Contemporary Liner Shipping Business
– A Game Theoretical Application

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Abstract

The shipping industry is known for providing transportation service at sea in terms of deploying vessels and accessing ports, making the shipping service itself one of the network-based services. From the perspective of traditional as well as neo-economics, the shipping industry is assumed to pursue profit maximization under the constraints of scarce resources, e.g. capital, assets, seafarers, or binding constraints derived from schedules, etc. In addition, in case that we are looking at the liner shipping business from the perspective of games, more and more players are getting involved in the shipping industry and most of them are becoming rational considering interdependencies among them. In other words, players do not only focus on their own businesses.

Taking into account their interdependencies and inter-relations, game theory provides a meaningful possibility to model and analyze the behaviors of the involved players in the liner shipping industry. The players in the liner shipping industry could be some or any of the following: linkage operators, e.g. liner shipping carriers, port operators, freight forwarders, customs, hinterland haulage carriers, inland navigation carriers, market regulators, etc. Generally speaking, liner shipping carriers and seaport/dry port operators are main players who operate the links and nodes, respectively. This thesis provides a well-groomed research on the liner shipping business, and some part of the analysis applies game theoretical approaches for vertical and horizontal cooperation among the links and nodes in the liner shipping industry.

Keywords: Maritime Shipping, Liner Shipping, Game Theory, Cooperation, Port

Chapter 1 Introduction

1.1 Background

The shipping industry provides transportation services among ports by ships at sea, and its service is based mainly on the networks built by shipping carriers. Carriers represent the supply side by providing transportation services while following certain regulations and policies. Shippers represent the demand side by booking transportation services. Besides freight rates, a shipper can decide to accept one of the carriers' offers taking into account his expectation of other shippers' decisions to avoid congestion, peak season pricing, risk, etc.

Shipping services for the carriage of international trade are traditionally organized, basically on two patterns, i.e., tramp shipping and liner shipping. Tramp ships are usually in search of bulk cargoes. Their movements would be governed by availability of bulk loads from port to port and country to country on a global scale. With the increase in the size of the ships, although the small tramps of the past have not altogether disappeared from the scene, the large bulk carriers and tankers for dry bulk are dominating this niche market.

In this thesis, liner shipping business is focused, where services are provided by liner shipping carriers with pre-designed routes and schedules for shippers at a fixed freight rate, following sequences of port-of-calls. The top liner shipping carriers have already established alliances and later on slot-based agreements within the shipping industry and are investigating to set up new business linkages together with customers, suppliers, competitors, consultants, and other companies, too. There are three basic means of obtaining liner fleet capacity, i.e., new building, second-hand purchasing and chartering in vessels. In the first two scenarios, owners are the operators themselves. In the third scenario, the owner is different from the operators. Eventually, the liner carriers, no matter whether they are owners or operators, are attempting to apply most up-to-date business patterns to survive in market dynamics.

Based on years of observation in the liner shipping industry, one character of the liner business, among others, is extracted. In brief, the liner carrier often, if not always, cooperates with its competitors. Though it seems extraordinary, such phenomenon can be analyzed from the perspective of cooperative and non-cooperative games. Therefore, in most chapters of this thesis, game theory is applied as a methodology to describe and further analyze collective market equilibrium and individual liner companies' behaviors. Equilibrium is a game situation where none of the players is able to obtain a better outcome by unilaterally changing her strategy. In other words, assuming that competitors keep their current strategies, a player would not be able to improve her benefit. Hence, under a situation of equilibrium, none of the players has a reason or motivation to change the chosen strategy. This situation characterizes a stable state of the system.

On one hand, the purpose of this thesis is to provide overview and analysis on the liner shipping industry followed by discussions on main challenges the industry has faced and is facing based on vertical and horizontal cooperation, respectively. Evidently freight transport, which is directly linked to economic activity and trade facilitation, the cycle of seaborne liner transport then very much relates to the cycle of trade as well as evolving technologies and regulations. Hence, on the other hand, the impact of the technologies on the liner business and the reaction of liner companies under new regulations are also discussed.

1.2 Research Framework

The framework of this cumulative thesis can be structured as Figure 1. The thesis consists of papers covering three main streams of the liner shipping business, i.e., vertical cooperation, horizontal cooperation and intra-organizational development. From the perspective of vertical cooperation, the liner carrier is collaborating with port operators; this holds no matter whether they are sea port operators or dry port operators in related hinterlands. From the perspective of horizontal cooperation, the liner carrier is collaborating with other liners, i.e., they are homogeneous. From the perspective of intra-organizational development, the liner carrier is reacting initiatively under circumstances of changing environmental regulations and technologies. In addition, publications are lined up along different streams with several keywords and abbreviations.

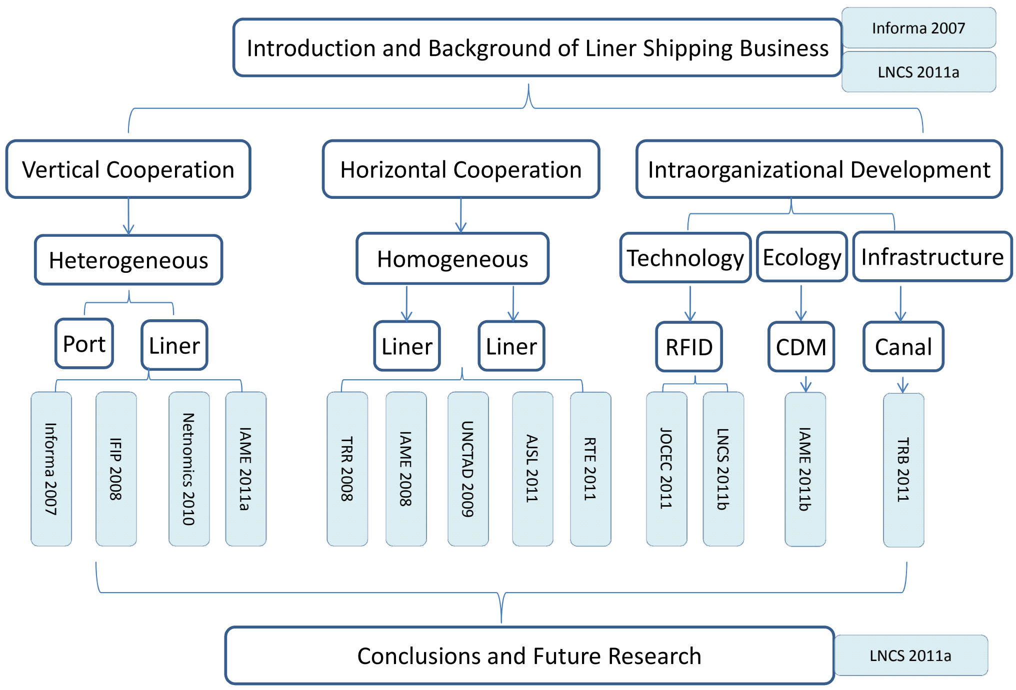

Figure 1. Framework of the Thesis

Included Publications

Below are the publications including refereed chapters in an edited book or proceedings as well as refereed papers in journals, which contribute for cumulating this thesis.

Table 1. Included publications and their associated abbreviations[1]

Abbreviations	Publications
Informa 2007	Xiaoning Shi and Stefan Voß, *Container Terminal Operations under the Influence of Shipping Alliances*, in Khalid Bichou, Michael G.H. Bell and Andrew Evans (eds.) *Risk Management in Port Operations, Logistics and Supply Chain Security*, Informa, London, pp. 135-167, 2007
IFIP 2008	Xiaoning Shi and Stefan Voß, *From Transocean Routes to Global Networks: a Framework for Liner Companies to Build Service Networks*, in Journal of Telecommunications and Information Technology, 3/2008, pp. 35-43, 2008, ISSN: 1509-4553
IAME 2008	Xiaoning Shi, Hilde Meersman and Stefan Voß, *The Win-Win Game in Slot-Chartering Agreement among the liner Competitors and Collaborators*, in Conference Proceedings of the Annual Conference of the International Association of Maritime Economists (IAME), Dalian, 2008
TRR 2008	Xiaoning Shi and Stefan Voß, *Iterated Cooperation and Possible Deviations among Liner Shipping Carriers Based on Non-cooperative Game Theory*, in TRR (Journal of Transportation Research Record), Vol. 2066, pp. 60-70, 2008 , DOI: 10.3141/2066-07
UNCTAD 2009	Honey Tousypanah, Xiaoning Shi and Jan Hoffmann, *Liner Shipping Connectivity in 2009*, in United Nations Conference on Trade and Development (UNCTAD) Transport Newsletter, Vol. 43, Iss.2, pp. 6-9, 2009
Netnomics 2010	Xiaoning Shi and Thierry Vanelslander, *Design and Evaluation of Transportation Networks: Constructing Transportation Networks from Perspectives of Service Integration, Infrastructure Investment and Information System Implementation*, Netnomics, Vol. 11, Iss. 1, pp. 1-4, 2010
IAME 2011a	Xiaoning Shi, Yi Zhang and Stefan Voß, *Actions Applied by Chinese Shipping Companies under GHG Emissions Trading Scheme*, in Conference Proceedings of the Annual Conference of the International Association of Maritime Economists (IAME), Santiago de Chile, 2011
IAME 2011b	Fang Li, Xiaoning Shi and Hao Hu, *Location Planning of Dry Port Based on Multinomial Logit*, in Conference Proceedings of the Annual Conference of the International Association of Maritime Economists (IAME), Santiago de Chile, 2011
AJSL 2011	Xiaoning Shi and Stefan Voß, *General and Modified Slot Chartering Agreements-Performance Comparison Based on Different Mechanisms*, in Asia Journal of Shipping and Logistics, Dec 2011, forthcoming
RTE 2011	Dong Yang, Miaojia Liu and Xiaoning Shi, *Verifying Liner Shipping Alliance's Stability by Applying Core Theory*, in Research in Transportation Economics, Vol. 32, Iss. 1, pp. 15-24, DOI: 10.1016/j.retrec.2011.06.002
JOCEC 2011	Xiaoning Shi, Dongkai Tao and Stefan Voß, *RFID Technology and its Application to Port-Based Container Logistics*, in Journal of Organizational Computing and Electronic Commerce, Vol. 21, Iss. 4, pp. 1-16, DOI: 10.1080/10919392.2011.614202. (in print)
LNCS 2011a	Xiaoning Shi and Stefan Voß, *Game Theoretical Aspects in Modelling and Analyzing the Shipping Industry*, in Lecture Notes in Computer Science, Vol. 6971, pp. 302-320, 2011

[1] Abbreviations beyond those in this table can be found in the appendix.

