shippers. The elasticity and willingness to pay are two important factors for customer value analysis. In this paper, we analyze the shippers' response to price variation by these two factors and formulate four types of price response functions to categorize shippers into several groups by the two factors. Each group has the different characteristics to pricing, so we apply the recency, frequency, and monetary (RFM) analysis to analyze each group. This paper integrates price response functions with RFM analysis to develop group pricing models, which can be used to support pricing decision making for liner carriers.

2. Price Response Functions

There are two factors, demand elasticity to price and willingness to pay, which influence the price response functions for the different types of shippers. The elasticity measures the rate of response of quantity demanded due to price variation. The shippers with low elasticity are not sensitive to price variation, probability of accepting higher price to this type of shippers should be much more certain and higher when raising price. On the other hand, the shippers with high elasticity are sensitive to price variation, probability of accepting higher price to this type of shippers will be dropped dramatically when raising price. Only if liner carriers can realize each shipper's price elasticity, they can grasp their price response and analyze the customer value of each shipper for pricing decision making support. Willingness to pay is the foundation of economic theory of customer value. This idea being, if something is worth having, then it is worth paying for (Whitehead, 2006). In this paper, the customer trade data are analyzed and categorized the shippers into several pricing groups according to the consumer's characteristics as described later. This paper proposes four types of price response function to describe the relationship between price and the probability of acceptable price as follows.

2.1. Inelasticity Price Response Function

Firstly, for the inelasticity function, when the price is raised, the probability of price acceptance to the shippers will be zero. This group has the most sensitive to the price variation. We define this group customer as the most sensitive and an inelasticity price response function shown in Figure 2(a).When the price is charged higher to a certain level, the probability of acceptable price to this group shipper will become zero. When salespersons offer them high price they can not afford or satisfy, the customers will withdraw their orders, so salesperson need to look up the previous trade data and offer them the price carefully.

2.2. Decreasing Elasticity Price Response Function

The second group of customers is also sensitive to the price, but the slope of the curve is decreasing sharply, which means that the probability of price acceptance to this group decline sharply. We define this group customer as a decreasing elasticity price response function shown in Figure 2(b). This group is somewhat like the forwarders, whose profit is the price difference between the price offered by carriers and the price they offered to their customers. Thus salespersons need to set the price carefully to prevent customers from quitting orders.

2.3. Constant Elasticity Price Response Function

The constant curve has the constant slope, and it means that the probability of price acceptance to the customers will decrease at a constant rate. We define this group customer as a constant elasticity price response function shown in Figure 2(c). The third group of customers has the linear relationship between the price and the probability of acceptable price to these customers, and it means that the probability will decrease by certain proportion to the price.

2.4. Increasing Elasticity Price Response Function

The slope of increasing curve is increasing, and it means the probability of price acceptance to this group of customers will decline slowly. This group of customers is insensitive to the price. When the price is raised, the probability of acceptable price to this group will decline slowly until to an unacceptable price level. We define this group customer as a increasing elasticity price response function shown in Figure 2(d). This group of customers can let liner carriers have most opportunity to make more revenue by offering them higher price. Thus salespersons can raise the price for these price-insensitive and high willingness-to-pay customers.

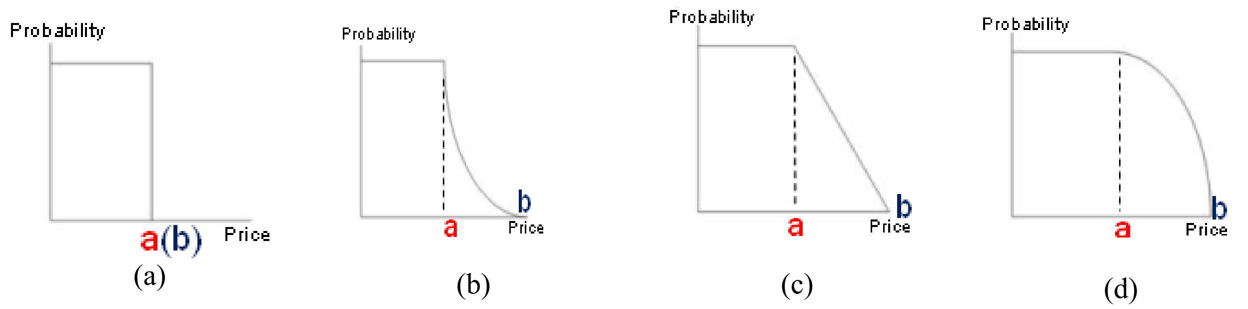


Figure 2: The Price Response Functions by Shippers' Purchase Behavior

In all the above price response functions, there are two price level **a** and **b**, the first price level **a** stands for the regular price offered to this customer. This level **a** can be acquired by mining trade data with this customer. The second price level **b** stands for the upper price ceiling offered to this customer. This level **b** is more difficult to be acquired, only through try-and-error pricing to define the level **b**. When we formulate the price response functions, the excepted willingness to pay (EWTP) of each group can be calculated by Eq. 1. As for the group with more EWTP, the salespersons could offer higher price to this group and get more profit. This can reduce the consumer surplus and achieve more economic efficiency in the market.

$$EWTP_i = a_i + \int_{a_i}^{b_i} f_i(x)dx \,, \qquad (1)$$

where *ai* = Acceptable price for customer *i,*
bi = Maximal possible price for customer *i,*
fi (x) = Price response function.

3. Customer Value Analysis

We use the variables of RFM analysis including recency, frequency, and monetary to analyze customer purchase behavior, and it can be applied to subgroup to reflect the different degrees of their trade importance. The idea is that dividing the customers into subgroup based on the partition of last purchasing date, number of purchases, and total dollar amount of each customer for the capacity in this sense. The last purchasing date for the capacity represents a customer’s preference. Customers who purchased recently were more likely to buy again versus customers who had not purchased in a while. The number of purchases for capacity stands for the demand degree to the customer, and total dollar amount of each customer means the value degree of capacity to the customer. We use RFM analysis to test an example of typical customer's transaction record to subgroup the customer's data. After that, we transform the customers’ transaction record into RFM values according to the three factors.

According to the normalized RFM values we got, we conduct the K-means cluster analysis, a multivariate statistical technique, to group entities into homogeneous subgroups on the basic of similarity according to the three key factors. After the grouping process, each customer would be positioned in the cluster with the most similarities. We manipulate SPSS 14.0 to group entities into homogeneous subgroups, and the result is that there are three clusters. We use the inverse function to transform the value of recency into the positive relationship with the customers’ value as in Eq. 2, and the normalized RFM values are shown as Table 2 and Table 3.

$$V_i = \frac{1}{X_i} \tag{2}$$

Table 2: Normalized RFM Customer Values

Customers	Recency	Frequency	Monetary
A	0.142857	6	33,000
B	0.5	8	46,000
C	0.25	8	49,000
D	0.166667	10	139,000
E	0.1	9	50,000
F	0.083333	12	38,000
G	0.1	8	29,000
H	0.333333	10	49,000
I	0.2	11	51,000
J	0.125	8	52,000
K	0.083333	10	56,000

Table 3: The Customer Clusters

RFM	Customers
1	D
2	B, C, E, H, I, J, K
3	A, F, G

Ha and Park (1998) proposed a strategic position of customer clusters with centers (average RFM values) of each customer cluster plotted on a graph. Average RFM value of each cluster will compare with the total average RFM values of all clusters. If the average RFM values of a cluster is greater than the total average RFM value, the ↑ (upward arrow) is assigned to the variable; on the contrary, if the average RFM value of a cluster is smaller than the total average RFM value, the ↓ (downward arrow) is assigned to the variable; on the other hand, frequency and monetary values are more reliable than recency value by Marcus (1998); moreover, the monetary value is more important than frequency value, hence, if there are same numbers of upward, the priority will follow the significance which is monetary, frequency and recency.

In our test case study, the result shows that there are both two upward arrows in the cluster 1 and the cluster 2, and the cluster 3 doesn’t have any upward arrow as shown in Table 4. There is no doubt that the customer in the cluster 3 is with lowest value in all customers. In addition, because cluster 1 and cluster 2 have the same upward arrows, we use the sequence method by Marcus, and the result is that the cluster 1 has the higher level than the cluster 2, because the monetary value is more important than recency value in consideration.

Table 4: The Priorities of Clusters

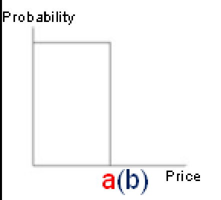
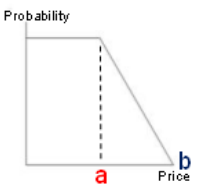
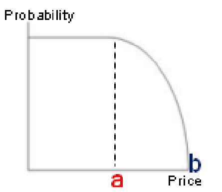
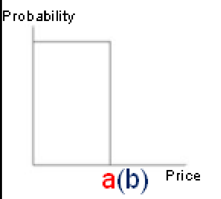
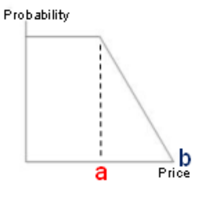
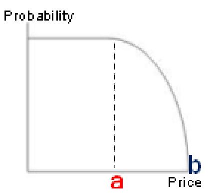
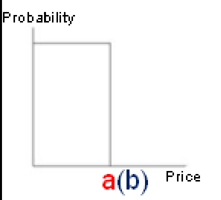
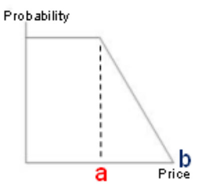
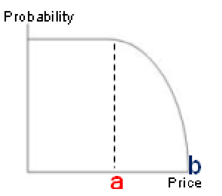
	Recency	Frequency	Monetary	Level
Average	0.239394	9.090909	51818.18	
RFM 1	R↓	F↑	M↑	First
RFM 2	R↑	F↑	M↓	Second
RFM 3	R↓	F↓	M↓	Third

4. Integrated Group Pricing Models

We integrated the RFM analysis with customer clustering information as shown in Table 3. When salespersons set the price for each customer, they need to consider the marginal costs of each order according to costing model in order to ensure that the trade will not lead to a loss for a carrier. Considering our previous example, the high value customers in RFM 1 have the low recency, high frequency, and high monetary, and it means that most deals of this customer is higher price, so we can conjecture that this kind of customer is not sensitive to the price, and then salesperson can set higher price to the customers in order to earn more revenue and profit and reduce the consumer's surplus.

Secondly, the low value customers in RFM 1 have the low recency, high frequency, and high monetary, and it means that this kind of customers is sensitive to the price and the amount is major part of revenue for the carriers, and the customers will leave or distrust the carrier when the price is too higher for them, so carriers need to set price carefully, and the price need to be above on the marginal costs. Besides, the low value customers in RFM 3 have the low recency, low frequency, and low monetary. It means that this kind of customer is sensitive to the price, but carrier don't need to be afraid that the customers will leave or distrust the carrier when the price is too higher for them, because the amount is minor part of revenue for the carriers, so a carrier can try to set higher price to the customers in order to make more revenue. When the customer increases the frequency of purchasing, the monetary and excepted willingness to pay will be increased. It will increase the customer's value.

Table 3: The Integrated Group Pricing Matrix by Price Response Function and RFM Analysis.

Response / RFM	Inelasticity	Decreasing Elasticity	Constant Elasticity	Increasing Elasticity
RFM 1: R↓, F↑, M↑				
RFM 2: R↑, F↑, M↓				
RFM 3: R↓, F↓, M↓				

5. Concluding Remarks

In the market with tremendous overcapacity, liner shipping companies require lots of changes and innovation in their pricing process so that carriers can make more reasonable profit. Salespersons must sell the space according to the standard operation procedure (SOP) to get more trade information, which can help them offer more reasonable price to each customer and reduce the customer surplus, and it can achieve much more financial effectiveness and market economic efficiency. Several conclusions and study contributions are summarized as below. In addition, some issues for further research and suggestions to this industry are also stated.

(1) By business process reengineering, the sales process for pricing should be restructured. The process has to assist the salesperson to contemplate the reserve price, customer's characteristics, historical transaction record, and the demand record in the past. The process would be better than the previous sales process. In addition, it could save the failed orders into customer database to provide the reference for the next pricing.

(2) Through the integrated pricing models, salespersons can make better pricing strategy and reduce the customer surplus through providing high elasticity customers with more flexible prices, and low elasticity customer with fixed prices. In addition, the excepted willingness to pay of each customer's category can be calculated to realize the customer's value for carriers.

(3) Through RFM analysis, we analyze customer purchasing behavior, and it can be applied to subgroup to reflect the different degrees of their importance, and then we conduct the K-means cluster analysis to group entities into homogeneous subgroups on the basic of similarity according to the three RFM factors.

(4) Test data are used to demonstrate the pricing models. It is recommended that a further research can analyze historical customers' transaction records to demonstrate this model to provide the decision making support, and to modify the models to be suitable for the actual situation for carrier's performance.