LNCS 2011b	Lei Hu, Xiaoning Shi, Stefan Voß and Weigang Zhang, *Application of RFID Technology at the Entrance Gate of Container Terminals*, in Lecture Notes on Computer Science (LNCS), Vol. 6971, pp. 209-220, 2011
TRB 2011	Xiaoning Shi and Stefan Voß, *The Impact of the Panama Canal Expansion on Liner Fleet Deployment and Operation-A New Agenda*, submitted for the Annual Conference of the Transportation Research Board (TRB), Washington, Jan 2012, under review

Non-included publications/work

There are also some publications that are not included in this thesis, which are listed as follows.

Table 2. Non-included publications and their associated abbreviations

Abbreviations	**Non-included Publications**
ComLog 2011	Jürgen W. Böse, Hao Hu, Carlos Jahn, Xiaoning Shi, Robert Stahlbock, Stefan Voß (Eds.), Computational Logistics, Lecture Notes in Computer Science (LNCS), Vol. 6971, Springer, 2011, ISBN:978-3-642-24263-2, ISSN:0302-9743, 369 pages
Online 2011	RFID 技术在港口基础设施建设中的应用研究-集装箱码头案例，胡磊、史小宁、周岱、张卫刚，中国科技论文在线，2011 年 11 月
LISS 2011	Fang Li, Xiaoning Shi and Hao Hu, *Location Selection of Dry Port Based on AP-The Case of Southwest China*, in Conference Proceedings of International Conference on Logistics Informatics and Service Science (LISS), 2011, ISBN：978-989-8425-66-9
IFSPA 2010	Jiaolong Lai, Xiaoning Shi and Hao Hu, China's *Oil Import Forecast and its Impact on Tanker Fleet Composition*, in Conference Proceedings of International Forum on Shipping Port and Airport (IFSPA), 2010
TransEco 2009	Xiaoning Shi, Weihong Hu and Hao Hu, *Transport Economics (Chinese Translated Version)*, ISBN: 978-7-114-08006-7, China Communications Press, Beijing, China, 2009

1.3 Research Methodology

Game theory (hereafter GT) is a methodology of decision making involving multiple parties such as persons, companies or agents. For instance, each company must consider what other companies will do. Classical literatures (Nash 1944, Von Neumann and Morgenstern 1944) together with applications of GT in industrial organizations (Gibbons 1992, Phlips 1995, Tirole 1988) usually discuss four classes of games: static as well as dynamic games of complete information and static as well as dynamic games of incomplete information. We assume that readers have a basic knowledge of GT; see, e.g., (Gibbons 1992, Phlips 1995, Tirole 1988). Corresponding to these four classes of games there are four notions of equilibrium in games: Nash equilibrium (NE), subgame-perfect NE, Bayesian NE, and perfect Bayesian equilibrium. The NE is a solution concept of a game, in which each player is assumed to know the strategies to be taken by the others and no player can be better off by changing his or her own strategy unilaterally. A subgame-perfect NE is a refinement of a NE used in dynamic games if it represents a NE of every subgame of the original game. Bayesian NE is a solution concept of Bayesian games where at least one player is unsure of the type (and so the payoff function) of another player, which might result in some implausible equilibria in dynamic games. To refine the equilibria generated by the Bayesian Nash solution concept or subgame perfection, one can apply the perfect Bayesian equilibrium solution concept. The characteristics of each game can thus be summarized in Table 3.

Table 3: Brief summary on solution concepts

Solution Concepts	**Nash equilibrium**	**Subgame-perfect Nash equilibrium**	**Bayesian Nash Equilibrium**	**Perfect Bayesian equilibrium**
Proposed by	John F. Nash	Reinhard Selten	John C. Harsanyi	N/A
Applications	Static games Pure strategy	Dynamic games Mixed strategy	Static games	Dynamic games Sequential games
Expressions	Normal form Extensive form	Extensive form	Extensive form	Extensive form
Approaches	Fixed point theorem	Backward induction	Bayes’s rule	Sequential rationality based on updated beliefs
Information set	Complete	Complete	Incomplete	Imperfect

A player in a game is a person or a business community making decisions or choosing a strategy from a set of given options. One player's decision affects that of the others. In a static game, players make decisions simultaneously without knowing information of other's decisions. In a dynamic game, players make decisions at different moments, i.e., a sequential decision making process happens due to the fact that other's decisions have been disclosed. A strategy in a game is one of the options from which a player may select. Such decision making process may be based on historic experience of himself and/or information disclosed by other players. Traditional applications of GT attempt to find equilibria. In an equilibrium each player of the game has adopted a strategy that none of the players involved is likely to deviate from.

Traditional applications of game theory attempt to find equilibria. In an equilibrium each player of the game has adopted a strategy that none of the players involved likely tends to deviate. Payoff means what a player gets after choosing a strategy. Pursuit of payoff maximization, usually, is the utmost goal of a player.

In this thesis, a player can be, e.g., a liner shipping operator, or a tramp shipping operator, or a community of liners -- an alliance -- behaving as a whole in the market. A set of strategies can include whether to cooperate with other competitors or deviate from the current situation, etc. Payoff of a player is the commercial benefit when a player chooses one of his strategies, e.g., the revenue after choosing to cooperate with his competitor. The shipping industry provides transport services among ports by ships at sea. Its service is based mainly on the networks built by carriers, representing the supply side by providing transport services while following regulations and policies. Shippers represent the demand side by booking transport services. Besides freight rates, a shipper can decide to accept one of the carriers' offers taking into account his expectation of other shippers' decisions to avoid congestion, peak season pricing, risk, etc.

Carriers similarly attempt to avoid overcapacity, cut-throat competition, lack of diversification, and other negative factors. Therefore, shippers or carriers can be regarded as players in games as they will not take action without considering what their competitors do.

Besides freight rates, a shipper can decide to accept one of the carriers' offers taking into account his expectation of other shippers' decisions to avoid congestion, peak season pricing, risk, etc. Carriers similarly attempt to avoid overcapacity, cut-throat competition, lack of diversification, and other negative factors. Therefore, shippers or carriers can be regarded as players in games as they will not take action without considering what their competitors do. In addition, both shippers and carriers must act subject to regulations and policies in the shipping industry. We must also consider the regulator designing regulations and policies with an eye towards how shippers and carriers will react to them. In this sense, a regulator can also be viewed as player, especially in principal-agent relations. The interactions among players in the shipping industry have a considerable impact on each player's strategy set. The relationship between homogeneous players, e.g. different carriers, is horizontal whereas the relationship between heterogeneous players, e.g. shipper and carrier, is vertical.

In addition to the aforementioned players, there is a growing trend for related service providers to integrate. For instance, truck haulage carriers integrate their business with shipping carriers so that door to door service can be achieved. Thus, games such as price auctions and principal-agent incentive games might also need to be considered, and these may be classified as either heterogeneous relations or principal-agent games as mentioned before. Therefore, GT can be a helpful tool in the analysis of the shipping industry given features of the industry that the decisions of multiple players affect each player's payoff.

When observing the literature, it can be seen that many meaningful tools are spread over a variety of papers and books, and not so many well groomed surveys on systematic application of the GT in the shipping industry are available. Hence, the preliminary goal in this chapter is to provide a survey on how the existing literatures deal with operational and strategic behaviors of either homogeneous or heterogeneous players in the shipping industry. In terms of discussing them step by step, i.e., from horizontal relations to vertical relations, this thesis tries to shed lights to kinds of interactions within the players. The related discussion can be very helpful for readers who also intend to analyze game theoretical aspects in the shipping industry.

In this chapter, the background of the liner industry and research methodology is introduced together with the research framework of the thesis. In Chapter 2, the vertical cooperation in the liner business is analyzed followed by horizontal cooperation in Chapter 3. Besides, in Chapter 4, technological aspects and ecological aspects are discussed. Finally, conclusions and future research trends are outlined in Chapter 5.

Chapter 2 Vertical Cooperation in the Liner Business

2.1 Definition

Basically any player of the shipping industry might play either cooperation games or competition games or both, within the designed mechanism and market circumstances including free market, monopoly, duopoly and even oligopoly. In this chapter, those players who actually provide different services are paid attention; in other words, they are rather suppliers or customers to each other than competitors in a certain niche market. In the transportation industry, there are certainly games to be investigated among vertically related players. The players who share the same value chain sometimes team up with each other so that better integrated service can be provided to the final customer. Once the service provider selection is to be involved, see Figure 2, the vertical relations become apparent. Such vertically related players might be liner carriers and port operators, shippers and freight consolidation/distribution centers as well as hinterland haulage carriers, etc.

Leader-follower models can be used to simulate the relationship among players, because some players, who have either more experience or higher negotiation power, distinguish themselves from their peers, become leaders in games. In contrast, those players who have relatively less experience or know-how may become followers in games.

From an industrial perspective, a transportation network is a spatial system of nodes and links over which the movement of cargo and passengers occurs (Talley, 2009), so is a shipping network. A node is a center in a transportation network from which cargo and passenger movements emanate. A physical link between two transportation nodes is the transportation way (e.g., waterway, highway, railway, and airway) over some distance between the nodes.

From a theoretical perspective (cf. graph theoretical concepts) a network can be represented as a graph, which is a mathematical structure consisting of a number of nodes (vertices) and links (edges). Furthermore, a path is a trail with neither repeated edges nor repeated nodes (Gross and Yellen, 2006). However, in shipping practice service providers may design some certain service route with repeated linkages as well as repeated ports-of-call within one service.

In addition, a decision maker representing a link takes into consideration directions and capacities of other links. The same applies to decision makers representing nodes, which inevitably underlies primary principles of game theory. Therefore, instead of just applying the path game, the problems investigated in this research are defined by means of link games and node games within networks. In order to better understand this mature and complex industry, major business issues in the shipping industry are outlined in Figure 2.

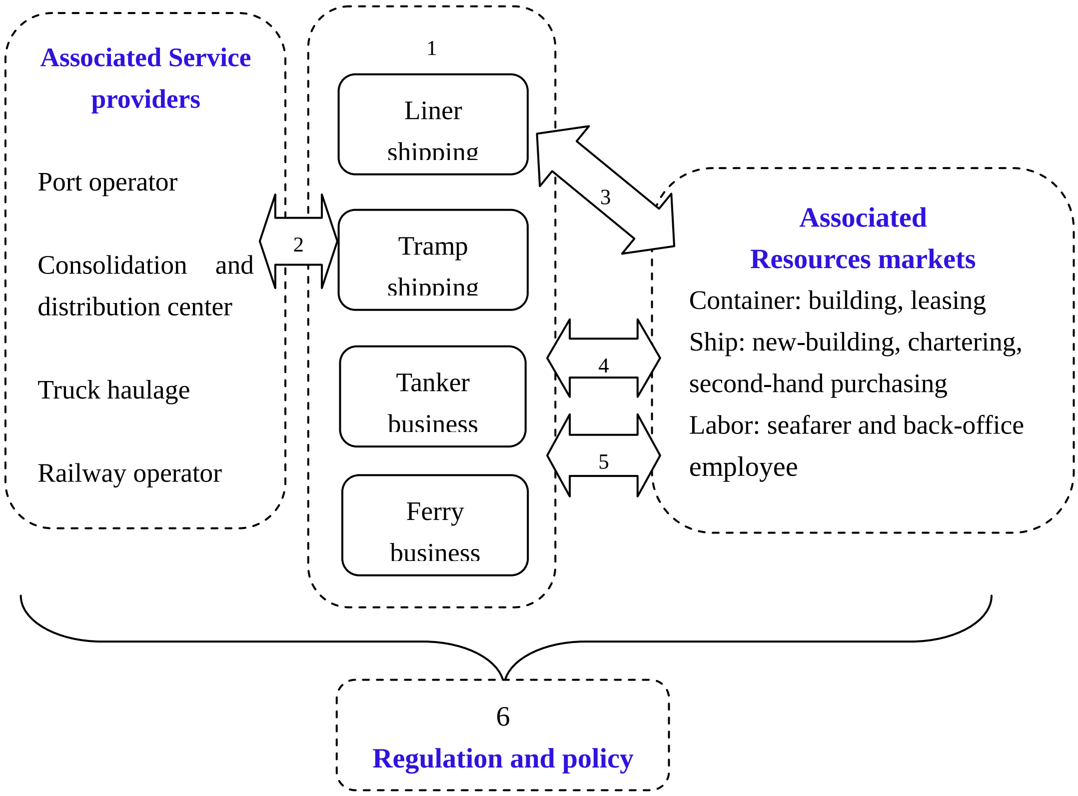

Figure 2: Structure of the shipping industry and its associated markets

The primary shipping industry consists of liner shipping, tramp shipping, the tanker business and the ferry business as shown in Box 1 of Figure 2. Liner shipping is a transportation service following announced and scheduled ports-of-call, regardless of whether it is ocean sea transport or short sea shipping. Tramp shipping is the transportation service that does not rely upon repeatedly scheduled ports of call, but rather on pick-up and delivery of cargos according to demands and either voyage charter or time charter-based contracts. The tanker business shares similar characteristics with tramp shipping, the main difference being that the cargo in this case is either crude oil/oil product or bulk. Finally, the ferry business provides service to passengers, which is beyond the main scope of this thesis taking into account the fact that the behavior of humans is relatively erratic compared to that of cargo. The interested reader could simply replace passengers, to some extent, with cargoes and then apply the same ideas of game theoretical thinking as discussed below. Within the primary shipping industry, the competition and strategic cooperation among the homogeneous carriers arise as horizontal games. Considering the fact that carriers act as links connecting different ports, the carrier related competition and cooperation can be viewed as one of horizontal relations at the macro level. In other words, it belongs to the link game in service networks. Therefore, a link game is dealing with the construction of links and reconstruction of paths by means of either consolidating or deconsolidating linkage supply, so that demand could be better satisfied.

In addition, as shown on the left side of Figure 2, the service provider's component of the shipping service includes port operators, consolidation/distribution centers as well as hinterland service operators such as truck haulage, railway operators and 3rd party logistics providers. The ports and consolidation/distribution centers are nodes which contribute to comprehensive service networks (Talley, 2009). In a figurative sense, a node makes efforts to attract more links by means of amplifying throughput and storage capacity of the node as well as hinterland connections, where this could relate to various aspects including, e.g., available infrastructures to avoid congestion regarding hinterland traffic. Once there are other competitive nodes within the same trading zone or graphical region, the nodes compete with each other in order to sustain as hub. Or the nodes have to cooperate with the existing hub because of their limited capacities. Therefore, the port and consolidation/distribution center related competition and cooperation can also be viewed as a center of horizontal relations among homogeneous players. However, it belongs to the node game. In sum, a node game is aiming to adjust the attractiveness of associated nodes to links in terms of changing the status of the node, so that better accessibility and capacity can be achieved.

Furthermore, links and nodes select each other in order to obtain better performance in tandem than it could be achieved in isolation. On one hand, the links select efficient nodes so that the waiting time and total voyage time could be shortened as well as to avoid potential risks. Sometimes, the links observe existing nodes and choose among them, as in the port selection problem of liner carriers (Rimmer, 1998). Sometimes, the links even propose and invest in new nodes when it is worthwhile to do so. On the other hand, nodes select weighted links so that the capacity of the nodes can be better utilized and higher profits can be achieved. In this case vertical relations among heterogeneous players occur (Shi and Voß, 2007). In addition, the accessibility and connections with other service providers are also vital to both the links and nodes from the aspect of strategic sub-network integration at the macro level. Therefore, the problem is presented as a network game.

The right hand side of Figure 2 depicts how associated resource markets support the shipping industry. In the case where containers are to be built or leased and workers are to be employed, bargaining and auction games are involved, (links 3 and 5 in Figure 2). In the case where ships are to be deployed, schedule optimization and network games are considered (link 4).

Finally, regulations and policies (Box 6) direct and control as appropriately as possible behaviors of the associated players who simultaneously account for interdependencies with others. The remainder of this paper introduces and demonstrates how the players in the shipping industry interact with each other, taking into account both individual and collective rationality, and how market regulators might improve market efficiency by means of game theoretical mechanism design.

2.2 Cooperation with Ports

Based on vertical cooperation defined in Section 2.1, investment on networks belongs to strategic behavior of liner carriers. The utmost aim of implementing infrastructure investment, in the hope of at the right moment, is to grasp the market opportunity as well as obtain priority of terminal handling service offered by port operators. Therefore, from the perspective of strategic behavior, such investments should at least consist two folds. Investment on fleet capacity affects fixed costs of a liner shipping company, while investments on port facility affects operational costs (or voyage costs) of a liner shipping service.

1) Investment on Fleet Capacity

Investment banks have long time launched an initiative to support ship owners in obtaining credits for supporting bigger fleet. Coming back on track of this initiative especially after the crisis could be envisaged in order to facilitate access to credits for the liner shipping market. Financing is a major concern for usually capital intensive transport operators, i.e., the liner shipping companies in this case. For most parts of the transport industry, vessels, aircraft, rolling stock, buses and trucks represent the most important financial assets and consequently the depreciation accounts for the largest part of the companies' fixed costs. However, it differs in time spans. The process of projecting, ordering, constructing and operating container ships varies between long distance service and domestic or short sea shipping service and the time span of operating a mega container ship may cover approximately twenty years.

2) Investment on Port Facility

Liner shipping companies select terminals to invest in the hope that their ships can have priority when to be handled in the terminals. On one hand, such investment projects are generally assessed by the liner shipping companies in view of increasing complexity of service networks built by them. On the other hand, such investment projects proposed by liner shipping companies help port operators upgrading port facility and terminal infrastructure in order to accommodate high end container ships with higher speeds and bigger capacities. As a result, the competitiveness of service network and corridors get increased. In addition, following this initiative, the port operators get benefits from such cooperation and can respond better to liner shipping companies' requirements.

2.3 Cooperation with Dry Ports

Sea ports discussed in Section 2.2 are traditional ports-of-call of liner carriers. However, as time goes by, liner carriers would like to expand their business revenue by attracting more customers from the hinterland. Therefore, liner carriers need also to cooperate with and/or to invest in dry ports in the hinterland. With the introduction of the dry port concept, one can also regard dry ports as nodes in the hinterlands (Jaržemskis, 2007). Therefore, liner companies also would like to further attract cargo freight volume which transport through these dry ports to obtain the possibility of increasing their revenues. Such idea is sorted out in this section of the thesis. In other words, not only the sea ports are regarded as nodes within the liner service network, the dry ports are also regarded as non-neglectable nodes because liner carriers want to amplify their business in related hinterlands. Li at al. (2011) discuss cooperation and operational issues of dry ports and carriers.

Chapter 3 Horizontal Cooperation in the Liner Business

3.1 Definition

After conferences, the top liner shipping carriers have already established alliances within the shipping industry and are investigating to set up new business linkages together with customers, suppliers, competitors, consultants, and other companies, too. A number of studies have attempted to explain this phenomenon using a variety of conceptual and theoretical frameworks. There are three basic means of obtaining fleet capacity, i.e., new buildings, second-hand purchasing and chartering in vessels. In the first two scenarios, owners are the operators simultaneously. In the third scenario, the owner is different from the operators. It can have significant leeway in adjusting to market demand. If at some point vessels will come out of charter: some might be returned to their owners while others may be replaced or have their contracts renewed at attractive rates. Such kind of cooperation among liner carriers are regarded as horizontal cooperation because these players are homogenous.