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Temporal Links between the Freight and Ship Markets in both Dry Bulk and Tanker Sectors

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Abstract

This paper examines the temporal relations between the freight and ship (newbuilding and second-hand) markets in two related sectors - the dry bulk and tanker sectors. Evidences show that the relations among these markets are differed for these two shipping sectors. These results imply that the ways of information transmitting across these three markets are different. Thus, ship owners should pay special attention to their decision making in different shipping sectors. Moreover, we suggest that this difference is more likely caused by the role played by the newbuilding price or even the newbuilding market.

Keywords: temporal links, freight market, ship markets

1. Introduction

It is well known that there are four closely related markets in the international shipping industry based on the linkage of cash flows, namely the freight, the second-hand, the newbuilding and the demolition markets. Indeed the freight market is a service market in which cargo-owners can rent vessels for sea transport services while the newbuilding, second-hand and demolition markets are all dealing with ships and can be viewed ship markets.

A very important point is that these markets are not independent but related to each other. In this paper, we examine these relations from a new point of view – the direction of ship flow. It is well known that world shipping is an economic activity directly dependent on global seaborne trade. Seaborne transport activities can then cause the demand for ships by the cargo-owners. In this circumstance, the cargo-owners will enter into a special contract with the ship-owners for the hire of their ships. For the ship-owners, they have two ways to get ships: purchase an old ship immediately in the secondhand market or order a new one in the newbuilding market. Ship-owners can hire out their ships in the freight market for just operating the ships for a period of time or they can also sell them to take the advantage of the value increase for speculation purpose in the secondhand market. Any decision made by the ship-owners on how to get the ships will influence the ship markets (newbuilding and secondhand markets) immediately. On the other hand, ship-owners have three ways to deal with the ships when the freight market is in recession - to sell them in the second-hand market, scrap them in the scrapping market or lay-up them for a period of time. The choice they made can also affect the market.

In this paper, the demolition market is not considered. We just focus on the timing of obtaining the ships. So the ship markets here specially mean the newbuilding and second-hand markets.

Furthermore, the shipping industry comprises the dry bulk and tanker sectors, each with its own distinct market structure. Comparing these two sectors, despite the different shipping routes, the shipped cargoes and the sizes of vessels, etc., the links between the freight and ship markets for these sectors may also be different.

Veenstra (1999) indicated the different economic structures with these two sectors. Specially, he pointed out that the role of second-hand prices differed in the dry bulk and tanker shipping sectors. *Kou and Liu (2010)* have also found opposite relations between the newbuilding and second-hand ship prices in these two shipping sectors.

Indeed, past studies usually were carried out within either the dry bulk or the tanker sector separately. Although in some studies, these two sectors are examined simultaneously (for example, *Glen 1997, Hale and Vanags 1992, Haralambides et al. 2004, Tsolakis et al. 2003*), their original intentions are not to compare and explain the difference between these two sectors.

Therefore, our aim is to investigate the temporal linkage between the freight and ship markets in two shipping sectors and to compare if these two sectors have the same or different structures. In order to study this issue, we choose a typical variable to represent each market. For the freight market, it has been established in previous work that the time charter rate is the variable that channels information on freight market developments to the ship markets (*Haralambides et al. 2004, Tsolakis et al. 2003, Veenstra 1999*). Thus, we choose time charter rates as represented variables in the freight market. For the ship markets, *Veenstra (1999)* has used order book as the typical variable to represent the newbuilding market in VAR model. Thus, linear relationship between the variables is the underlying assumption of his model. However, linear or non-linear relationships between order book and freight rate (or second-hand price) are unknown to us. Then, using newbuilding price as the key variable to represent newbuilding market seems more reasonable than order book. First, the second-hand ship price can be viewed as a discount newbuilding price under some normal circumstance. Second, researchers in the past suggested that the expected future time charter rates could be viewed as current secondhand ship price. Although we do not know the exact function between the three variables, at least the existence of some linear relationship between them is plausible. Furthermore, in shipping industry, since the movable capital assets are traded, ship prices over time are of great importance to investors taking decisions. Thus, we choose newbuilding and secondhand ship prices in these two markets.

Research on the temporal relationships can provide insight on the directions of information flow between the freight and ship markets and on how well these markets are linked. This information is important to agents in shipping and may be of interest to ship owners, charterers and investors in their decision making activities. Research on the difference between the dry bulk and tanker sectors is important because if the market linkages are different, the investment timing on ships will be different in these two sectors. Knowing the difference, ship owners and investors can pay special attentions to their decision making in different sectors.

The remainder of this paper is organized as follows. The next section is the literature review. The third section discusses methodology used in this paper. The fourth section presents the results of the tests within all ship segments in two shipping sectors and discusses the implications of these results. The last section concludes the paper.

2. Literature Review

Regarding the research on the links between the freight and ship markets, past studies usually paid their attention to only two of them in just one shipping sector (dry bulk or tanker). For example, past studies have worked on the relationship between the secondhand ship price and time charter rate (*Alizadeh and Nomikos 2007, Strandenes 1984*), or the relationship between the freight rate and newbuilding price (*Hawdon 1978, Xu et al. 2008*), or the relationship between the newbuilding and second-hand ship price (*Kou and Liu 2010*).

Alizadeh and Nomikos (2007) investigated relationship between 5-year-old ship price and 1-year time charter rate in the dry bulk shipping. Results suggested that these two variables are cointegrated in every ship segment. Causality between them is from time charter rate to second-hand ship price.

Strandenes (1984) studied the relationship between the time charter rate and the second-hand ship price using annual data. She explained the second-hand price as a function of discounted earnings at current market and the market replacement value of the ship which was assumed to be equal to the corresponding newbuilding price.

Hawdon (1978) developed and estimated an econometric model of the behaviour of annual average tanker spot rates for the period 1950-1973. He found that current level of freight rates have a significant impact on newbuilding ship prices, while lagged freight rates are non-significant. But he didn't test whether the lagged newbuilding ship price has impact on freight rate.

Xu et al. (2008) used panel cointegration to test the dynamic relationship between international sea freight rate and shipbuilding price in dry bulk market. She found that freight rate is sensitive to shipbuilding prices and they have a positive directional relationship in the dry bulk sector.

Kou and Liu (2010) investigated the temporal relationship between the newbuilding and second-hand ship prices in both the dry bulk and tanker sectors. They found the temporal linkage in the dry bulk sector is from the second-hand to the newbuilding ship price but it is opposite in the tanker sector.

Studies related to the linkage among three markets are *Haralambides et al. (2004), Tsolakis et al. (2003)* and *Veenstra (1999)*.

Tsolakis et al. (2003) used the Error Correction Model (ECM) to analyze second-hand ship prices in the tanker and dry bulk markets under the supply-demand equilibrium model. *Haralambides et al. (2004)* extended *Tsolakis et al. (2003)*'s research to include both second-hand ship prices and newbuilding ship prices. Their results showed that the newbuilding prices and time charter rates have the greatest effect of all variables on the second-hand prices. This is also the reason why we use the newbuilding, secondhand ship price and time charter rate as represented variables in our model.

Veenstra (1999) is the only researcher who mentioned and verified the casual links between the main ship markets are different in the dry bulk and tanker sectors. He presented a structural VAR model consisted of five variables: order book, trade flow, second-hand price, time charter rate and spot charter rate. His purpose is to offer insights into the structure of the whole shipping industry. Then he investigated this issue with the average data series rather than separating ship segments. In addition, he used quarterly data sample from 1980 to 1995 in which only 60 observations contains. This sample size seems limited by using structure VAR model. Another question discussed above is that he chose order book rather than newbuilding price as the key variable in the newbuilding market. His results indicated that the role of secondhand prices differed in the dry bulk and tanker shipping sectors.

In summary, most of the existing works either concerned two or three markets, the purposes of them are usually not to compare the results drawn from the dry bulk and the tanker sectors but to find the influence of one variable on another. In other words, their results just suggested the degree of impact between the markets in two sectors. From these results, we are still unclear about how fast one market reflects new information relative to another. Furthermore, *Veenstra (1999)* has already inferred that the tanker and dry bulk sector may differ in the information transmitting because the role played by the second-hand market. However, there is a lack of work on testify this inference.

Thus the aim of our work is to study the temporal links between the freight and ship markets within specific ship segments. Then we will compare the different linkages between the dry bulk and tanker sectors and testify if this difference is caused by the second-hand market.

3. Methodology

We will use the Granger causality test to capture the temporal relationship between freight and ship markets. This test requires stationary data. To test the stationarity of each series, Augmented Dickey Fuller (ADF) (*Dickey and Fuller 1981*) and the Phillips and Perron (PP) (*Perron 1988; Phillips and Perron 1988*) methods will be applied.

From results of the past research, we know that the price series in our study are likely non-stationary. *Engle and Granger (1987)* pointed out that the non-stationary time series are cointegrated if the linear combination of the series is stationary. In this paper, *Johansen (1988, 1991)* cointegration test will be applied to test for possible existence of cointegration.

For the Johansen cointegration test, it usually used with VAR model together. The VAR model contained cointegrated variables can be also called Vector Error Correction (VEC) model. A VEC model is a restricted VAR designed for use with non-stationary series that are known to be cointegrated. The basic *p*-lag VAR model is as follows:

$$Y_t = c + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \cdots + \Pi_p Y_{t-p} + \varepsilon_t \tag{1}$$

where Y_t is a k vector of macroeconomic variables, Π_i are matrices of coefficients to be estimated, c is the intercept, p is the lag length and ε_t is an unobservable zero mean white noise vector process which can be also viewed as a vector of innovations. Then the general cointegration VAR model is written as:

$$\Delta Y_t = c + \Pi Y_{t-p} + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{2}$$

The matrix Π contains the components of the long-run cointegration relations between the variables, if they exist. Johansen test focuses the examination of the matrix Π which can be interpreted as a long-run coefficient matrix. The test for cointegration in Y_t is performed by calculating the rank of the Π matrix. There are three possibilities for this rank: first, it can be zero indicating no cointegration relations; second, it can be equal to the total number of components indicating stationary of all time series in the model; third, it can also be r rank between zero and the total number of components. In this case, there are r cointegrating vectors in Y_t. *Johansen (1988, 1991)* proposed trace statistic and maximum eigenvalue statistic to determine the rank of Π.

After determining the existence of cointegration, we can carry out Granger causality test to capture the casual linkages. If there is no cointegration, tests of Granger causality based on VAR involving the first differences of the data will be used. The bivariate VAR model of the first difference data are estimated with:

$$\begin{aligned} \Delta x_t &= c_1 + \sum_{j=1}^{q} \alpha_{1j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{1i} \Delta y_{t-i} + \varepsilon_{1t} \\ \Delta y_t &= c_2 + \sum_{j=1}^{q} \alpha_{2j} \Delta y_{t-j} + \sum_{i=1}^{q} \beta_{2i} \Delta x_{t-i} + \varepsilon_{2t} \end{aligned} \tag{3}$$

where Δx_t and Δy_t denote the variables for the first difference. $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of the corresponding error terms which contain all the other information that may affect *x* and *y*, and *q* is the optimal lag length. All the criteria of selecting a lag length are discussed in *Lütkepohl (1991)*. In this paper, *Schwarz (1978)* (SC) and Akaike's Information Criterion (AIC) will be employed. If SC and AIC choose different orders, we will try both of the lags. Which criterion will be used depends on the size of data sample and whether the test results are robust.

If cointegration does exist, Granger causality test based on the VEC model will be adopted instead of using the first difference data based on VAR model. The Granger causality test based on the VEC model can be expressed as:

$$\begin{aligned} \Delta x_t &= c_1 + \sum_{j=1}^{q} \alpha_{1j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{1i} \Delta y_{t-i} + \delta_1 ECT_{t-1} + \varepsilon_{1t} \\ \Delta y_t &= c_2 + \sum_{j=1}^{q} \alpha_{2j} \Delta x_{t-j} + \sum_{i=1}^{q} \beta_{2i} \Delta y_{t-i} + \delta_2 ECT_{t-1} + \varepsilon_{2t} \end{aligned} \tag{4}$$

Compared with equation Eq. 3, Eq. 4 has an additional term ECT_{t-1}, which is known as the error correction term containing long-run relationship between cointegrated variables since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments, δ is the coefficient of this term.

Thereafter, the Granger causality test examines the null hypothesis that $\beta_{1i} = 0$ or $\alpha_{2j} = 0$ for all *i* and *j* (*i*, *j*=1, 2… *q*) in both Eq. 3 and Eq. 4. When $\beta_{1i}=0$, the null hypothesis is that *y* does not Granger cause *x* in the first regression in Eq. 3 and Eq. 4. When $\alpha_{2j}=0$, the null hypothesis is that *x* does not Granger cause *y* in the second regression in Eq. 3 and Eq. 4. Thus, evaluation of the significance of variables in VAR should be conducted.