Not only a liner shipping company can be regarded as a player in a shipping alliance, but also a liner shipping strategic alliance itself can be viewed as a player when it competes with other alliances. In this chapter, it is assumed that those liner companies are unable to make enforceable contracts through outside parties. The aims of publications lined up in this chapter are summarized as follows:

1) Indicate the motivations of short-term cooperation among several liner carriers;
2) Analyze pros and cons of being members in liner shipping strategic alliances;
3) Explain the behavior of deviation or departure of a player when it faces turbulence and unpredictable shipping circumstances;
4) Advise ways to enhance long-term alliance stability by increasing benefits while decreasing drawbacks.

Among those four main points, the differences between short-term cooperation and long-term alliance are the amounts of sub-games and the potential pay-off in the future. Specific models based on the assumption of non-cooperative behavior are set up and iterated games to give those differences clear explanations. The outcome of this paper will be helpful for the liner shipping carriers attempting to succeed in the shipping industry with greater efficiency, better customer service and lower cost.

3.2 Era of Conferences

The liner carriers need to continuously respond to fluctuations in international trade, phase-out services in sluggish markets and establishing a stronger presence in growth areas. As a consequence, structure reorganization appears. Several major lines/loops have already been reorganized and are receiving larger vessels, improving the productivity. Besides offering a better port coverage, as mentioned in Chapter 2, for shippers, improved regional services need to be launched. In this sense, global liner shipping operators have advantage to achieve a relatively good level of responsiveness.

In an attempt to protect carriers in the conferences from the new steam ships serving trades to India and the Far East, the traditional liner shipping companies established cartels in 1875 to control the important trades between these regions. Under the liner conference system, which has long been an established feature of the shipping industry, a group of ship-owners of one or several nationalities serve a group of ports on a given route. Research on the liner conferences and liner shipping strategic alliances has paid great attention for decades either from the perspective of globalization or from the perspective of impact on the port operations and supply chain partners' cooperation etc. Among liner carriers these 'top 20' are of interest in most references and surveys together with their evaluation and the formation of strategic alliances.

Before the 1990s, the liner carriers cooperated with others by means of conferences. Since the mid-1990s, the development of the liner shipping industry could be briefly divided into three phases shown in Shi and Voß (2007, 2008). Based on the information shown in these papers, some business issues can be derived from such transformation. It is necessary to highlight the capacity of the supply side. Once overcapacity happens, a liner might need to figure out ways to keep its market share as well as providing consistently high-quality services though she might simultaneously need to decrease size of her fleet.

3.3 Era of Strategic Alliances

This Section focuses on liner shipping strategic alliances and their establishment and transformation within the framework of non-cooperative game theory, which is considered as effective tool to analyze motivations, competitive structures, strategies and potential pay-offs in a number of industries including the turbulent liner shipping industry.

An alliance is a close, collaborative relationship between two, or more, firms with the intent of accomplishing mutually compatible goals that would be difficult for each to accomplish alone (Spekman et al., 2000). On one hand, we should note that liner shipping alliances are collaborative relationships among different companies while each member is financially independent. On the other hand, if the expected benefits are not gained, a liner company would no longer choose collaboration as a strategy, which leads to the transformation of alliances.

The motivations leading independent liner companies into alliances are sketched as follows:

1) Globalization: In the liner shipping industry, globalization of trade markets has been the driving force behind alliance formation. The shippers' demand for better routing networks (Fagerholt 2004, Gilman 1999 and Lim 1998) and connections (Notteboom 2004 and Haralambides et al. 2000) can be met by means of alliances.
2) Knowledge Transfer: Alliances expand the scope of knowledge and practices available to the partners and ease access to the related knowledge (Mowery et al. 1996).
3) Competition: Cooperation with another liner carrier can extend supply to meet increasing demand without waiting for newly-built mega container ships, which makes liner companies more agile to the increasing market demand raised by shippers (Brooks 1983, Brooks 1993, Brooks et al. 1993, Brooks 2000, Baird and Lindsay 1996) and decrease the development time (Notteboom 2006) accordingly.
4) Development: Given that many mergers and acquisitions fail to achieve their stated objectives, alliances are a less costly alternative to achieve development (Dodgson 1992).
5) Financial Reasons: The liner shipping industry faces high fixed costs mainly due to the construction costs of mega vessels (Cullinane et al. 1999). When firms cooperate intensively in a number of fields, the high fixed costs would decrease dramatically (Song and Panayides 2002) offering better value and better connections with customers at a competitive price (Yoshida et al. 2001).

Motivated by these reasons, alliances go through a series of stages such as strategy formulation, partner selection, negotiation, implementation and evaluation. Each stage is built on a changing alliance landscape as the vision for the alliance becomes a reality and then grows into a mature business (Spekman et al. 2000).

3.4 Era of Slot Agreements

Besides the liner alliances as one of the means to cooperate in the liner industry, vessel-sharing and slot-chartering agreements are also very common among the liner collaborators even if they are competitors at the same time. In this section, slot-based agreements are discussed, including slot exchange and slot chartering. The co-existing competition and collaboration make the negotiation of slot-chartering agreements quite tough. The liner carriers who are involved in the slot-chartering agreements are regarded as the players and the pay-off of the games should be win-win games rather than zero-sum games. Otherwise, such slot-chartering agreements may not be attractive enough to keep their either short-term or long-term cooperation.

Thus, the main idea of this section is to explain the negotiation stages as well as to design an efficient mechanism to balance the slot requirements and the equilibrium prices under different circumstances. Furthermore, the negotiation and pricing model is to be applied and demonstrated. The output of this section is of interest to decision makers working in the liner shipping companies as well as in some other business domains.

The players of slot-based agreements and other definition can be categorized as follows.

1) Vessel provider: The party providing the vessels and/or space, who may be the registered owner or a disposing owner. Vessel provider is usually applied in the vessel sharing business.
2) Slot owner: The operating liner which provides and maintains vessels (which contain the slots to be chartered) within the terms of the agreement; regardless of whether the vessels are owned or chartered for other parties regarding other contracts.
3) Slot charterer: The liner which purchases and utilizes the agreed number of slots as specified in the agreement. Slot owner and slot charterer are usually applied in the agreements related to slots, i.e., slot-exchanging agreement and slot-chartering agreements.
4) Slot: The space on board a ship occupied by one 20'x8'x8'6 ISO container or the equipment weight of 10 GWT/TEU (Gross Weight Tonnage including tare weight/Twenty Feet Equivalent Unit), whichever is reached first, transported on the routes as defined in the associated agreements. Usually, according to the real world business, a slot is prefixed with the direction that it is supposed to be shipped.

Comparing the definitions of vessel provider and slot owner, in the remainder of this chapter we assume the slot owner to denote the party of an agreement who provides slots, and assume the slot charterer to denote the party of an agreement who charters slots. In a simple way, owner and charterer in this section mean the slot owner and the slot charterer, respectively.

From the perspective of capacity limitation, the slot-chartering problem could be viewed as two persons zero-sum game because the reduced slot allocation of one player after bargaining comprises the added slots that the other player would achieve based on the negotiation. In this sense the decision variables are related to the quantities of slots allocated to each player.

From the perspective of bargaining processes, the slot-chartering problem may also differ depending on whether there is an effective long-term replenishment mechanism. The mechanism design on slot-chartering price together with the respective quantity of the slots is valuable to be observed. In order to design an appropriate mechanism, the following two situations should be considered, respectively: the slot owner has superior bargaining power over the related charterer, and the reverse situation. Furthermore, during the iterated negotiation processes, the higher the position of any given player the more he tends to push down the position of others. Concerning the long-term replenishment contract based on game theoretic analysis, we also refer to Kim and Kwak (2007).

From the perspective of profit sharing which results from a slot-chartering cooperation, which is one form of link games it could be viewed as non-zero-sum game since additional profits might occur when liners provide more options to shippers. To the best of our knowledge, so far no such research has been done in the ocean sea shipping industry. However, similar research considering the hinterland trucks pick-up and delivery tasks had recently been developed by Krajewska and Kopfer (2006) as well as Krajewska et al. (2008).

Briefly speaking, most of the valuable resources of an entity could be regarded as 'slots.' Once the resources are not so sufficient to manufacture production or provide services, the entity might, after harsh negotiations, choose to cooperate with its competitors at certain price by sharing certain quantities of resources. Thus, the backward-deduction and price setting mechanism discussed in these papers (Shi and Voß 2011a, b) might be valuable and useful when applied, in an appropriate way, in other business domains.

3.5 Era of Auctions

Due to the crisis since 2008, most liner carriers are still struggling against economical downturn. However, they are getting ready to rebound by means of tending to get ready to rebound as soon as trade begins to accelerate. This phase of liner shipping business performs more like current airline services. Based on above mentioned discussion, pros and cons of liner shipping service can be briefly summarized. As mentioned, the liner shipping business as main segment of international transportation is derived from international trade. Therefore, it suffers major impacts of the recent global crisis. During the crisis, demand for international transportation services is decreasing rapidly and some liner companies are facing economic difficulties and many even nearly bankruptcy. However, the liner shipping business also enjoys the tiny peak curve during recovery from the crisis. Many top liner companies are reported making profit in 2010. It deserves to be noted that the International Monetary Fund (IMF) mentions that after the crisis, there will be a slow increasing rate of the economy. It takes longer time to get recovered.

Together with the decline of traditional liner conferences, innovative means of cooperation arise, which can be classified along three levels of cooperation: vessel-sharing, slot-exchanging and slot-chartering. Nowadays, apart from the business patterns mentioned in Sections 3.2, 3.3 and 3.4, auctions on slots becomes an uprising phenomenon, just like what happens in the airline industry.