4. Estimate Results

4.1 Data Analysis

The data used in this paper consists the time series of monthly newbuilding and 5-year-old ship prices, 6-month, 1-year and 3-year time charter rates for three different-size carriers in both dry bulk (Capesize, Panamax and Handysize) and tanker (VLCC, Suezmax and Aframax) sectors from Clarkson Research Studies, Lloyd's Shipping Economist and Fearnleys. The categories of the ship segments in each sector are divided as most studies in the past (*Alizadeh and Nomikos 2007, Haralambides et al. 2004, Kavussanos 1996, Kavussanos 1997, Tsolakis et al. 2003*). All ship prices are quoted in million dollars in each category and time charter rates are measured in dollars per day. *NP* and *FP* will use to represent the newbuilding and 5-year-old second-hand ship prices. For the time charter rate, *TC* broadly means the time charter rate and *TC*6, *TC*1 and *TC*3 are used for the 6-month, 1-year and 3-year time charter rates, respectively. The logarithmic transformation of series is applied with all data series.

In this paper, we use *TC*6, *TC*1 and *TC*3 to test the temporal relations in the dry bulk sector. In the tanker sector, ships are usually hired in a longer time period than in the dry bulk sector. Therefore, *TC*6 are not available. Then we just consider *TC*1 and *TC*3. One problem is that the data for *TC*3 is not so widely available in the tanker sector. The starting point of *TC*3 is Dec. 2001 for all the tanker types. Since the data series of *TC*1 are all from Jan. 2000, the data samples of *TC*3 are enlarged from Jan. 2000 to the original data series. Then the adjusted sample period of 3-year time charter rate is from 2000 to Oct. 2008. The notations used for the new sample is *TC*3'. Since the data sample of *TC*3 is relatively limited, the test results from *TC*3' are more trustable.

We applied ADF and PP tests to examine the stationarity of each series. Results are the same as most studies in the past, namely all the prices and time charter rates are satisfied I(1) process.

We then applied *Johansen (1988)* test to examine the existence of cointegration between the newbuilding price, second-hand price and time charter rates. The estimation results are summarized in Table 1. Here we just give trace statistic results.

As the findings in Table 1 show, the time charter rate and ship prices are cointegrated for most of the ship segments in the dry bulk sector. One exception is the existence of cointegration among *TC*6, *NP* and *FP* in the Panamax segment. For the Panamax vessels, cointegration does not exist with using trace statistics. In the tanker sector, *TC*, *NP* and *FP* are only cointegrated in the VLCC ship segment. For the Suezmax and Aframax tankers, no cointegration could be found. Comparing these results with the dry bulk sector, it seems that these three variables tie more closely in the dry bulk sector than in the tanker sector. This finding reveals the distinct structures of two shipping sectors. In addition, asset play is significant then speculation is more likely to be happened in the tanker sector. Meanwhile, these three variables are more likely to have a long-run relationship for large ship types (Capesize and VLCC).

Table 1: Cointegration test results in two shipping sectors

Hypothesized No. of CE(s)	Ship type	Lags	λ_{trace}	0.05 Critical Value	Ship type	Lags	λ_{trace}	0.05 Critical Value
		Capesize			VLCC			
None	*TC*6,	*q*=2	56.41309**	29.79707	*TC*1,	*q*=2	53.86795**	29.7971

At most 1	*NP* and *FP*		18.05794*	15.49471	*NP* and *FP*		11.09526	15.4947
At most 2			2.724816	3.841466			0.002788	3.84147
None	*TC*1, *NP* and *FP*	*q*=2	52.52243**	29.79707	*TC*3', *NP* and *FP*	*q*=2	38.09448**	29.7971
At most 1			19.15854*	15.49471			11.64747	15.4947
At most 2			3.248650	3.841466			0.016645	3.84147
None	*TC*3, *NP* and *FP*	*q*=2	43.12533**	29.79707	*TC*3, *NP* and *FP*	*q*=2	42.61477**	29.7971
At most 1			13.34411	15.49471			17.37051*	15.4947
At most 2			0.449850	3.841466			0.464803	3.84147
	Panamax				Suezmax			
None	*TC*6, *NP* and *FP*	*q*=2	21.43779	29.79707	*TC*1, *NP* and *FP*	*q*=2	23.43648	29.7971
At most 1			6.045812	15.49471			7.079093	15.4947
At most 2			2.514359	3.841466			0.001166	3.84147
None	*TC*1, *NP* and *FP*	*q*=2	31.72669*	29.79707	*TC*3', *NP* and *FP*	*q*=2	21.10283	29.7971
At most 1			11.72797	15.49471			7.622421	15.4947
At most 2			1.969166	3.841466			0.058478	3.84147
None	*TC*3, *NP* and *FP*	*q*=2	35.43023*	29.7971	*TC*3, *NP* and *FP*	*q*=3	25.27856	29.7971
At most 1			14.60661	15.4947			9.942263	15.4947
At most 2			0.474882	3.84147			0.607510	3.84147
	Handysize				Aframax			
None	*TC*6, *NP* and *FP*	*q*=2	43.73723**	29.79707	*TC*1, *NP* and *FP*	*q*=2	24.93157	29.7971
At most 1			11.33900	15.49471			7.005578	15.4947
At most 2			3.002197	3.841466			0.058514	3.84147
None	*TC*1, *NP* and *FP*	*q*=2	56.05595**	29.79707	*TC*3', *NP* and *FP*	*q*=2	24.14568	29.7971
At most 1			16.16873*	15.49471			7.114220	15.4947
At most 2			3.219941	3.841466			0.067019	3.84147
None	*TC*3, *NP* and *FP*	*q*=2	36.05628**	29.79707	*TC*3, *NP* and *FP*	*q*=3	30.05167*	29.7971
At most 1			14.07369	15.49471			4.383573	15.4947
At most 2			2.313907	3.841466			0.185861	3.84147

Notes: * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level.

4.2 Temporal relations in two shipping sectors

Granger causality is employed to investigate the temporal linkages between the time charter rates and ship prices. Table 2 summarizes the temporal linkages for all ship types we concerned. For the dry bulk sector, we can observe that although the relationships may be different with using different durations of the time charter rate (*TC*6, *TC*1 and *TC*3), the temporal links between *TC*1, *NP* and *FP* are exactly the same for all the ship types in the dry bulk sector. Results from *TC*1 show that 1-year time charter rate plays as an indicator in the dry bulk ship sector. It leads both *NP* and *FP*. Results drawn from *TC*6 and *TC*3 are slightly different with *TC*1 for the Capesize vessels. In the Handysize segment, the relations with these three variables are more uncertain, the direction runs between *NP* and *FP* can be changed with using *TC*6 and *TC*3. However, one conclusion is obvious and notable that time charter rate plays as an indicator in the dry bulk sector. In other words, the freight market reacts to the new information more quickly than the ship markets, and information transmits from freight market to ship markets in this shipping sector.

For the tanker sector, it appears that the temporal linkages among *TC*, *NP* and *FP* are more similar for the Suezmax and Aframax vessels, i.e. *NP* and *TC* significantly lead *FP*. Unlike these two ship segments, it is found that causality can also run from *NP* to time charter rates (*TC*1 or *TC*3) for VLCC vessels. The difference may be because the relatively longer period time of hiring for this kind of vessel. Then, the time charter rate in this ship segment respond to the information outside slower than the newbuilding ship price. Meanwhile, the relationships between *TC* and *FP* also appear distinct direction for the VLCC tankers. Because, most of the cases, one-way causality runs from *TC* to *FP* in the Suezmax and Aframax segments whereas causality from *FP* to *TC* is more significant than it is from *TC* to *FP* in the VLCC ship segment.

Indeed, a mutual relationship exists between *TC* and *FP* at 5% significant level. Overall, results for specific ship types indicate the distinct characteristic for the VLCC vessels. So it is worth to investigate this ship segment separately in the future.

Table 2: Granger causality test results in two shipping sectors

Capesize								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
ΔFP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.022521	8.138687	11.05831	0.004070	18.32106	18.40763	4.663044	0.243713	4.666004
(0.8807)	(0.0043**)	(0.0040**)	(0.9491)	(0.0000**)	(0.0001**)	(0.0308*)	(0.6215)	(0.0970)
ΔFP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.463348	15.52406	18.33930	0.187358	32.09429	32.65503	3.335979	0.975270	5.248843
(0.4961)	(0.0001**)	(0.0001**)	(0.6651)	(0.0000**)	(0.0000**)	(0.0678)	(0.3234)	(0.0725)
ΔFP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.086143	8.176288	10.42677	0.174206	46.78157	48.26500	0.689392	0.160656	1.000323
(0.7691)	(0.0042**)	(0.0054**)	(0.6764)	(0.0000**)	(0.0000**)	(0.4064)	(0.6886)	(0.6064)
Panamax								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
ΔFP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.017058	17.15193	35.54651	3.308737	18.10370	19.92208	0.015397	1.354078	1.650273
(0.8961)	(0.0000**)	(0.0000**)	(0.0689)	(0.0000**)	(0.0001**)	(0.9012)	(0.2446)	(0.4382)
ΔFP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.038042	29.58790	42.32346	1.557739	31.78742	39.24770	0.547773	1.327670	1.904513
(0.8454)	(0.0000**)	(0.0000**)	(0.2120)	(0.0000**)	(0.0000**)	(0.4592)	(0.2492)	(0.3859)
ΔFP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.029617	37.11237	48.47750	2.490379	28.14116	37.74548	0.033490	0.002669	0.034477
(0.8634)	(0.0000**)	(0.0000**)	(0.1145)	(0.0000**)	(0.0000**)	(0.8548)	(0.9588)	(0.9829)
Handysize								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
ΔFP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	$\Delta TC6_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
6.561820	4.934070	14.41462	0.100036	9.577832	9.577832	1.891969	2.971787	3.967186
(0.0104*)	(0.0263*)	(0.0007**)	(0.7518)	(0.0020**)	(0.0083**)	(0.1690)	(0.0847)	(0.1376)
ΔFP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
1.944122	8.654803	14.38118	1.242318	19.93999	22.85875	0.739754	2.861619	4.333012
(0.1632)	(0.0033**)	(0.0008**)	(0.2650)	(0.0000**)	(0.0000**)	(0.3897)	(0.0907)	(0.1146)
ΔFP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
4.388947	9.796195	19.40553	8.685586	4.697005	14.99461	3.775556	5.011155	10.81764
(0.1114)	(0.0075**)	(0.0007**)	(0.0130*)	(0.0955)	(0.0047**)	(0.1514)	(0.0816)	(0.0287*)
VLCC								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
ΔFP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.435240	0.165141	0.497031	5.432197	4.148579	8.866533	19.66168	9.938883	20.63669
(0.5094)	(0.6845)	(0.7800)	(0.0198*)	(0.0417*)	(0.0119**)	(0.0000**)	(0.0016**)	(0.0000**)
ΔFP_{t-1}	$\Delta TC3'_{t-1}$	All	ΔNP_{t-1}	$\Delta TC3'_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.003293	1.403426	1.716187	9.261323	3.914238	11.79035	17.70410	7.556378	18.03006
(0.9542)	(0.2362)	(0.4240)	(0.0023**)	(0.0479*)	(0.0028**)	(0.0000**)	(0.0060**)	(0.0001**)
ΔFP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	$\Delta TC3_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.970870	0.488552	1.069014	14.16410	2.841322	15.36741	13.08544	2.878414	13.09760
(0.3245)	(0.4846)	(0.5860)	(0.0002**)	(0.0919)	(0.0005**)	(0.0003**)	(0.0898)	(0.0014**)
Suezmax								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
ΔFP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	$\Delta TC1_{t-1}$	All	ΔNP_{t-1}	ΔFP_{t-1}	All
0.933185	1.221578	3.092692	7.777389	28.79299	44.46884	0.255498	0.080470	0.513781

(0.3340)	(0.2691)	(0.2130)	(0.0053**)	(0.0000**)	(0.0000**)	(0.6132)	(0.7767)	(0.7735)
$\Delta FP_{t\text{-}1}$ 1.039531 (0.5947)	$\Delta TC3'_{t\text{-}1}$ 5.237506 (0.0729)	All 6.158332 (0.1876)	$\Delta NP_{t\text{-}1}$ 6.440350 (0.0399*)	$\Delta TC3'_{t\text{-}1}$ 23.92146 (0.0000**)	All 37.02077 (0.0000**)	$\Delta NP_{t\text{-}1}$ 2.526668 (0.2827)	$\Delta FP_{t\text{-}1}$ 1.280323 (0.5272)	All 5.437787 (0.2453)
$\Delta FP_{t\text{-}1}$ 0.060839 (0.8052)	$\Delta TC3_{t\text{-}1}$ 2.727246 (0.0986)	All 3.221554 (0.1997)	$\Delta NP_{t\text{-}1}$ 2.217323 (0.1365)	$\Delta TC3_{t\text{-}1}$ 10.91618 (0.0010**)	All 13.79807 (0.0010**)	$\Delta NP_{t\text{-}1}$ 0.407997 (0.5230)	$\Delta FP_{t\text{-}1}$ 0.844302 (0.3582)	All 0.963081 (0.6178)
Aframax								
Dependent variable: ΔNP_t			Dependent variable: ΔFP_t			Dependent variable: ΔTC_t		
$\Delta FP_{t\text{-}1}$ 0.387322 (0.5337)	$\Delta TC1_{t\text{-}1}$ 2.258778 (0.1329)	All 3.584122 (0.1666)	$\Delta NP_{t\text{-}1}$ 11.24748 (0.0008**)	$\Delta TC1_{t\text{-}1}$ 25.43698 (0.0000**)	All 45.65966 (0.0000**)	$\Delta NP_{t\text{-}1}$ 0.156409 (0.6925)	$\Delta FP_{t\text{-}1}$ 1.189086 (0.2755)	All 2.053777 (0.3581)
$\Delta FP_{t\text{-}1}$ 2.509692 (0.2851)	$\Delta TC3'_{t\text{-}1}$ 0.544641 (0.7616)	All 3.759587 (0.4395)	$\Delta NP_{t\text{-}1}$ 11.03172 (0.0040**)	$\Delta TC3'_{t\text{-}1}$ 12.52520 (0.0019*)	All 26.70216 (0.0000**)	$\Delta NP_{t\text{-}1}$ 2.000887 (0.3677)	$\Delta FP_{t\text{-}1}$ 7.575589 (0.0226*)	All 12.40396 (0.0146*)
$\Delta FP_{t\text{-}1}$ 1.397147 (0.2372)	$\Delta TC3_{t\text{-}1}$ 1.430030 (0.2318)	All 4.034975 (0.1330)	$\Delta NP_{t\text{-}1}$ 4.230823 (0.0397*)	$\Delta TC3_{t\text{-}1}$ 10.02662 (0.0015**)	All 16.81710 (0.0002**)	$\Delta NP_{t\text{-}1}$ 0.000509 (0.9820)	$\Delta FP_{t\text{-}1}$ 2.826543 (0.0927)	All 3.119556 (0.2102)

Notes: * indicates statistical significance at 5% level; ** indicates statistical significance at 1% level; Numbers in (·) are p-Value.

Results from cointegration and Granger causality tests display different relationships when using different durations of time charter rate. In order to compare the temporal linkage among three markets, first, a typical relation should be chosen to represent the temporal linkages in these two sectors. For the dry bulk sector, relationships among *TC*1, *NP* and *FP* is established to represent the most common relationships between three markets. For the tanker sector, *TC*3' is chosen to represent VLCC vessels whereas *TC*1 is to express Suezmax and Aframax vessels. Results are summarized in Figure 1.

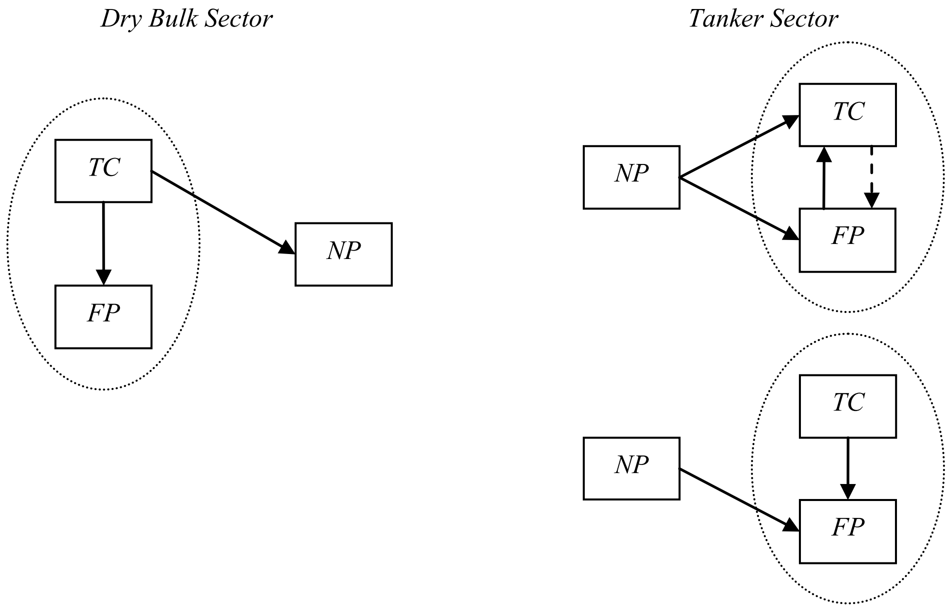
Comparing the results drawn from two shipping sectors, it can be seen that there are some similarities. Results of the cointegration test show that time charter rate and ship prices are more likely to have a long-run relationship for the large ship types (Capesize and VLCC). Moreover, both shipping sectors show an uncertain correlation between second-hand ship price and time charter rate. But causality runs from the time charter rate to the second-hand price most of the time.

Despite the similarity, results also revealed the significant differences for these two sectors. First, from the cointegration test, results show that *TC*, *NP* and *FP* tie more closely in the dry bulk sector. It means that the possibility of cointegration existence among these three variables is higher in the dry bulk sector than in the tanker sector. This difference implies that asset play is more likely to be happened in the tanker sector.

The second difference is that the temporal relationships between freight and ship markets are differ for the dry bulk and tanker sectors. For the dry bulk sector, the time charter rate is an indicator of international shipping. In the counterpart, this indicator is more likely played by the newbuilding prices in the tanker sector. From Figure 1, it can be clearly seen that ship prices can not be found Granger cause time charter rates for all dry bulk vessels, and second-hand prices or time charter rates can not be found Granger cause newbuilding prices in the tanker sector. If extending this conclusion to the whole shipping market, it can be concluded that information transmitted from freight market to ship markets in the dry bulk sector but from newbuilding ship market to the others in the tanker sector.

Furthermore, *Veenstra (1999)* has suggested that the causal links in the dry bulk and tanker sector are different and it is because the roles of second-hand ship price or the even the second-hand market are distinct. It is one possibility that the way of information transaction changed when passing through the second-hand market. However, from Table 2, the temporal linkages between three markets in both two sectors show that second-hand ship price can not lead either time charter rate or newbuilding price. From this point of view, the role of second-hand ship price plays the same situation in these two shipping sectors. Then this difference may be caused by another possible reason - the newbuilding price or newbuilding ship market. As shown in Figure 1, no matter what kind of relationship between *TC* and *FP*, for the dry bulk sector, *NP* is leaded by *TC* or *FP* either with the three-variable or two-variable framework. In the contrary, for the tanker sector, *NP* plays as a leader to *TC* and (or) *FP*. Therefore, there also exists the possibility that the difference drawn from two shipping sectors is caused by the role of the newbuilding price or the newbuilding market. As results shown from this paper, the newbuilding market in the tanker sector responds to the new information much quicker than it in the dry bulk sector. The lead-lag relation is hard to observe between *NP* and *TC* in the tanker sector for Suezmax and Aframax vessels. And for the VLCC tankers, *NP* even leads *TC* most of times. It means that the order activity is more important in this shipping sector especially for the larger tankers. Other markets can be affected by the decision of booking newbuilding ships.

Figure 1: Comparison between Two Sectors



Notes: The solid line indicates that Granger causality is significant at 1% level, while the dashed line indicates that Granger causality is significant at 5% level.

5. Conclusions

This study investigates the temporal links between the freight and ship (newbuilding and second-hand) markets in two shipping sectors - the dry bulk and tanker sectors. The cointegration test results show that asset play more likely happens in the tanker sector than in the dry bulk sector. The evidence from Granger causality test indicates that the temporal linkages among these markets are differed inside these two shipping sectors. And the time charter rate is an indicator in the dry bulk sector, however, this indicator is played by the newbuilding price most of the time in the tanker sector. Meanwhile, it is suggested that this difference is more possible to be caused by the role played by newbuilding price or the newbuilding market. Moreover, results for specific ship types indicate the distinct characteristic for the VLCC vessels. So it is worth to investigate this ship segment separately in the future.

All these findings in this paper suggest that the temporal relationships between these shipping markets are more complex than previously expected. They all imply that the economic structures are obviously distinct for the dry bulk and tanker sectors. Therefore, investigations should be conducted separately for the dry bulk and tanker sectors in the future.

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Determinants of Container Ship Investment Decision and Ship Choice

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Abstract

Ship investment is one of the most complicated yet essential decisions vexing both existing and potential shipowners, due to market uncertainty and competition. This research applies choice models on observed ship investment data to examine shipowners' behaviour in making investment decisions and selecting specific ships. We found that ship investment increases with the growth rate of demand, but not of price. Preference for large ships is more sensitive to unit cost. The substitutability of new vessels with an equal-size used ship increases with ship size; for second-hand vessels, it decreases.

Keywords: Container ship; Capacity investment; Ship choice; Nested Logit Model

1. Introduction

Shipping is one of the world's most capital-intensive industries due to the high cost of purchasing a ship. A super post-Panamax vessel of 8,000 TEUs+, for example, costs about US$118 million (Dekker, 2006). Shipping companies have to pay a high capital cost, which often accounts for half of the total cost to run a large new ship. On the other hand, although second-hand ships are less expensive to purchase and hence require lower capital cost, they are not as efficient as new ships and they also lack varieties in the market. To achieve best scale efficiency, shipping companies may require different ship sizes for different trade routes. Two common issues faced by shipowners when they need to increase their capacity are: Should a shipping company order a new ship or purchase a second-hand one? What is the right size to purchase? It is not easy to address the two questions, and the situation can be more complicated due to the volatility and uncertainty of the container freight market.

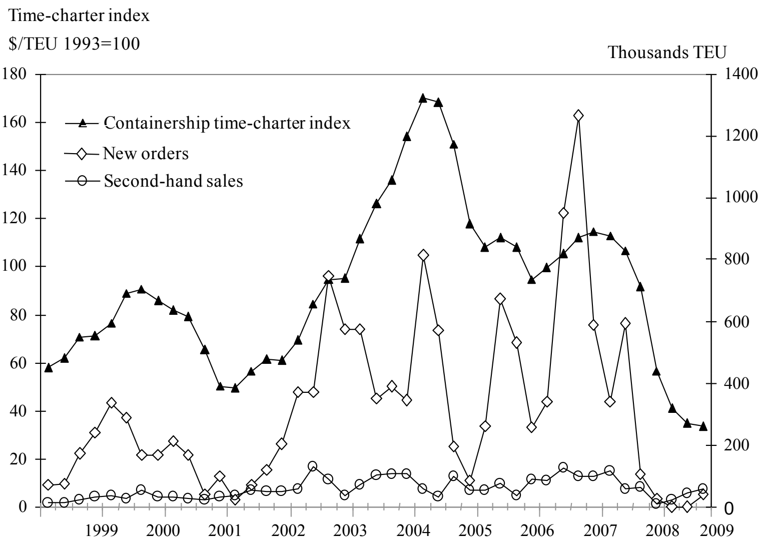

Figure 1: Container time-charter index and the demand for capacity from 1999 to 2009
Source: Clarkson Research Services Limited 2009

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The volatility of the container freight market is shown in Figure 1, which indicates the quarterly time-charter index for container ships from 1999 to 2009, and the demand for carrying capacity including the number of new orders and second-hand sales (in TEU slots). Motivated by the high freight rate, shipowners rush to order additional new vessels and expect to use them to improve operating efficiency, attract more customers, gain larger market share, and earn more profit (Luo et al., 2009) after delivery. Contrary to the expectation, the uncertain future demand and the collective behaviour of individual shipowners in capacity investment during the booming freight market only result in overcapacity in the shipping industry and low freight rate in the market. The market freight rate after the delivery is most likely not as high as expected. In this case, the high capital cost in running new ships may shake the financial ground of the shipping company.

Concerned about the possible low freight rate in the future, purchasing a second-hand ship may be a better decision as it needs less lead-time, so that the capacity can add to the running fleet to gain immediate profit increase. However, in the end, the higher operation cost of used ships and inefficiencies may make the shipping company not competitive enough. Moreover, the high periodical maintenance cost can also be a prohibitive burden to the shipping company.

In addition to satisfying the needs of the demand increase, decisions in shipping investment may also be made strategically, either to deter new entrants, or to compete with peers. This strategic behaviour in shipping capacity investment may add another dimension to the already complex environment for shipowners.

The difficulties in ship investment decision making, and the significant role of shipping capacity in both the private shipping business, and in international trade, maritime safety and environment (Luo et al., 2009), highlight the importance of studies about the behaviour in ship investment decisions. Compared with the volume of existing research on shipping freight rate (Beenstock & Vergottis, 1993; Tvedt, 2003; Kavussanos, 1996; Kavussanos, 1997; Veenstra, 1999; Tsolakis et al., 2003; Alizadeh & Nomikos, 2007; Merikas et al., 2008), there are relatively few publications for the analysis of ship investment decision making. Among the few publications, Fusillo (2003) modelled the excess capacity and tested whether shipping companies used excessive capacity to defend opportunistic rivals. However, the results from his random effects model show limited support for the entry deterrence hypothesis. Wu (2009) developed an economic model to calculate the optimal fleet capacity of representative container shipping lines in Taiwan, assuming cost minimization.

Bendall and Stent (2005) assessed ship investment under uncertainty, using ROA (Real Option Analysis) in an express liner service. None of these studies tried to reveal ship investment behaviour from the observed data on the ship investment and selection.