By applying auctions on slots, performances of networks and revenues are expected to be better. One of the performances of liner service network is connectivity. In view of the macro level, performance of networks needs to be evaluated in a manner of connectivity, and most probably evaluated by international organizations. For example, the United Nations of Conference on Trade and Development (UNCTAD) keeps releasing the Liner Shipping Connectivity Index each year.

In the era of auctions, service categories and pricing schemes evolve accordingly. Regarding contemporary liner shipping service, the existing pricing scheme can be categorized into three different types, i.e., capacity-based pricing, time-based pricing, and service-based pricing.

1) Capacity-based pricing means the price of using a slot depends on the capacity constraints given by the liner carriers. An apparent example is the soaring freight rate retained to upcoming peak season, i.e., when supply falls short of demands. Despite the carriers being competitors all the time, they might build up a temporary pricing partnership so that each of these carriers can obtain a freight rate increment simultaneously.
2) Time-based pricing means the price of using a slot depends on the Total Travel Time (TTT) of this specific voyage. When a service ordered by a shipper cannot be performed by one single voyage, one or more transshipments occur. Generally speaking, the more transshipments are involved, the longer TTT can be expected. However, the liner carrier might offer some priority to certain carriages so that even if transshipment is involved, these carriages can still enjoy quite efficient connections, which results in shorter TTT. Obviously, such time-saving service as fast-lane or quick-connection, no matter how to name it, costs more to the shipper.
3) Service-based pricing means the price of using a slot depends on the service quality offered by the carrier. For instance, in case a reefer container is to be carried, the price of providing carriage of such cargo is expected to be relatively high.

Above mentioned pricing scheme is set between the seller of slots and the buyer of the slots. The seller of slots can be owner of a container ship and/or operator of container ships. The buyer of the slots, in most cases, can be a shipper and/or consignee. However, taking into account the cooperation among liners, the buyer of slots can then also be a liner who rents slots, i.e., buys service from her business partner based on designed slot-chartering agreements. As mentioned, in the era of auction, service categories and pricing schemes evolve accordingly. The slot buyers then can auction on the price of slots whenever capacity is constrained or time is limited. Therefore, the output of the service price turns more flexible than that of before.

Chapter 4 Intra-organizational Development

4.1 Technology Aspect

Exceptional and outstanding customer relationships will give a liner a big presence. Extremely rigorous standards and processes need to be established for every area of operations, with special attention to service: shipping documents and arrival notices are expected to be highly accurate and detailed; customer service section responds rapidly to the slightest question or request for information; calls are never transferred; all problems are addressed immediately; and managers are available 24 hours a day, seven days a week. A competitive liner who is able to provide tailor-made transport solutions to its shippers will be regarded by them as preferred carriers as a reward. A strategy of strong geographic expansion, innovation and cost leadership enables a liner to grow sustainably.

From the technological aspect, applying state-of-the-art information systems is a dream of the liner companies. Some timely action plan can be laid out in terms of joint discussion in the past as well as in terms of applying state-of-the-art decision support systems. Avoid harm trust built between VIP shippers and carriers; it is vital for a successful liner to flawlessly organized shipping.

With the gradual promotion of the concept of the Internet of Things (IoT), its related technologies are expected to have impact on the operational processes of any kinds of logistics, and further promote their efficiency and effectiveness. As one of the technologies that enable the implementation of the IoT, Radio Frequency Identification (RFID) is becoming increasingly important and it is used in production, manufacturing as well as supply chain management. Many RFID applications seem to focus on closed-loop scenarios devised to solve particular problems in real business cases where alternative solutions are not feasible (Hu et al. 2011). RFID tools play an important role in supporting assembly lines, medical, logistics, and supply chain management processes. RFID tools can identify, categorize, and manage the flow of goods and information throughout the supply chain. Moreover, RFID brings greater visibility to business processes, e.g., in supermarkets, customs authorities, etc. In an ideal world, it can ensure the necessary data transfer to reach optimal supply chain conditions.

Innovation management and process re-engineering of container terminals may refer to the analysis and redesign of workflows of port operations (Voss and Boese, 2000). Related re-engineering can be used in ports to lower costs and increase quality of service. Information technology may be seen as key enabler for a radical change in ports and terminals. To which extent RFID is an enabler for related change still needs to be investigated (Shi et al. 2011). Transportation companies around the world value RFID technology due to its impact on the business value and efficiency. Since RFID technology is mature, we can use this technology in the access control systems of container terminals. In this way, we may decrease the workload in the gate of the container terminal and improve the efficiency in receiving the containers. Regarding yard management, shipping and freight and distribution centers are some areas where RFID tracking technology is used.

4.2 Ecology Aspect

From the ecological aspect, reducing environmental impact and related consumption is one of the most important areas for environmental action. Therefore, innovative eco-friendly technologies are applied or are about to widely applied soon. Many leading liners have been actively committed to reducing the environmental impact of its vessels for years. By updating the fleet, latest eco-friendly technologies can be applied ranging from design of new ships to operations of existing ships. Ways that have been considered or performed by liner companies are summarized as follows (Shi et al. 2011).

1) Modernizing fleets and slow steaming
2) Preserve marine life through rigorous ballast water management and the use of tin-free antifouling paints
3) Offer eco-friendly shipping solutions, such as eco-containers (with bamboo flooring, light steel containers) and a wider range of intermodal transport options
4) Develop an environmentally responsible corporate culture
5) Enhance skills of seafarers and accelerate the learning curve for seafarers by using navigation simulators is regarded as a reasonable training tool

Together with the convening of the COP15 United Nations Climate Change Conference Copenhagen 2009, the reduction of Greenhouse Gas (GHG) emissions has once again become a popular topic. All countries present at the meeting have discussed on the standard of emissions, but failed to reach an agreement as one might ever have expected.

Although the shipping industry has not been included in the mandatory emission reduction list in the 'Kyoto Protocol,' as the global climate problem turns to be severe, countries in Annex I in the 'Kyoto Protocol' and the EU begin to put pressure on the International Maritime Organization (IMO). As a result, the IMO has put the issue of reducing GHG emissions in the shipping industry on the agenda and committed to introduce a specific standard for emissions reduction by 2011.

Moreover, in March 2009, the State Council of the People's Republic of China has issued a strategic policy on the promotion of transforming Shanghai into an international financial and shipping centre. Under such circumstance, an in-depth study of a carbon emission reduction model is far-reaching not only for the development of the Chinese shipping industry, but also for shipping companies to gain a favorable position in the carbon credits exchange market.

In the publication (Shi et al., 2011) lined up in this section, cost-benefit analysis is applied to get a cost-benefit ratio in GHG emissions trading. It is compared with the cost-benefit ratio resulting from GHG emissions reduction through technical methods in the shipping industry, thus showing the feasibility of GHG emissions trading. An in-depth study is carried out, aiming to enhance the professionalism and technical knowledge of the Chinese shipping industry regarding GHG emissions reduction. In addition, proposals for corresponding actions are raised for shipping companies' reference, so that they will have an advanced position in the GHG emissions exchange market in the near future.

4.3 Infrastructure Aspect

From the network construction aspect, infrastructure as some bottleneck, e.g, the Panama Canal can dramatically affect the liner shipping business. The Panama Canal holds 43% of global shipping traffic.
The East/West axis is the busiest, connecting the large industrial zones of Western Europe, North America, and East Asia. Three main routes run along this critical thoroughfare: the Asia/Europe Seaway; the Transatlantic Seaway liking Europe and the United States; and the Transpacific Seaway connecting Asia to the United States. Moreover, traffic within the Americas is concerned.

In the past, vessels were forced to make their way around the Cape of Good Hope and the Strait of Magallan or Cape Horn, but construction of the Suez and Panama Canals reduced distances significantly, spurring growth along the East/West axis. Completed in 1869, the 200-km Suez Canal has become the route of choice for vessels transiting between Asia and Europe, with over 20,000 vessels passing through it each year. The Panama Canal, which opened in 1914, now handles annual traffic of more than 13,000 vessels traveling primarily between Asia and the US East Coast and between Europe and South America's West Coast as well as within the Americas.

The additional capacity could benefit a number of seaways. For example, large vessels operating between Asia and the US East Coast currently travel around the tip of South Africa; a widened Panama Canal would give them the option of taking a Transpacific route and then passing through the Canal to the Atlantic. Defined than the East/West and North/South axes, intra-regional seaways form a dense web of connections that account for a full 40% of the world's shipping trade. Intra-Asian routes are the busiest, accounting for 77% of the world's intra-regional traffic, as compared with only 14% for intra-European. The reason is simple: Asia is not only the world's leading exporter, but is also one of its leading import zones, with China leading the way. The publication (Shi and Voß 2011c) lined up in this section discusses impact of the Panama Canal Expansion on the liner shipping business, which might bring a new era of mega-container ships.

To summarize content in Chapter 5, the philosophy that liner carriers would like to cope with the slowdown in the world economy, is actually tuning the patterns of their behaviors. The performance of a liner carrier relies on its strengths and competence to survive market dynamics from all aspects of technology, ecology and infrastructure.

Chapter 5 Conclusions and Future Research

5.1 Conclusions

In Chapter 1, background of a real world business was briefly overviewed and a framework of the cumulated publications was depicted. In addition, game theory as a methodology was introduced. Cooperation with sea ports and dry ports was analyzed in Chapter 2. Besides, in Chapter 2 and Chapter 3, vertical cooperation and horizontal cooperation in the liner shipping business was defined, respectively. The historical and contemporary service patterns of the liner shipping service are groomed along time periods. Non-cooperative game theory was applied for analyzing individual behavior or liner companies, etc., in Chapter 3.

In Chapter 4, as technological aspect, RFID technology application to container terminal operations was sketched and its potential benefit of applying the RFID technology was demonstrated, followed by observations on ecological aspect and infrastructure aspect, too. Sustainability and environmental friendly approaches were also discussed in Chapter 4.