Outside of the shipping literature, capacity investment behaviour is a major topic in broader subject areas such as economics, game theory, and decision theory. Hay and Liu (1998) specified a model of oligopolistic investment behaviour, and tested it with panel data for manufacturing industries. They found that non-cooperative, cooperative, and competitive behaviours in capacity investment exist in different sectors. Gilbert and Lieberman (1987) revealed that there are both coordinative and pre-emptive investment behaviours in the chemical product industries. Wenders (1971), Spence (1977), Dixit (1979; 1980), Porter and Spence (1982), Reynolds (1986), and Haruna (1996) have each developed theoretical model on strategic capacity investment as a deterrent to entry or pre-emption of other firms' capacity expansion. Esposito and Esposito (1974), Hilke (1984), Lieberman (1987), and Driver (2000) also examined the existence of strategic investment behaviour in various industries in empirical studies.

Despite the existing literature on shipping market analysis or on the economic and game theory analysis for capacity investment behaviour, there has been no empirical research on shipowners' capacity investment and ship selection behaviour in the container shipping market. By applying discrete choice analysis on the observed data about ship investment and selection decisions for the container shipowners in the world, this paper reveals important factors that determine the decision on ship investment, and the choice of a particular ship type.

The paper is organized as follows. Section 2 first describes the theoretical analysis of the investment decision. Then it introduces the nested logit method to model the ship choice decision in the container shipping market.

Section 3 describes the data resource and the definition of the variables used in the analysis. Section 4 presents the empirical results of the logit models and discusses the shipowner's decision-making process. Section 5 concludes the study.

2. A theoretical model on the decision making process of ship investment

Ships are expensive assets in the maritime transportation, especially in the container shipping market. From the perspective of the shipowner or the shipping company, the basic investment decision is whether to invest at certain market conditions, be it to satisfy the market needs, or to deter the new entrant, or to compete with the peers. Irrespective of the motivations behind the decision, once the decision to invest is made, the next question is to consider whether ordering a new ship or buying a second-hand vessel is more suitable. The last decision is to decide on which specific type of ships to be bought according to the specific needs of the shipowner. The decision tree in Figure 2 depicts this decision-making process.

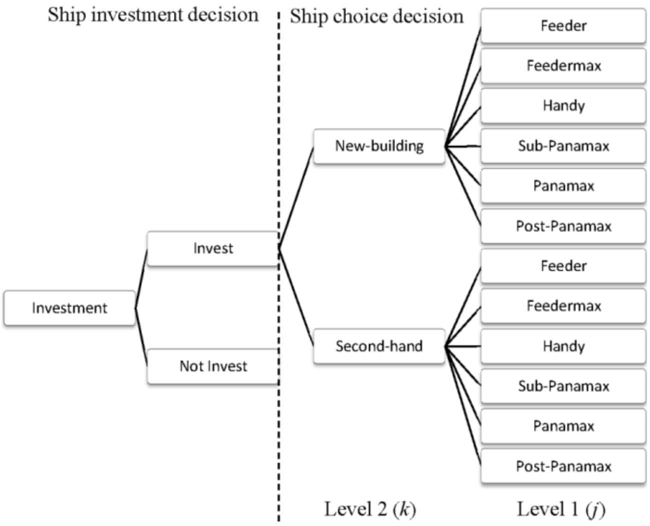

Figure 2 Shipowner's capital investment decision procedure

Figure 2 consists of two distinctive decision problems. The left part is the ship investment decision, which is different from the right part - the ship choice decision. The investment decision includes two choices – to invest or not to invest. If the decision is to invest, it leads to the ship choice decision; otherwise, there is no further decision to make. However, in the ship choice decision, there are an equal number of choices after selecting the new ship or second-hand one. Therefore, ship investment is a binary choice decision, while the ship choice decision is a multiple-choice problem. In this empirical analysis, the first problem is modelled using a binary choice logit model, and the second one is analyzed by applying a nested logit model.

2.1 Logit model for investment decisions

Assuming that there is no strategic behaviour in ship investment, the fundamental reason for a shipping company to increase its capacity is to meet the market demand. When the demand is increasing, the ship operator can increase the speed of the ship to satisfy the demand in the short-run. However, sailing fast is costly, and there is a certain limit on how fast a ship can sail. Therefore, the decision on whether to invest in capacity expansion depends on the demand, the existing capacity, and the impact of speed on cost, and freight rate. To illustrate the influence of such factors on the ship investment decision, we start from a very simple case where the company is running a fixed service between two ports.

2.1.1. Basic operation mechanism for a shipping fleet

Assume the shipping company has N identical container vessels of K TEU slots and it uses n vessels in a transportation activity. For each vessel, the operation cost is C and the layup cost is LC. The distance between two ports is L. The voyage cost $V(s)$ is an increasing function of ship speed s with positive increasing rate, that is, $V'(s)>0$ and $V''(s)>0$, following Beenstock & Vergottis (1993) and Stopford (2009). Using ρ for the average working hours of one ship in a year, the total number of trips a ship can make in a year can be written as $s\rho/L$. For simplicity, assume capital and financial costs are part of the operating cost C. Finally, the demand the shipping company faces is Q and the market freight rate is P.

Based on the above assumptions, the problem for the shipping company is to maximize its annual profit *w.r.t.* with respect to the number of ships in the active fleet n ($n \le N$) and ship speed s , that is,

$$\max_{n,s} \pi = PQ - nC - ns\rho V(s)/L - (N-n)LC \quad (1)$$

$s.t.\ ns\rho K/L \le 0$ and $n \le N$.

Solving this problem using the Kuhn-Tucker method, we can get $ns\rho K/L=Q$. This implies that the shipping company will satisfy the demand using the number of active ships and adjusting the ship cruise speed.

Depending on the number of available ships, the shipping company can adjust the cruise speed according to the following two cases:

Case 1: $n < N$. In this case, $LC+sV'(s)s\rho C/L=0$, that is, the optimal vessel speed when there are layups in the company. Because shipping companies have enough capacity, they will normally not invest in acquiring additional vessels.

Case 2: $n = N$. In this case, the optimal speed is $s^*=QL/(N\rho K)$, that is, the shipping company has to increase the vessel speed to accommodate the increasing demand. However, due to the high voyage cost at high cruise speed, it is not always economical to run at high ship speed. In this case, the shipping company will have an incentive to purchase more ships, as long as the savings from the reduced speed can offset the incremental capital and financial cost, operation cost and voyage cost. Next, we analyze the condition for purchasing additional ships.

2.1.2. Factor analysis for ship investment facing demand increase

Facing a demand increase from Q to Q_H, the shipping company needs to increase vessel speed to $s_H=Q_HL/(N\rho K)$ to satisfy the demand. At this speed, the operating cost will increase to $V(s_H)$. However, with the additional vessel, the optimal speed could decrease to $s_{HI}=Q_HL/[(N+1)\rho K]$. Assuming that the ship cost is CK and the loan rate is d, if the annual marginal profit *w.r.t.* the number of ships can offset its marginal annual capital cost, that is, $\pi(N+1)-\pi(N)-dCK \ge 0$, it is better for the shipping company to buy the additional vessel.

Using y to denote this net marginal profit, through a series of simplification process, it can be written as

$$y=Q_H[V(s_H)-V(s_{HI})]/K-C-dCK. \quad (2)$$

In theory, when $y>0$, the shipping company should purchase a ship; the larger the value y, the more likely the company will buy a ship. Clearly, the probability for the shipping company to purchase a ship increases with demand and the increasing rate of voyage cost *w.r.t.* ship speed, decreases with ship size, operating cost, and ship price.

In addition to the factors identifiable through theoretical analysis (Eq. 2), in practice, the expectation for future freight rate and shipbuilding lags strongly affect the capacity investment decision. Because expectation is not observable, it can be approximated by the demand growth (GQ) assuming that an individual's expectation is based on the past market performance. An increasing demand will increase the probability for the shipowner to invest in capacity, while a decreasing market will suppress the investment intention of the shipowner (Luo et al., 2009).

Lastly, the strategic behaviour in capacity competition adds another dimension to the complex decision making process for ship investment. Shipping companies with different market power may have different strategies facing different market structure. Larger dominant companies could invest excessive capacity to prevent new entrants, or to expel existing smaller companies. In a competitive market, an existing company has to follow the capacity growth of its peers in order to keep its market share. Within shipping alliances, the members may take turns to invest in order to avoid overcapacity in a specific route. The capacity investment behaviour of the peers ($OINV_{it}$) also plays an important role in the decision making process of capacity investment.

In summary, the investment decision of the shipping company i at time t can be expressed as a function of the observable variables discussed above, and an unobservable part, the random error ε_{it}, that is,

$$Y_{it}=y_{it}+\varepsilon_{it} \quad (3)$$

where $y_{it}=f(Q_t, GQ_t, K_{it}, CK_{it}, OINV_{it})$, and Y_{it} takes value 1 if invest, 0 if not. Assuming that ε_{it} is an independently and identically distributed (*iid*) extreme value, the shipowner's capacity investment behaviour can be modelled using a binary choice logit model (Green, 2003). To test the different investment strategies, we also estimated the model for new entrants and incumbents separately, in addition to the general model that does not distinguish them. If entry deterrence or pre-emptive strategies exist, there should be different responses to the demand and competition, which can be detect using the statistical test.

2.2 Nested logit model for ship choices

The second decision in the ship investment process, as shown in the right part of **Error! Reference source not found.**, is the selection of ship types. To analyze shipowners' behaviour in selecting a ship type, a nested logit model (Mcfadden, 1978; Mcfadden, 1980; Green, 2003) was adopted, based on two important observations:

(1) Shipping companies selecting a used ship often have urgent needs for the ship. Ordering a new ship may take too long. Therefore, the decision for used ones or new ones is at a higher level.
(2) Ships in the same category, or nests (used or new), are more substitutable. If a shipping company cannot find a specific vessel type in the second-hand nest, most likely it will find another type of second-hand ships for replacement.

The traditional logit model is inappropriate because it cannot satisfy the *IIA* (Independence from Irrelative Alternatives) requirement (Train, 2003), while the nested logit model only requires *IIA* for the alternatives in the same nest, not in different nests.

The nested logit model follows the standard specification by (Train, 2003). Mcfadden (1978) has shown that the estimated coefficient on the inclusive variable should be between 0 and 1. Otherwise, the assumption on the nest structure is inappropriate. Therefore, we use this property to test if the proposed nested structure in **Error! Reference source not found.** is appropriate. Furthermore, if the model is appropriate, it is expected that the substitutability between the ships within the same nest should be larger than that in different nests.

3. Data description

3.1. Data for the investment decision model

Lloyd's Fairplay maintains a ship registration database that contains detailed records about the owner, order and delivery date, and ship transaction information for over 120 thousand vessels over 100 GT, of which 5724 are container vessels owned by 926 shipowners as of January 1, 2009. These data, together with the market data at the time of the transaction, are fitted into a binary choice model to explore the ship investment decision from 1999 to 2008. A separate analysis is carried out for the incumbents and new entrants, to examine possible different behaviour between them. The variables used in the model are explained next.

$NINV_{it}$, $EINV_{it}$ and INV_{it} : Three binary dependent variables represents the investment decision of new entrants, existing firms, and all firms respectively.

$THROU_t$ and $GTHROU_t$: Two variables used to examine how demand changes the investment decision. The former is the global container throughput in million TET, and the latter is its growth rate.

K_{it} : The total capacity (in thousand TEU) of firm i at the beginning of year t. It is calculated backward from each shipowner's capacity on January 1, 2009, using the equation $K_{it-1}=K_{it}-ADD_{it}+SELL_{it}+SCRAP_{it}$, where ADD_{it} is the delivery of new ships and purchase of second-hand ships, $SELL_{it}$ is the selling of second-hand ships. These two values are from Lloyd's Fairplay database. $SCRAP_{it}$ is the scrapping of used ships obtained from CSIN (Clarkson's Shipping Intelligence Network) from 2004 to 2008. Ship scrapping before 2004 is ignored because the data are not available. However, this will not affect regression results because the total demolition from 1999 to 2008 only accounts for 0.5 percent of the total container carrying capacity (Drewry annual report). For new entrants, K_{it} equals 0.

$AVGK_{it}$: The average vessel size (in thousand TEU) of firm i, defined as the total capacity divided by the number of vessels of the firm.

$TCMI_{it}$: The time-charter index for container ships. If a firm invests in any ships, $TCMI_{it}$ is the monthly average time-charter index at the month when the ship is ordered or bought. If not, $TCMI_{it}$ is just the time-charter index of that year. $GTCMI_{it}$, $NBPMI_{it}$, and $SEPMI_{it}$ are the growth rate of time-charter index, new-building price index and second hand price index, calculated in the same way. These data are from Clarkson Research Services Limited 2009.

$OINV_{it}$: The capacity investment rate of all other firms, defined as $OINV_{it}=\sum_{i\neq i} KINV_{lt} / \sum_{l\neq i} K_{lt}$, where $KINV_{lt}$ is the actual capacity invested by firm l. It is designed to examine how a shipowner responds to the capacity investment of the competitors.