In summary, for liner shipping business operators, to survive against market dynamics throughout decades in the past was not an easy task. However, once related business partners are regarded as players of the game, it helps to better understand the contemporary liner shipping business. The liner shipping market keeps showing the players a fantastic dynamics which motivate some newcomers as well as making others evolve.

5.2 Future Research

In the previous chapters, we have addressed issues including service categories, network construction, connectivity, pricing schemes and strategic investment. There are further research areas in this field deserving dedicated observation, e.g., online auctions as further service provided to Shippers.
Such initiative of online auction on the service per slot would in particular facilitate liner companies to interact timely with their customers.

Reliability is also one of performance indices of liner shipping service network, which has not been discussed in this thesis. It is generally accepted that time reliability can have significant influence on route choice behavior. Therefore, from a micro level perspective, further research on performance of networks needs to be evaluated in a manner of reliability, but most probably evaluated by carriers and shippers. However, in viewpoints of the author, accessibility of shipping line networks relies more on port operation and handling systems of the port-of-calls. Furthermore, there are some other indices to evaluate networks as well, e.g., accessibility and stability. Stability of shipping line service relies more on behaviors of alliances' members. In this thesis, we did not cover these two indices, though important, in details.

Domestic services, e.g., inland navigation might also be an interesting further research. In reality, those ships deployed for domestic services and inland waterway service are often those smaller ones or aged ones phased out from international service. Further efforts can be paid to accelerate and implement above outlined ideas, including liner shipping networks reconstruction taking into considerations the dynamic routing derived from online auctions as well as services derived from domestic markets.

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Appendices

Appendix 1. Abbreviations and their explanations

CDM	Clean Development Mechanism
COP15	Copenhagen 15 – United Nations Climate Change Conference 2009
GHG	Greenhouse Gas
GT	Game Theory
GWT	Gross Weight Tonnage
IMF	International Monetary Fund
IMO	International Maritime Organization
IoT	Internet of Things
ISO	International Standards Organization
NE	Nash Equilibrium
RFID	Radio Frequency Identification
TEU	Twenty Feet Equivalent
TTT	Total Travel Time
VIP	Very Important Person

Appendix 2. (LNCS 2011a) Xiaoning Shi and Stefan Voß, *Game Theoretical Aspects in Modelling and Analyzing the Shipping Industry*, in Lecture Notes in Computer Science, Vol. 6971, pp. 302-320, Springer, 2011，ISBN:978-3-642-24263-2

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Appendix 15. (TRB 2011) Xiaoning Shi and Stefan Voß, *The Impact of the Panama Canal Expansion on Liner Fleet Deployment and Operation-A New Agenda*, submitted for the Annual Conference of the Transportation Research Board (TRB), Washington, Jan 2012, working paper under review

Eidesstattliche Versicherung:

Hiermit erkläre ich, Xiaoning Shi, an Eides statt, dass ich die Dissertation mit dem Titel:

"Contemporary Liner Shipping Business – A Game Theoretical Application"

selbständig und ohne fremde Hilfe verfasst habe.

Andere als die von mir angegebenen Quellen und Hilfsmittel habe ich nicht benutzt. Die den herangezogenen Werken wörtlich oder sinngemäß entnommenen Stellen sind als solche gekennzeichnet.

Hamburg, 22 Sep, 2011	Xiaoning Shi
Ort/Datum	Unterschrift

Game Theoretical Aspects in Modeling and Analyzing the Shipping Industry

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Abstract. The shipping industry is known for providing transport service in terms of deploying vessels and accessing ports, making shipping one of the network-based services. From the perspective of traditional as well as neo-economics, shipping is assumed to pursue profit maximization subject to scarce resources, e.g. capital, assets, seafarers, or binding constraints derived from schedules, etc. Players could be any of the following: linkage operators, e.g. liner shipping carriers, port operators, freight forwarders, customs, hinterland haulage carriers, inland navigation carriers, market regulators, etc. Taking into account interdependencies and interrelations, game theory provides a meaningful way to model and analyze behaviors of the involved players. In this paper we provide a survey on game theoretical approaches within the shipping industry.

1 Introduction

Game theory (hereafter GT) is a methodology of decision making involving multiple parties such as persons, companies or agents. For instance, each company must consider what other companies will do. Classical literatures [48,73] together with applications of GT in industrial organizations [21,50,70] usually discuss four classes of games: static as well as dynamic games of complete information and static as well as dynamic games of incomplete information. Corresponding to these four classes of games there are four notions of equilibrium in games: Nash equilibrium (NE), subgame-perfect NE, Bayesian NE, and perfect Bayesian equilibrium. The NE is a solution concept of a game, in which each player is assumed to know the strategies to be taken by the others and no player can be better off by changing his or her own strategy unilaterally. A subgame-perfect NE is a refinement of a NE used in dynamic games if it represents a NE of every subgame of the original game. Bayesian NE is a solution concept of Bayesian games where at least one player is unsure of the type (and so the payoff function) of another player, which might result in some implausible equilibria in dynamic games. To refine the equilibria generated by the Bayesian Nash solution concept or subgame perfection, one can apply the perfect Bayesian equilibrium solution concept. The characteristics of each game can thus be summarized in Table 1.

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Table 1. Brief summary on solution concepts

Solution Concepts	Nash equilibrium	Bayesian Nash Equilibrium	Subgame-perfect Nash equilibrium	Perfect Bayesian equilibrium
Proposed by	John F. Nash	Reinhard Selten	John C. Harsanyi	N/A (see, e.g. [39])
Applications	Static games Pure strategy	Dynamic games Mixed strategy	Static games	Dynamic games Sequential games
Expressions	Normal form Extensive form	Extensive form	Extensive form	Extensive form
Approaches	Fixed point theorem	Backward induction	Bayes's rule	Sequential rationality based on updated beliefs
Information set	Complete	Complete	Incomplete	Imperfect

We start with a game in normal form which is a possible way of describing a game. Unlike extensive form, normal-form representations are not demonstrating a game by a graph or tree, but rather represent the game by way of a matrix or formulations. A game in this form consists of (1) players denoted by $i = 1, 2, ..., n$, (2) strategies or, more generally, a set of strategies indexed by x_i available to player i and (3) payoffs $\pi_i(x_1, x_2, ..., x_n)$ achieved by each player.

A player in a game is a person or a business community making decisions or choosing a strategy from a set of given options. One player's decision affects that of the others. In a static game, players make decisions simultaneously without knowing information of other's decision. In a dynamic game, players make decisions at different moments, i.e., a sequential decision making process happens due to the fact that other's decisions have been disclosed. A strategy in a game is one of the options from which a player may select. Such decision making process may be based on historic experience of himself and/or information disclosed by other players. Traditional applications of GT attempt to find equilibria. In an equilibrium, each player of the game has adopted a strategy that none of the players involved is likely to deviate from.

Payoff means what a player gets after choosing a strategy. Pursuit of payoff maximization, usually, is the utmost goal of a player. In this paper, we emphasize ways of thinking when decision makers face the shipping business. Therefore, the category of games and their applications are from an industrial viewpoint taking into account that shipping is a network based service. Within this framework, a player can be, e.g., a liner shipping operator, or a tramp shipping operator, or a community of liners – an alliance – behaving as a whole in the market. A set of strategies can include whether to cooperate with other competitors or deviate from the current situation, etc. Payoff of a player is the commercial benefit when a player chooses one of his strategies, e.g., the revenue after choosing to cooperate with his competitor. The shipping industry provides transport services among ports by ships at sea. Its service is based mainly on the networks built by carriers, representing the supply side by providing transport services while following regulations and policies. Shippers represent the demand side by booking transport services. Besides freight rates, a shipper can decide to accept one of the carriers' offers taking into account his expectation of other shippers' decisions to avoid congestion, peak season pricing, risk, etc. Carriers similarly attempt to avoid overcapacity, cut-throat competition, lack of diversification, and other negative factors. Therefore, shippers or carriers can be regarded as players in games as they will not take action without considering what their competitors do. In addition, both shippers and carriers must act subject to regulations and policies in the shipping industry. We must also consider the regulator designing regulations and policies with an eye towards how shippers and carriers will react to them. In this sense, a regulator can also be viewed as player, especially in principal-agent relations. The interactions among players in the shipping industry have a considerable impact on each player's strategy set. The relationship between homogeneous players, e.g. different carriers, is horizontal whereas the relationship between heterogeneous players, e.g. shipper and carrier, is vertical.

Mechanism design is one of the branches of GT where protocols are designed for players by regulators. Sometimes also called reverse GT, it studies solution concepts for a class of private information games. More specifically, it is a case of vertical games; we may also categorize it as principal-agent. In addition to the aforementioned players, there is a growing trend for related service providers to integrate. For instance, truck haulage carriers integrate their business with shipping carriers so that door to door service can be achieved. Thus, games such as price auctions and principal-agent incentive games also need to be considered, and these may be classified as either heterogeneous relations or principal-agent games as mentioned before. Therefore, GT can be a helpful tool in the analysis of the shipping industry given features of the industry that the decisions of multiple players affect each players payoff. When observing the literature, the authors find that many meaningful tools are spread over a variety of papers and books, and not so many well groomed surveys exist on systematic application of GT in the shipping industry. Our goal is to provide a survey on how the existing literatures deal with behaviors of either homogeneous or heterogeneous players in the shipping industry. In terms of discussing them step by step, i.e., from horizontal relations to vertical relations, we shed lights to kinds of interactions among the players. The related discussion can be helpful for readers who intend to analyze GT aspects in the shipping industry. Due to the need for short explanations, we focus only on the intuition behind the business patterns discussed in this paper. Our second goal is to provide ample but by no means exhaustive references on specific applications of various GT techniques.

The remainder of this paper is organized as follows. In Section 2, operational business and strategic behaviors are categorized. In Section 3 and Section 4, we introduce and demonstrate in various dimensions how players in the shipping industry interact with each other taking into account both individual and collective rationality. Moreover, in Section 5 we show how market regulators might improve market efficiency by means of game theoretical mechanism design.