Finally, the two variables, $ONFINV_{it}= \sum_{i\neq i} KINV_{lt} \times NINV_{it} / \sum_{l\neq i} K_{lt}$, $OEFINV_{it}= \sum_{i\neq i} KINV_{lt} \times EINV_{it} / \sum_{l\neq i} K_{lt}$, are defined to capture the different responses to the investment of new entrants and the existing ones. $ONFINV_{it}$ represents all other new entrants' capacity investment ratio, and $OEFINV_{it}$ represents all other incumbents' capacity investment ratio.

3.2. Data for the ship choice model

The data used for ship choice model include the observed ship-selection records for shipowners who ordered new ships or bought second-hand vessels from 1998 to 2008. It involved 858 companies and 4963 vessels, with 64 percent new buildings (10.4 million TEU) and 36 percent second-hand vessels (5.8 million TEU). These variables are explained next.

$CHOICE_{ij}$: The binary dependent variable represents a firm's choice on ship type j: it equals to 1 if the firm selects ship type j; otherwise, 0.

$FEEDER_i$, $FEEDERMAX_i$, $HANDY_i$, $SUBPANAMAX_i$, $PANAMAX_i$, $POSTPANAMAX_i$: The dummy variables indicate different types of container vessels.

NEW_i and $SECOND_i$: dummy variables for new or second-hand ships respectively. K_{it}, $THROU_t$, and $GTHROU_t$ are the same as those defined in the investment decision model.

TC_{jt}, GTC_{jt}, NBP_{jt}, and SEP_{jt} are the time-charter rate and its growth rate, the newbuilding price and the second-hand price for vessel type j at year t.

$UINVC_{ijt}$: The unit investment cost, defined as $UINVC_{ijt}$=[$NEW_{ij} \cdot NBP_{jt} + SECOND_{ij} \cdot SEP_{jt}$] /TEU_{ijt}, where TEU_{ijt} denotes the size of the ship. This definition ensures that the $UINVC_{ijt}$ is specific to each firm i, each ship type j, and each nest k.

The last variable $CONLAG_{ijt}$ is the actual shipbuilding lag for the selected vessel type. For the un-chosen types, it is the average construction lag of that type. For second-hand vessels, the construction lag is 0.

4. Results and discussion

Following the decision making process, we first present and explain the results from the binary choice model, and then the ship choice behaviour using the results from the nested logit model.

4.1 Model results for the ship investment decision

To analyze the investment behaviours for different shipowners, four models were applied to different sample data and the results are shown in **Error! Reference source not found.**. Models 1 and 2 are designed to analyze the investment behaviour of all shipowners. Comparing with model 2, model 1 has two extra variables: the existing capacity (K_{it}) and average ship size ($AVGK_{it}$), used to test their impacts on the investment decision. Comparing with model 2, models 3 and 4 are for existing firms and new ones respectively. **Error! Reference source not found.**1 also provides the t-values for the null hypothesis $H_0 : \beta_i^{m3} = \beta_i^{m4}$, that is, the coefficients are the same for the corresponding variables of models 3 and 4.

Table 1 Results from binary choice models for ship investment decisions

Dep. Var.	(1) INV$_{it}$	(2) INV$_{it}$	(3) EINV$_{it}$	(4) NINV$_{it}$	$H_0 : \beta_i^{m3} = \beta_i^{m4}$
C	-7.411**	-7.145**	-7.004**	-7.885**	2.199*
THROU$_t$	0.003*	0.003*	0.002	0.003	-591.001**
GTHROU$_t$	5.038	6.554*	1.772	10.699*	-0.492
K$_{it}$	0.018**				
AVGK$_{it}$	-0.069**				
NBPMI$_{it}$	0.031**	0.029**	0.033**	0.014	192.45**
TCMI$_{it}$	-0.003	-0.002	-0.003	0.001	-261.77**
GTCMI$_{it}$	-3.016**	-3.034**	-2.207**	-3.288**	16.51**
ONFINV$_{it}$	116.848**	107.01**	80.759**	119.325**	-0.094
OEFINV$_{it}$	-4.595**	-4.638**	-3.249**	-5.053**	2.171*
Observation	10186	10186	10186	10186	
Log likelihood	-3448	-3699	-2798	-2111	
Probability(LR stat)	0.000	0.000	0.000	0.000	

*Note: * Significant at the 0.05 level; ** Significant at the 0.01 level, two-tailed test.*

Almost all the coefficients shown in Table 1 were significantly different from zero. The coefficients on $THROU_t$ and $GTHROU_t$ for all the 4 models were positive, indicating the positive impact of high market demand on the investment decision for both new firms and existing ones. The positive coefficient for K_{it} suggests that the larger firms are more likely to invest; and the negative estimate on $AVGK_{it}$ indicates that shipping companies with larger ships have lower probability for investment.

Because the new building price ($NBPMI_{it}$) is highly correlated with second-hand price, only the new building price is included to represent the price in both markets. The estimation result shows a high statistical relationship between the ship price and the likelihood for the shipowner to acquire additional ships. This is because the ship price increases with the increase in demand for ships.

$TCMI_{it}$ and $GTCMI_{it}$, the time-charter rate and its increasing rate, approximated the freight rate in the container shipping market. While $TCMI_{it}$ is not an important factor for ship investment decisions, $GTCMI_{it}$ has negative impacts on the probability of investment. Possibly, because freight rate is volatile and uncertain, shipowners may associate the high increasing rate with high risk. Therefore, they may hesitate to invest at high $GTCMI_{it}$.

The last two variables, $ONFINV_{it}$ and $OEFINV_{it}$, capture the response of capacity investment to the new entrants' investment ratio and that of incumbents. The positive coefficient of $ONFINV_{it}$ indicates a high probability of investment when the container shipping industry sees many new entrants: a sign for the blooming market, which will definitely encourage investment. This also explains the negative coefficients for $OEFINV_{it}$: according to their definition, $OEFINV_{it}$ and $ONFINV_{it}$ are complements.

The t-values in the last column of Table 1 reveals that the investment decisions between the incumbents and new entrants were significantly different over a set of factors, namely the changes in demand ($THROU_t$), investment cost ($NBPMI_{it}$), and the changes in time-charter rate ($TCMI_{it}$ & $GTCMI_{it}$). In addition, their responses to the incumbents' investment ($OEFINV_{it}$) were also statistically different: although their investment both decreased, the new entrants decreased more than the existing ones did. This may imply the existence of market barriers in container shipping: new entrants need to overcome more hurdles to acquire a container vessel than incumbents do. Finally, their responses to the investment of the new entrants ($ONFINV_{it}$) showed no significant statistical difference. This suggests that the incumbent firms have no intention to pre-empt new comers.

4.2 Model results from the ship selection decision

Having determined to expand the capacity, the next decision facing a shipowner is which ship to choose: a new ship or a second-hand one, a large ship or a small one, following the decision tree in Figure 2. Table 2 presents the results from the nested logit model.

Table 2 Results from the nested logit model for ship choice decisions

Parameter	Coefficient	Standard Deviation	t-Value	P-Value
FEEDER_L1	-9.961**	0.366	-27.200	<.0001
FEEDERMAX_L1	-5.340**	0.284	-18.830	<.0001
HANDY_L1	-1.392**	0.192	-7.240	<.0001
SUBPANAMAX_L1	-1.031**	0.108	-9.580	<.0001
PANAMAX_L1	-0.304**	0.051	-5.960	<.0001
UINVC_L1	-394.097**	8.974	-43.910	<.0001
TC_L1	0.153**	0.011	13.560	<.0001
GTC_L1	-0.386	0.623	-0.620	0.535
NEW × CONLAG_L2G1	1.036**	0.205	5.050	<.0001
NEW × K_L2G1	0.001**	0.000	3.290	0.001
NEW × GTHROU_L2G1	-2.149**	0.718	-2.990	0.003
NEW × NBP_L2G1	0.076	0.056	1.350	0.177
SECOND × SEP_L2G1	0.215**	0.068	3.150	0.002
INC_L2G1C1	0.306**	0.049	6.220	<.0001
INC_L2G1C2	0.242**	0.058	4.170	<.0001
Number of Observations	4933			
Number of Cases	59196			
Chi-Square	8218.8			
Log Likelihood	-8149			

* Significant at the 0.05 level, two-tailed test.
** Significant at the 0.01 level, two-tailed test.

The coefficients of the inclusive variables (INC_L2G1C1 and INC_L2G1C2) were between 0 and 1, indicating that the nest structure is consistent with shipowners' ship choice behaviour: shipowners will first decide to buy a new vessel or a used one before considering the size of the ship.

With Post-Panamax (the largest vessel) as the reference choice, the negative coefficient for each ship type means that the possibility to choose that ship-type is lower than the largest vessel. The coefficients increased from the smallest vessel (feeder vessel, -9.961) to the largest (Panamax. -0.3), showing preference increase with ship size. This trend reflects shipowners' continuous pursuit of scale economy offered by large container ships.

The negative coefficient of *UINVC* suggests that high cost per TEU reduces the preference for that ship type. On the revenue side, the positive coefficient on *TC* indicates the high preference for ships with higher time-charter rate. This result is consistent with shipowners' profit maximizing behaviour in ship choice. The estimated coefficient is not significant for the variable *GTC*, indicating that the growth rate of the market price does not affect ship choice.

The coefficients for the interactive variables reveal the preference over new vessels or second-hand ships for five variables, namely the shipbuilding lag, the existing capacity of the shipping company, demand growth rate, the newbuilding price and the second-hand price. The results are explained below:

1. The positive coefficient for NEW×CONLAG implies that the longer the shipbuilding lag, the higher the preference for new ships: larger vessels that take longer time to build can provide better economy of scale.
2. The positive coefficient for NEW×K indicates that shipping companies with larger capacity prefer new vessels. Such companies have probably been in the business for a long time and have a long-term plan for capacity expansion. Therefore, they can place new orders according to their future capacity needs. Even with the unexpected market fall, they can retire the old ships to increase fleet efficiency.
3. The coefficient for NEW×GTHROU was negative and significant, indicating that new ships are not as attractive as used ones when the demand growth rate is high: comparing with new ships, second-hand ships can meet immediate market demand and earn quick revenue.
4. The coefficient for NEW×NBP was not significant, indicating that the price of new ships is not a critical factor in ship selection behaviour: most shipping companies decide to order new ships not for their low price, but for the high market demand.
5. Lastly, the positive significant coefficient on SECOND×SEP uncovers the nature of the second-hand market: the high price is a result of the high preference.

Having explained the impacts of individual variables on the ship selection behaviour, we demonstrate how a change in one variable affects the preferences of ship types, including the same ship types and the different types in the same nest, and those in different nests. Such analysis is particularly helpful to understand the ship selection behaviour of the shipowners. For example, we may want to know the change to the probability of selecting each ship type if the unit investment cost (*UINVC* in section 3.2) for a new Panamax container vessel increases by 1 percent. Based on Green (2003), the elasticity of selecting a ship type j in nest k for an attribute change of ship type j^* and nest k^* ($\eta^{jk}_{j^*k^*}$) is:

$$\eta^{jk}_{j^*k^*} = \frac{\partial \ln prob(j,k)}{\partial \ln x_{j^*k^*}} = \left[1_{k=k^*} \cdot (1_{j=j^*} - p_{j|k}) + \tau_k (1_{k=k^*} - p_k) p_{j|k}\right] \beta_x x_{j^*k^*} \tag{4}$$

where $x_{j^*k^*}$ is the changing variable, and β_x is its coefficient. This elasticity has three different cases: (*a*) own-elasticity: the elasticity for the ship type with an attribute change; (*b*) cross-elasticity: the elasticity for different ship types in the same nest; and (*c*) cross-nest elasticity: the elasticity for the ship that belongs to a different nest:

$$\eta^{jk}_{j^*k^*} = \beta_x x_{j^*k^*} \times \begin{cases} [(1-p_{j^*|k^*}) + \tau_{k^*}(1-p_{k^*})p_{j^*|k^*}] & \cdots\cdots j = j^* \text{ and } k = k^* \quad (a) \\ [-p_{j^*|k^*} + \tau_{k^*}(1-p_{k^*})p_{j^*|k^*}] & \cdots\cdots j \neq j^* \text{ and } k = k^* \quad (b) \\ -\tau_{k^*} p_{k^*} p_{j^*|k^*} & \cdots\cdots j \neq j^* \text{ and } k \neq k^* \quad (c) \end{cases} \tag{5}$$

Clearly, for a variable change of a specific ship type, the cross-elasticity is the same for other ship types in the same nest (from 5-b), which is different from the cross-nest elasticity (from 5-c). This is due to the relaxed *IIA* requirement of the nested logit model: it only requires IIA for the types in the same nest, not across different nests. In other words, if the unit cost for a new feeder vessel increases, the IIA only requires that the probability for shipowners to choose other new container vessels will increase by the same proportion. It does not require that the probability to choose second-hand container vessels also increase by the same proportion.
To demonstrate the actual probability changes revealed in the current ship selection behaviour, we calculated the elasticity for all the ship types in both new and second-hand ships *w.r.t.* the unit cost of each ship type, which is shown in **Error! Reference source not found.**.