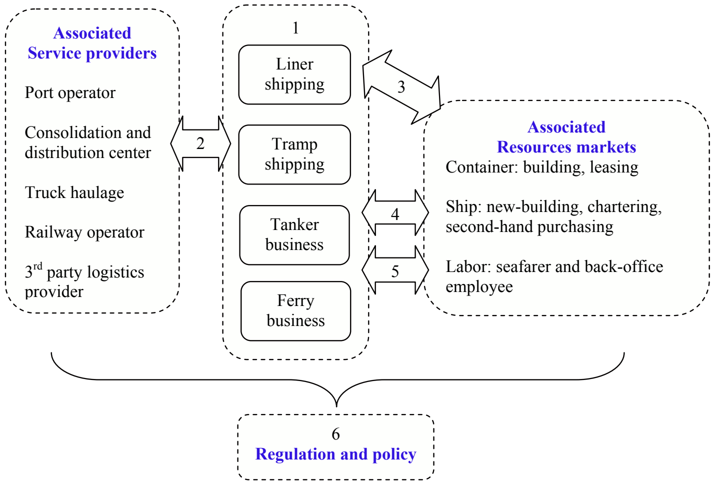

Fig. 1. Structure of the shipping industry and its associated markets

2 Games in Shipping Networks

From an industrial perspective, a transport network is a spatial system of nodes and links over which the movement of cargo and passengers occurs [68], so is a shipping network. A node is a center in a transport network from which cargo and passenger movements emanate. A physical link between two nodes is the transportation way (e.g., waterway, highway, railway, and airway) over some distance between the nodes. From a theoretical perspective (cf. graph theoretical concepts) a network can be represented as a graph, consisting of a number of nodes (vertices) and links (edges). Furthermore, a path is a trail with neither repeated edges nor repeated nodes [23]. However, in shipping practice service providers may also design service routes with repeated linkages as well as repeated ports-of-call within one service. In addition, a decision maker representing a link also considers directions and capacities of other links. The same applies to decision makers representing nodes, which inevitably underlies primary principles of GT. Therefore, instead of just applying the path game, the problems investigated in this research are defined by means of link games and node games within networks (Section 3). In order to better understand this mature and complex industry, we first outline major business issues. Then the informal business description is translated into formal game theoretical problems. Figure 1 shows the varieties of business relations comprising the shipping industry.

The primary shipping industry consists of liner shipping, tramp shipping, the tanker business and the ferry business (Box 1 of Figure 1). Liner shipping is a service following announced and scheduled ports-of-call, regardless of whether it is ocean sea transport or short sea shipping. Tramp shipping is a transport service that does not rely upon repeatedly scheduled ports of call, but rather on pick-up and delivery of cargos according to demands and either voyage charter or time charter-based contracts. The tanker business shares similar characteristics with tramp shipping, the main difference being that the cargo in this case is either crude oil/oil product or bulk. Finally, the ferry business provides service to passengers, which is beyond the scope of this paper taking into account the fact that the behavior of humans is relatively erratic compared to that of cargo. The interested reader could simply replace passengers, to some extent, with cargos and then apply the same GT thinking as discussed below. Within the primary shipping industry, the competition and strategic cooperation among the homogeneous carriers arise as horizontal games. Considering the fact that carriers act as links connecting different ports, the carrier related competition and cooperation can be viewed as one of horizontal relations at the macro level (i.e., a link game in service networks). Therefore, a link game is dealing with the construction of links and reconstruction of paths by means of either consolidating or deconsolidating linkage supply, so that demand could be better satisfied.

As shown on the left side of Figure 1, the service providers component of the shipping service includes port operators, consolidation/distribution centers as well as hinterland service operators such as truck haulage, railway operators and 3rd party logistics providers. The ports and consolidation/distribution centers are nodes contributing to comprehensive service networks [68]. In a figurative sense, a node makes efforts to attract more links by means of amplifying throughput and storage capacity of the node as well as hinterland connections, where this could relate to various aspects including, e.g., available infrastructures to avoid congestion regarding hinterland traffic. Once there are other competitive nodes within the same trading zone or graphical region, the nodes compete with each other in order to sustain as hub [47]. Or the nodes have to cooperate with the existing hub because of their limited capacities [42]. Therefore, the port and consolidation/distribution center related competition and cooperation can also be viewed as a center of horizontal relations among homogeneous players. However, it belongs to the node game. In sum, a node game is aiming to adjust the attractiveness of associated nodes to links in terms of changing the status of the node, so that better accessibility and capacity can be achieved.

Furthermore, links and nodes select each other in order to obtain better performance in tandem than in isolation. On one hand, the links select efficient nodes so that the waiting time and total voyage time could be shortened as well as to avoid potential risks. Sometimes, the links observe existing nodes and choose among them, as in the port selection problem of liner carriers [54]. Sometimes, the links even propose and invest in new nodes when it is worthwhile to do so. On the other hand, nodes select weighted links so that the capacity of the nodes can be better utilized and higher profits can be achieved. In this case vertical relations among heterogeneous players occur [60]. In addition, the accessibility and connections with other service providers are also vital to both the links and nodes from the aspect of strategic sub-network integration at the macro level. Therefore, the problem is presented as a network game.

The right hand side of Figure 1 depicts how associated resource markets support the shipping industry. If containers are built or leased and workers are employed, bargaining and auction games arise, (links 3 and 5 in Figure 1). If ships are to be deployed, schedule optimization and network games are considered (link 4). Finally, regulations and policies (Box 6) direct and control as far as possible behaviors of the associated players who simultaneously account for interdependencies with others (related to mechanism design; see Section 5).

Besides demonstrating how players in shipping interact with each other we also mention how market regulators might improve market efficiency by means of game theoretical mechanism design. Assume there is a shipping carrier (maybe a tramp shipping carrier operating bulk in the past), who attempts to diversify its business in terms of entering the liner shipping market. First, it might face a market entry barrier game when starting the liner business (Section 3.1). The strategy set consists of two options, i.e., to enter or not. The strategy set of existing liners would include two actions: to defend (and if so to which extent) against the new entrant or not. The pay-offs for both the new liner and the existing liners would be reflected in their utility matrices. In case the new liner succeeds in the first game, this new liner might further consider being a member of existing liner strategic alliances. Then it faces the problem of fair allocation of profits (Section 3.2). If it does not have enough capital and fleets to cooperate fully with other liners, it might consider cooperation in terms of slot-chartering which can be modeled as a kind of auction game (Section 3.3). However, as the shipping industry keeps changing continually, the liner adjusts its competitive strategy as well as its long-term cooperation partners by means of learning (Section 4.3) undiscovered information (Section 3.5) in iterated and evolutionary sub-games (Section 3.4). If this liner eventually performs well enough, it might invest in related industries, such as container building and leasing business (Section 3.6) as well as the port operation business (Section 4). In addition, it needs to widen its thinking based on the idea of customer relationship management: How would its customer (shipper) behave given various alternative liner carriers in the shipping network (Section 4.1)? The shipper might maximize its own utility by avoiding congestion on sea routes (Section 4.2). Similarly, the liner itself may achieve cost savings by avoiding congestion at ports (Section 4.2), too. Therefore, it could be better for this liner to investigate the whole shipping network by taking into account network games (Section 4.4). In addition, it needs to follow the relevant regulations and policies as well as motivate its freight forwarders to grasp the market share as much as possible (Section 5). Furthermore, even if it becomes more sophisticated compared to when it first started the business, it might also obtain fast responses on how other players act by building an algorithmic system (Section 6), which can approach an equilibrium, in case of any.

3 Horizontal Relations among Homogeneous Players

We start with an example as a motivation to depict a simple game in a service-based network. Assume, some liner companies are providing nearly identical service to the market, i.e., these services are pre-arranged as well as announced with fixed vessels, fixed schedule, fixed freight rate, fixed sequence of port-of-calls. Each service and port-of-calls are eventually constructing a network, while service routes can be regarded as sets of edges and port-of-calls as nodes. Then, we consider a directed network $G = (V, E)$ with finite sets of nodes $v \in V$ and edges $e \in E$. In this case, the liner carriers are the network owners because the shipping service network is built by them, i.e., $l_1, l_2, ..., l_n$. A liner is denoted as l_i. Then, the entire capacity of a certain edge is $Q = \sum_{i=1}^{n} q_i$ where q_i denotes the capacity of liner l_i along that edge. Given capacity provided by all liner carriers, the price of the shipping service of that edge is $p = p(Q) = a - b \sum_{i=1}^{n} q_i$. In this expression, a and b are positive parameters to be defined in price-supply relation. Furthermore, once a liner carrier is regarded as a player, its strategy set consists of different options of providing certain amounts of capacities. The bigger the supply (Q) the lower is the market price (p), and vice versa. So, a and b can be estimated by a series of values Q and p in different scenarios. The capacity is denoted as q_i. The payoff of this player is $u_i = q_i p(Q) - c_i q_i$ for $i = 1, 2, ..., n (i \neq j)$, where c_i denotes its cost function. From the perspective of this liner carrier, which is assumed to be selfish, the aim of successfully playing the game is to maximize the output based on above mentioned payoff function.

It should be noted that link games together with node games could by no means be separated no matter what niche market of the shipping industry is to be observed. In this section, horizontal competition and cooperation among homogeneous players is considered. We start with the market entry game before deepening the business issues into more sophisticated games.

3.1 Market Entry Barriers Game

Once a liner attempts to enter a certain route, it becomes a competitor of the existing liners operating this route. Therefore, the market entry barriers game may apply. Such games happened when liner shipping conferences functioned before the mid 1980s. Then, the conference deployed a "battle ship," operating on the same route, following the same schedule as the newly entered liner, but at a much lower price. The aim of such a deployment was to build up entry deterrence [19] and prevent new entries by means of grasping shippers providing lower prices. Losses from these lower prices would be commonly allocated among cartel members of the fighting conference. It is doubtful whether the new entry could survive under a situation of low competitive price. However, the protecting company has to predict the rival's cost function compared to its own in order to set up entry barriers as well as to better prepare for the competition [43].