Table 3 Ship selection elasticity with respect to the unit cost of each ship type

Effect on	NFeeder	NFeedermax	NHandy	NSubpanamax	NPanamax	NPostpanamax
NFeeder	-2.709	1.282	1.694	0.679	1.137	0.166
NFeedermax	1.053	-4.676	1.694	0.679	1.137	0.166
NHandy	1.053	1.282	-8.505	0.679	1.137	0.166
NSubpanamax	1.053	1.282	1.694	-14.023	1.137	0.166
NPanamax	1.053	1.282	1.694	0.679	-18.020	0.166
NPostpanamax	1.053	1.282	1.694	0.679	1.137	-30.524
SFeeder	0.034	0.111	0.206	0.100	0.185	0.030
SFeedermax	0.034	0.111	0.206	0.100	0.185	0.030
SHandy	0.034	0.111	0.206	0.100	0.185	0.030
SSubpanamax	0.034	0.111	0.206	0.100	0.185	0.030
SPanamax	0.034	0.111	0.206	0.100	0.185	0.030
SPostpanamax	0.034	0.111	0.206	0.100	0.185	0.030
Cross-nest ratio	30.97	11.55	8.22	6.79	6.15	5.53
Effect on	**SFeeder**	**SFeedermax**	**SHandy**	**SSubpanamax**	**SPanamax**	**SPostpanamax**
NFeeder	0.179	0.215	0.285	0.114	0.149	0.202
NFeedermax	0.179	0.215	0.285	0.114	0.149	0.202
NHandy	0.179	0.215	0.285	0.114	0.149	0.202
NSubpanamax	0.179	0.215	0.285	0.114	0.149	0.202
NPanamax	0.179	0.215	0.285	0.114	0.149	0.202
NPostpanamax	0.179	0.215	0.285	0.114	0.149	0.202
SFeeder	-1.612	0.866	1.279	0.583	0.880	1.193
SFeedermax	0.618	-2.909	1.279	0.583	0.880	1.193
SHandy	0.618	0.866	-5.576	0.583	0.880	1.193
SSubpanamax	0.618	0.866	1.279	-8.865	0.880	1.193
SPanamax	0.618	0.866	1.279	0.583	-11.345	1.193
SPostpanamax	0.618	0.866	1.279	0.583	0.880	-11.032
Cross-nest ratio	3.45	4.03	4.49	5.11	5.91	5.91

Note: the prefix 'N' and 'S' refer to the new-building and second-hand groups.

Error! Reference source not found. contains two parts. The upper part is the elasticity for the unit cost change of new vessels, while the lower part is that of second-hand vessels. The last row at each part is the cross-nest ratio, defined as the ratio between cross-elasticity and cross-nest elasticity. Each column holds the elasticity for a unit cost change in one ship type identified by the table header. For example, the first column is the elasticity for the unit cost change of new Feeder vessels, and the last column is that for new Post-Panamax vessels. This table exhibits several interesting properties:

1. For a unit cost increase of any ship types, the own-elasticity is always negative, while cross-elasticity is always positive. For example, the own-elasticity of new feeder vessels (first row, first column) is -2.709, while the cross-elasticity in the upper part of the first column is 1.03. The negative elasticity indicates an inverse relationship between demand and its price: shipowners' preference for a specific ship-type will decrease with the price of that ship-type. The positive elasticity shows the substitutions between different vessel types: the cost increase of one ship type will increase the demand of the other vessel types.
2. The cross-elasticity is always higher than cross-nest elasticity. This reflects the higher substitutability among the ships in the same nest, than that in a different nest. If the cost of one new ship type increases, shipowners will be more likely to select other new vessels than second-hand ones. Similarly, they will select other second-hand vessels for a cost increase in used ones.
3. Generally, the larger the ship size, the higher the absolute value of the own-elasticity. This indicates that the demand for large ships is more sensitive to the unit cost than the smaller ones.
4. The cross-nest ratio for new ships decreases with ship size, indicating the higher substitutability for larger new container vessels: the larger second-hand ships are relatively newer than the smaller used

ships; therefore, they are closer to new ships than the smaller ones. On the other hand, the cross-nest ratio for second-hand ships increases with the ship size, implying the lower substitutability of large second-hand container vessels using the new ones of the same size: larger new container vessels cost higher and take longer time to build.

To summarize, the empirical results presented in this section reveal how shipowners make ship investment decisions, and how they select the type of ships to suit their own needs. In making ship investment decisions, firstly, the demand growth rate is a major positive contributor, while the growth of time-charter rate, as an indicator for market price, holds back the investment. Secondly, consistent with the theoretical analysis, larger companies will invest more often, while the companies with bigger ships will invest less frequently. Thirdly, high investment from new firms (hence low investment from incumbents) is a good indicator for booming markets, which significantly increases the probability of investment for all firms, new or existing. Fourthly, contrary to theoretical analysis, high new building price does not reduce the probability of ship investment; instead, it has a significant positive relationship with ship investment. Finally, there is no significant difference between new entrants and the existing companies in response to the investment of new entrants: evidence showing no pre-emptive capacity in the container shipping industry.

The nested logit model for ship choice behaviour reveals the preferences of the investors over different kinds of ships, used or new, small or large, from three different aspects. First, from the perspective of individual variables, the coefficients on the inclusive variables indicate that the assumption on the decision-making process for ship selection (as described in Figure 2) fits the actual decision process of the ship investors. Also, larger vessels are preferred than the smaller ones; ships that can bring larger profit (higher time-charter rate and lower unit cost) are highly preferred. Secondly, new ships are preferred if the shipbuilding lag is long, or if the company has larger capacity; they are not preferred when the growth rate of demand is high, and the preference for new or second-hand ships is not related to the new building price, a typical situation in a derived market. Finally, larger vessels are more sensitive to their own cost change than smaller ones; cross-elasticity is always higher than cross-nest ones. Large second-hand ships are better substitutes to large new vessels than smaller ones, while smaller new vessels are closer substitutes to used ones.

5. Summary, conclusion and discussion

This article presents an empirical analysis that reveals shipowners' behaviour in making ship investment decisions and selecting ship types. It starts with a theoretical analysis to identify the important factors in capacity investment for a simplistic, profit-maximizing firm with a fleet of equal-size vessels operating between two ports and facing increasing demand. From the assumption on the decision-making process of ship investment and selection, two logit models were selected: binary choice model for the investment decision, and nested logit model for the ship selection decision. Ship investment data, including all the container ships over 100 gross tons in the Lloyd's Fairplay ship registry database before January 1, 2009, was employed in this analysis. This data involves 5724 container vessels and 926 shipowners. Both models and most of the coefficients were highly significant. The results can largely explain the underlying behaviour in the ship investment decisions and ship choices.

For ship investment decisions, the results show that shipowners mainly focus on the real demand growth: they are cautious about the high growth rate in the market price due to its volatility and uncertainty. Although larger shipowners tend to invest more, shipowners with bigger vessels tend to invest less. There is no obvious difference between existing firms and the new entrants in responding to competitors' investment: their investment will both increase with the new entrants' investment, and will decrease with the incumbents'.

The empirical results also support the assumption about the decision making process of ship choice: shipowners first decide to purchase a new ship or a second-hand one, then the size of the ship. Generally, they prefer larger vessels and the vessels that maximize profit (higher time-charter rate and low unit cost), regardless of new or second-hand ships. New vessels are preferred when the shipbuilding lag is long (indicating larger ships), not when the demand increasing rate is high. Companies with large capacity prefer new ships. Finally, the preferences of larger vessels, both for new and second-hand vessels, are more sensitive to the change in the unit cost. For new ships, larger vessels have higher substitutability, while the smaller vessels do for second-hand vessels.

This research does not have detailed data on the specific route that the ship is deployed. Therefore, the results obtained in this research are applicable to the global scale. Some of the results, such as the strategic behaviour in capacity investment, may not be necessarily applicable when a specific route or region is considered. Nevertheless, the results from this research can provide insights into how existing shipowners worldwide make ship investment decisions, which can benefit the global shipping companies, the financial investors, or maritime administrations in the decision making process.

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Lease Accounting and US Transportation Industry

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Abstract

This paper investigates the implications to financial ratios in the context of lease accounting. Total US investment in equipment & software exceeded $1 trillion in 2009, and end-users are estimated to finance approximately 51% (or $518 billion). By classifying the asset acquiring in the form of a lease, the corporation can manipulate its accounting ratios and show a favorable financial performance. The abuse in lease classification can serve the unethical conduct of hiding debt problems. This paper would focus on the transportation industry because carriers typically engages in a significant amount of leased assets, such as trucks, vessels, and airplanes, of which managers have inclined to treat them as operating leases. For example, research findings indicated that the average ratios of operating lease to capital lease payments for stores was about 18 to 1; while the ratio for airlines was about 26 to1. Find a proper way to assess the financial ratios of such companies in the context of lease accounting provides a fruitful area research.

Keywords: Accounting ratios, capital lease, operating lease, lease capitalization, transportation industry, G4+1.

1. Introduction

Managers can improve the looks of their year-end balance-sheets by structuring their leases for expensive assets. In 1976 the US Financial Accounting Standards Board (FASB)[1] issued the accounting standard for leases,[2] which provided guidance on how to distinguish "capital" leases from "operating" leases.

Since leases do not appear as long-term debt, by structuring the asset acquiring as a lease, the corporation can show a favorable debt-to-equity ratio (D/E ratio). The D/E ratio shows the relative proportion of shareholders' equity and debt used to finance a company's assets (Peterson, 2006). The D/E ratio measures how much money a company should safely be able to borrow over long periods of time. The D/E ratio compares the company's total debt (including short term and long term obligations) with the owner's equity. The two components of the ratio are taken from the firm's balance sheet.

The abuse in using the leasing arrangement to hide the debt problems of their companies was the key motivation of establishing the FASB 13. When a firm has a large amounts of operating leases, such as transportation companies in air and ocean carriage, of which its carriage capacity is achieved by signing long term time charterparties, lease accounting becomes a critical issue when outside creditors need to evaluate the financial performance of these companies. For example, the 1973 balance sheet of United-Airlines recorded $936 million in long-term debt and $700 million in equity capital, which gave the impression of a manageable ratio. However, the capitalized value of outstanding leases was $815 million; if adding this contractual

[1] In the US, the FASB is the designated organization for establishing standards of financial accounting that govern financial reports preparation. The standards set by FASB are officially recognized as authoritative by the Securities and Exchange Commission (SEC) (Financial Reporting Release No. 1, Section 101, and reaffirmed in its April 2003 Policy Statement) and the American Institute of Certified Public Accountants (Rule 203, Rules of Professional Conduct, as amended May 1973 and May 1979).
[2] Statement of Financial Accounting Standard No. 13 "Accounting for Leases" (hereafter "FASB 13").

commitment to the long-term debt, the readers would immediately see United-Airlines faced a serious debt problem.[3]

This paper would focus on the transportation industry because carriers typically engages in a significant amount of leased assets, such as trucks, vessels, and airplanes, of which managers have inclined to treat them as operating leases. To properly assess the accounting ratios of such companies, the area of lease accounting should deserve the attention of academia and the professional literature.

This paper examines the current accounting treatment for operating leases, particularly with its impacts on the calculation of key accounting ratios. This is a fruitful area of research for two reasons:

(1) Given the practical nature that accounting ratios are commonly used as tools to determine creditworthiness of a company.
(2) The current activities of the FASB and the IASB[4] on reviewing the accounting standards on "operating" leases.

2. Lease Financing

Lease financing provides a significant source of funds for businesses to acquire asset items. In 1994, leasing provided approximately one-eighth of the world's annual equipment financing requirements, and leasing in the US alone amounted to $140.2 billion (London Financial Reporting Group 1996). In just 15 years, total US investment in equipment and software in 2009 exceeded $1 trillion. End-users are estimated to finance approximately 51% of this amount of equipment investment, or $518 billion (Equipment Leasing and Finance Association, 2009).

Leasing arrangement has particular implications to transportation companies. For example, transportation sectors are losing money as the US dollar has lost about 25 percent of its value from 2004 to 2008, according to the Federal Reserve's Trade Weighted Major Currency Dollar index, and almost 10 percent against China"s yuan in 2007 (Hoffman, 2008). In order to find a suitable strategy for survival, transportation companies are increasing using software to aggregate enormous amounts of shipping data in its own data farms. In the US, more than half of all investment in equipment and software is currently being acquired under leases (Equipment Finance and Leasing Foundation, 2007).

One potential benefit of leasing is that management can respond to economic changes more quickly in adjusting the company's fixed asset requirements. Although lease financing is often more expensive than other types of debt financing, leasing can allow managers to find the most productive configuration by trying different types of equipment.

One of the major concerns in reporting lease agreements is the possibility of off-balance-sheet financing (SEC, 2005). Off-balance-sheet financing allows a company to keep off capital expenditures from a company's balance sheet through various classification methods. Therefore, a manager can use off-balance-sheet financing to keep the debt to equity (D/E) and leverage ratios low. One typical motivation for a manager to adopt off-balance-sheet financing is that when the loan agreement a company previously entered into has included a term that a large expenditure would break negative debt covenants. Operating leases are one of the most common forms of off-balance-sheet financing.

By signing an operating lease, a company may realize the future economic benefits of an asset without recording either the asset or the obligation of lease payments in its balance sheet. The cost of the lease is

[3] Forbes, (Jan 15, 1975) "To Capitalize or Not to Capitalize, that is the question", Vol. 115, Iss. 2; pg. 42.
[4] IASB stands for International Accounting Standards Board. The IASB's membership was representative of accounting standards boards, rather than of professional accounting bodies, across national borders; therefore, it is in the best position to undertake the task of drafting a set of global accounting standards. The IASB and the FASB published the Summary Report of the Leases Working Group Meeting on February 15, 2007 to recognize the difficulty in defining the operating and finance leases. http://www.fasb.org/board_meeting_minutes/10-07-08_leases.pdf

recognized as a charge on the income statement. As a result, the leased asset is not included in the calculation of the liquidity ratios.

3. Leasing Agreement

A true leasing agreement is an executory contract. Such contract does not constitute a sale or create a security interest. Under a true leasing agreement, the asset owner allows the lessee quiet enjoyment if and only if the lessee continues to fulfill its ongoing obligations. Upon a default, the asset owner has a right to repossess the asset and bears a duty to find another lessee in mitigating damages.

The typical equipment lessor is the financial institution, such as a bank. The typical lease terms include the right of the lessee to return the leased asset at lease expiry with no further obligations, as well as optional lessee purchase and renewal rights, features which distinguish leases from loans.

The leasing terms in some industries are rather standardize, for example, the very specific nature of the regulations governing load size and the high degree of specialization of transportation companies, such as trucking and ocean carriers for containers would allow little possible variation in leasing terms.

Take the US trucking industry as an example, there is little variation in available interest rates due to the intense competition among lenders. It also means that there will be limited variations in payment terms. The length of the warranty on the truck is the key factor determines the length of the lease. A typical contract for truck leasing runs for less than 75% of the estimated life of the truck. The present value of all the lease payments is less than 90% of the fair value of the truck. The lease typically has a non-cancelable condition, and ownership of the truck will revert back to the lessor at when the lease terminates.

4. Altman Model

Accounting ratios are used to assess credit standing of a business entity. For example, the interest coverage and fixed charge coverage ratios look at a company's ability to generate income for meeting debt obligations. Debt-equity ratio looks on the relative amount of outside (creditor) funding of a company's operations.

In order to recognize the effects of leasing agreement on accounting ratios, some writers proposed a simplified decision rules. For example, Graham and Dodd's Security Analysis (Cottle et al., 1988) suggests that the off balance sheet liability from operating leases is estimated by multiplying the current period's rent expense by eight.

On the other hand, there are more sophisticated models developed for incorporating a wide array of data to judge a company's likelihood of facing financial distress. The best known model is the Altman Z-score (Altman, 1968).

In a simple version, the Altman Z-score model can be seen as a simple weighted average of the following five specific accounting ratios:

(1) *working capital in relation to total assets,*
(2) *retained earnings in relation to total assets,*
(3) *earnings before interest and taxes in relation to total assets,*
(4) *sales in relation to total assets, and*
(5) *the ratio of market value of equity to book value of liabilities*

Even though the Altman model is some 40 years, it is the model most embraced by practitioners (IOMA, 2003). The Altman model has stood the test of time and offered the advantages of simplicity and effectiveness. Academic researchers often used the Altman model to evaluate the impacts of lease capitalization of lease arrangements (Jesswein, 2009).

5. Lease Capitalization

Current accounting standards specify two ways of reporting leased assets. Operating leases are viewed as true leasing agreements. The business entity simply reports the cost of the lease payments made in the current period as rental expense. By leasing rather than purchasing an asset, from the perspectives of operation, a company can improve its economies of scale in a way as the owner of assets, but it can reduce the costs of upgrading equipment and improve risk sharing. However, leasing arrangements can result in off-balance sheet implications to a company's financial reporting (SEC, 2005).

On the other hand, if the business enters into a noncancelable lease agreement that extends through most of the asset's useful life, the lease agreement must be capitalized. The classification rules can be found in FASB 13. The principle is that the current leasing standards determine whether leases are capitalized based on the risks and rewards of ownership. The lessee would account the contract as a capital lease if a non-cancelable lease meets any one of the following requirements:

> *(1) the lease transfers ownership of the property to the lessee*
> *(2) the lease contains a bargain purchase option*
> *(3) the lease term is equal to at least 75 percent of the estimated useful life of the leased properly,*
> *(4) the present value of the minimum lease payments is at least 90 percent of the fair market value of the leased property.*

The FASB 13 approach has been highly criticized because it focuses on the contract rather than the way in which the leased asset is being used.

At one point, the FASB issued a special report supporting a position that leases should be viewed in terms of property rights, rather than ownership rights. Under this approach, many lease contracts that are classified as operating leases should be capitalized.

The first published study of the impact of lease capitalization on accounting ratios was conducted by Nelson (1963), who examined the effect of lease capitalization on the debt-equity ratio of eleven US companies. Nelson found a significant change in the rankings of the companies after capitalisation compared to before capitalization.

More recently, professor Eugene A. Imhoff from University of Michigan, developed a method to estimate the impact of operating lease capitalization on two ratios (return on assets and debt to equity) for 14 US companies (seven matched industry pairs, selected to represent high and low operating lease use). Imhoff's method allows key financial statement ratios to be calculated as if the noncancelable operating leases had been capitalized at their inception (Imhoff, Lipe, & Wright, 1991).

Imhoff finds material differences in the ratios for both 'high' and 'low' lessees, and concludes that operating lease capitalization can materially affect inter-firm comparisons of key financial statement ratios. Imhoff observed that most financial analysts concern over off-balance sheet financing via operating leases, however, they routinely used financial ratios without making adjustment for the lease effects. Imhoff opined that by capitalizing the long-term operating lease commitments would enhance the comparability of firm performance.

Thomas Noland, associate professor from University of Houston showed the potential impact of this approach by using a sample of 273 privately-held companies in the trucking industry (Noland, 2006). The mean and standard deviation of the sample are as following:

Mean & Standard Deviation for a sample of trucking companies *(dollar in thousands)*			
Variable	**Sample Size**	**Mean**	**Standard Deviation**
Sales	273	$7450	$2879

Incomes before taxes	273	$284	$411
Current assets	273	$1083	$766
Net operating property	273	$1323	$1549
Total assets	273	$2649	$2307
Current liabilities	273	$811	$621
Total debt	273	$1645	$1579
Current ratio	273	3.89	26.19
Debt ratio	273	0.64	0.32
Return on trans. assets	273	2.69	18.37
Profit margin	273	0.04	0.05

The variables used in the above table have significant implications in the methods in evaluating the creditworthiness of a company because (1) they are used in calculating the ratios that are used by creditors in writing the debt covenants, (2) they form the accounting numbers that are used by investors in performance valuation (Beattie, Goodacre and Thompson, 2000(a) and 2000(b)).

Noland's findings are applicable to industries where leased equipment comprises a significant portion of companies' fixed assets. The results illustrate the economic impact of leasing on the profitability and liquidity of the business as following:

1. *After capitalization, the figures looked less favorable. For example, both the current ratio and return on assets became lower; the debt ratio became higher.*

2. *Companies relied primarily on leasing appeared to be in a more favorable financial position prior to lease capitalization. Once the leases were capitalized, they were generally in a less favorable financial position than the companies which purchase the assets.*

3. *If one classifies the portion of the asset to be depreciated within the coming year as a current item, then it can reduce the impact of capitalization on the current ratio. The justification of this treatment is based on the concept of asset use rather than asset ownership. The lessee makes a contract to acquire the right to use the asset, such as a truck, then the annual right to use will expire within the coming year, and this would meet the definition of a current asset.*

6. Recent Development In Lease Accounting

The Group of Four Plus One (G4+1) represents a cooperative effort in lease accounting researches by national accounting standard setters from US, UK, Canada, Australia, and New Zealand, plus the International Accounting Standards Committee.

Conclusions reached by the G4+1 are not recognized as GAAP in any financial reporting jurisdiction. However, by the very nature of its membership, the research findings are expected to influence the future standard setting concerning lease accounting in many jurisdictions. Under the G4+1 proposal, lessees recognize the fair value of any assets and liabilities contained in a lease contract. Recognition begins when the lessor makes the asset available to the lessee. Thus, lessee balance sheets are expected to reflect additional lease liabilities if this new approach is adopted.

The Enron debacle in 2001 caused a focus on off balance sheet financing, including operating leases. The resulted Sarbanes-Oxley Act and the Public Company Accounting Oversight Board (PCAOB) were established to reduce the off-balance sheet transactions, such as synthetic leases. In 2004 there were approximately 200 public companies that needed to restate their financial results due to lease accounting issues.

Academic researches found that financial performance in terms of accounting ratios are different depends on whether one applies lease capitalization or not. Should we capitalize all the lease arrangements? Capitalizing all leases would simplify the process of classifying a lease. However, it would add complexity to the lessee because he has to calculate:

(1) the present value for every piece of asset items in the lease (could be thousands of PCs and company vehicles);

(2) the amount for depreciation on the asset over the shorter of the lease term or the useful life;

(3) the separate amounts of the lease payment between imputed interest cost and reduction in implied principal; and

(4) the amount for deferred taxes, as the lease is treated as an operating lease for income tax purposes.

Chapter 1 of the 2000 G4+1 paper[5] sets out the deficiencies of existing accounting standards for leases. The paper then discusses the scope of revised accounting standards for leases in chapter 2.

In chapter 3, the paper discusses:

a) Whether a lessee should recognize assets and liabilities about the rights and obligations of a lease when the lessor has substantially performed its obligation to provide the lessee with access to the leased asset?

b) Whether the fair value of the rights and obligations of the lease be recorded at the beginning of the lease term?

c) Whether the fair value of the rights obtained by a lessee can be less than the present value of the total minimum payments of the lease (assuming that the lease is negotiated on an arm's length basis)?

Chapter 4 discusses contingent rentals. Chapter 5 talks about residual value of the leased asset. Chapter 6 addresses on what discount rate should be applied to the rental payments. Chapter 7 focuses on discusses the accounting approaches to sale and leaseback transactions.

In chapter 8, the paper discusses whether a gain should be recognized at the beginning of the lease term if:

(a) there is evidence that the value of the leased assets (less its liabilities) has increased as a result of the lease contract, and

(b) the increase can be measured reliably

Chapter 9 is on disclosure of separate components of the leased assets. Chapter 10 discusses the initial measurement of residual interest assets. Chapter 11 discusses the treatment of contingent rentals from the lessor's perspective. Chapter 12 discusses three alternative views on how a lessor's residual interest asset should be measured during the lease term.

7. Conclusion

[5] The G4+1 published the document entitled "*Leases: Implementation of a New Approach*"

This paper explores lease accounting and capitalization in relation to transportation industry. There is a need for additional research related to lease accounting, especially in the context of ethics. The research should focus on the role of rules and that can enhance ethical behavior in lease classification.

The threshold for ethical behavior should be set at higher level than that of legal behavior. As indicated by the Enron tragedy, there were many smart people who knew how to maneuver around the legal rules, and these smart people showed less concerns on understanding why the rules had been written in the first place (Eichenwald, 2005). Satava et al. (2006) opined that the rule-based tradition of financial reporting could become a useful vehicle for rule manipulating in reporting financial statements.

What is the key factor that motivates a manager to hide the leased assets and related liabilities on the firm's balance sheet? The simple answer is that 'window dressing'' of the financial performance promotes his self-interest. By honestly putting the lease on the balance sheet may result in violation of loan covenants, which may affect the amount of compensation he will be received as a manager, especially when his compensation is linked to the firm's earnings). The way how a manager is compensated will determine the likelihood a manager will engage in the legal but unethical rule maneuvering of structuring the lease as operating type to avoid capitalization.

Byrnes, in Business Week (June 5, 2006), estimates that S&P 500 firms have more than $300 billion in leases that do not appear on lessee balance sheets and estimates the tally at $1.25 trillion when all public companies are considered. The classification of lease as operating type is common in transportation sector. For example, Revsine et al. (2005) show that the average ratios of operating lease payments to capital lease payments for variety stores is 18 to 1; while the ratio for airlines is 26 to1.

On reducing the unethical behavior in maneuvering reporting rules, such as lease classification, Satava et al. (2006) suggested that a "principles-based approach'" could improve the ethical conduct of accountants and auditors. Is the approach welcome by the professionals, on commenting the ethics of structuring lease contracts to avoid capitalization, said a senior audit manager of a Big Four accounting firm: [O]n lease accounting, the rules win out and ethical behavior takes a back seat (Frecka, 2008).

An ideal approach should be found to guide managers in meeting their fiduciary responsibilities, at least in the area of lease classification, in a way to go beyond mere professionalism when reporting their financial performance to shareholders and creditors.

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