3.2 Fairness and Power Indices

It should be noted that fair cost allocation can be applied to the liner conferences. Fairness does not automatically mean the allocation of costs or profits on an average base. In most cases, there exist leading players and follower players based on their performance powers. In other words, there exist partner asymmetries in the strategic alliances [24]. When all the involved players accept a cost allocation method taking into account power differentiations, it can be viewed as fairness, too. As for the power differentiation among the players we refer to at least five indices [1]: the Shapley-Shubik index [58], the Banzhaf index [3], the Johnston index [30], the Deegan-Packel index [10], and the Public Good index [29]. Furthermore, players within alliances or collusion might consider stability of the organization not only since the formation of the organization but also along the iterated procedure in terms of designing an effective mechanism. For instance, instability of shipping cartels is a standard feature of elementary economic theory [62,63,64]. Generally speaking, the empty core can be applied to explain why previous shipping conferences and current alliances exist, so it works for any industrial cartels alike [78]. In addition, the fairness among the partners needs to be considered as one of the main factors of associated mechanism design.

3.3 Auction Game

Together with the decline of traditional liner conferences, innovative means of cooperation arise, which can be classified along three levels of cooperation: vessel-sharing, slot-exchanging and slot-chartering. These various forms of cooperation are of importance for the liner carriers as well as of interest for researchers. The main difference between vessel-sharing, slot-exchanging and slot-chartering is that vessel-sharing focuses more on network integration [14] and fleet deployment [69], whereas slot-exchanging focuses more on route implementation, and slot-chartering more on price-and-quantity decisions [59]. Concerning the competition and cooperation among the liner carriers, i.e. the link game, much research has been done based on a variety of observations including shippers choice [6], oligopoly market status, overcapacity issues [19] and additional profit allocation approaches as well as fairness based on the Shapley value [56,57] derived from cooperative GT [74,66,41]. For the analysis of liner strategic alliances we also refer to [65,61]. When relations among homogeneous liner carriers are to be discussed in terms of non-cooperative games, there are different perspectives which might lead to various models. From the perspective of capacity limitation, the slot-chartering problem could be viewed as two persons zero-sum game because the reduced slot allocation of one player after bargaining comprises the added slots that the other player would achieve based on the negotiation. In this sense the decision variables are related to the quantities of slots allocated to each player. From the perspective of bargaining processes, the slot-chartering problem may also differ depending on whether there is an effective long-term replenishment mechanism. The mechanism design on slot-chartering price together with the respective quantity of the slots is valuable to be observed. Regarding the replenishment existing in other areas, e.g. in military management, see [40]. In order to design an appropriate mechanism, the following two situations should be considered, respectively: the slot owner has superior bargaining power over the related charterer, and the reverse situation. Furthermore, during the iterated negotiation processes, the higher the position of any given player the more he tends to push down the position of others. For long-term replenishment contracts based on GT analysis see, e.g., [34]. From the perspective of profit sharing resulting from a slot-chartering cooperation, which is one form of link games, it could be viewed as non-zero-sum game since additional profits might occur when liners provide more options to shippers. To the best of our knowledge, so far no such research has been done in the ocean sea shipping industry. For similar research considering the hinterland trucks picking-up and delivery tasks see [37,38].

3.4 Iterated and Evolutionary Games

From the perspective of negotiation processes, iterated sub-games affect the repeated assignment of either capacities or extra profits [61]. One output of iterated games is to emphasize the evolution of ongoing processes. Players either turn out to be more rational, or capture more information and knowledge on the games. In addition, the mechanism of sub-games might turn out to be more truthful, or just the other way around. Those possibilities could be realized only based on iterations of the game. Fundamental knowledge of evolutionary GT can be found in [76]. Whether the iteration is converging is of great importance to all players involved. The iteration during the negotiation process can be interpreted as a sequence of best responses provided by all players. Therefore, contraction mapping maybe applicable to find a solution to the fixed point equation $x = f(x), x \in R_1$ [7]. One can think of a contraction mapping in terms of iterative play: player 1 selects some strategy, based on this player 2 selects a strategy, etc. If the best response mapping is a contraction, the NE obtained as a result of such iterative play is stable but the opposite is not necessarily true, i.e., no matter where the game starts, the final outcome is the same. See [49] for an extensive treatment of stable equilibria. The feature of contraction iteration of a game can be well applied as an explanation on formation of slot-sharing agreements among liner carriers. However, market circumstances are vital for the stability of the agreements. Once the market changes, e.g. freight rates increase sharply, the previous stable equilibria set by a certain agreement turns to be unstable, or the contraction process deviates from its way.

3.5 Asymmetric Information

From the perspective of incomplete and imperfect information among the involved players of shipping agreements, the true cost and individual prediction on the market share are, to great extent, the business confidentialities of each player. Thus the involved players do not have full information about quantity options and consequently each possible quantity of capacity depends on the probabilities that other players perform different actions/behaviors. The unequal status of information derives from the fact that some shipping related companies may pose superior information regarding their own costs and operating procedures. In addition, a shipping related company may know that another company may have better information, and therefore, choose actions that acknowledge this information shortcoming [7]. In some cases, the players simultaneously choose actions or one of the players chooses an action without knowing actions of the other players. Then the game could be viewed as static. If one liner already knows actions of the others before making a decision, the game could be viewed as dynamic. Furthermore, a player would use a mixed strategy when he is indifferent between several pure strategies. When the mixed strategy is mentioned, it means that one player is uncertain about what another player will do. So he gives each action of his strategy a probability to better respond to other players' actions. Related research in supply chain management, however, shows that under certain acceptability assumptions, asymmetric information need not imply decisions which are too far from optimal; see, e.g., [16]. This is valid for the case where asymmetric information and opportunistic behavior is taken into account together with a mediator who supports the negotiation process. This mediator repeatedly generates new candidate contracts, which need to be accepted or rejected by the agents according to particular strategies. Some research based on a GT framework suggests that learning processes might imply a contingence of the equilibrium [51]. Thus, iterated negotiations on price and quantity of the slot-chartering agreements deserve further research. Actually because of asymmetric information, the players are not exact homogeneous anymore. Those players can then be categorized into either leader or follower of a game. After player 1 observes the information on another player and/or his decision, the game turns to be a Stackelberg game. In a Stackelberg duopoly model, player 1, the Stackelberg leader, chooses a strategy first and then player 2, the Stackelberg follower, observes this decision and makes his own strategic choice. Since in many scenarios the ship operator as an upstream firm, e.g. the wholesaler, possesses certain power over the typically freight forwarder as a smaller downstream firm, e.g. the retailer, the Stackelberg equilibrium concept can be applicable in many shipping related business. Besides dynamic games and leader-follower games, asymmetric information may also result in signaling games and Bayesian Games.

3.6 Asset Flows

The assets available for providing transport services, exist in the whole network, but not all of the assets are utilized. In this section, the utilized asset flows are discussed, while the unused ones are discussed in the next paragraph. In some recent research, e.g., [52] assigned involved players right to choose flow rate, energy amount, or bandwidth to reach equilibrium subject to the maximum flow, amounts or width, respectively.

Taking into account the characteristics of the special products related to transport capacity, one might realize that the transport capacity does not always equal the customers' requirements in terms of quantities. Therefore, either overcapacity or lack of service might occur. In both situations, imbalance between the transport capacity and customers' requirements would result in extra 'costs.' In case of overcapacity, the wasted capacity can be interpreted in terms of the well-known newsboy problem, which belongs to classical Operations Research [33]. Transport capacity not occupied when the ship (or truck) starts its trip, i.e., the empty part of the capacity is just like yesterday's newspaper – it usually exists without being of any value any more. This asks for efficient revenue management tools as they are available in the airline industry; see, e.g., [25]. In case of lack of service, the extra costs can be interpreted as opportunity costs. The carrier might regret as it might be more profitable to prepare more capacity to grasp the market share instead of accounting for lost sales because he does not have the capability to fulfill the requirements. Furthermore, the imbalance of trade flows results in an empty container inbound dilemma: empty containers have to be shipped back to export origins so that they can be used for further shipments. Thus, when setting parameters of the network games, empty containers should be labeled as certain load but without profits or even with negative profits, so that more realistic models could be derived.

4 Vertical Relations among Heterogeneous Players

Basically any player of the shipping industry might play either cooperation games or competition games or both, within the designed mechanism and market circumstances including free market, monopoly, duopoly and even oligopoly. In this section, we pay attention to those actors who actually provide different services; i.e., they are rather suppliers or customers to each other than competitors in a certain niche market. In the transportation industry, there are games to be investigated among vertically related players. The players who share the same value chain sometimes team up with each other so that better integrated service can be provided to the final customer. Once the service provider selection is to be involved, see Figure 1, the vertical relations become apparent. Such vertically related players might be liner carriers and port operators, shippers and freight consolidation/distribution centers as well as hinterland haulage carriers, etc. Leader-follower models can be used to simulate the relationship among players, because some players who have either more experience or higher negotiation power distinguish themselves from their peers becoming leaders in games. In contrast, those players who have relatively less experience or know-how may become followers in games. In case of inter-company management, human resources arrangement and the salary bargaining problem [13] can be interpreted as the process of learning labors' potentials, hence a principal-agent model might be of use to motivate the labors in terms of design bonus and penalty mechanism. The ships owned by a carrier, without intracompany cooperation, could also be viewed as inter resources, and apply a principal-agent model, too.

4.1 Route Choice Game

The transportation industry is part of the service industry, i.e., the actual revenue must come from the first order customers who have the requirements to move cargoes or passengers themselves from origins to destinations taking into account the resource constraints together with customer preferences. The efforts of vertically related games, horizontally related games and network games are to smooth the resource constraints and to fulfill customer preferences. In that sense, the customers themselves need to "play the game." They use their common sense on the current service network, collect up-to-date information, and learn how to optimize the utilities in terms of route choice and modal choice, as traditional discrete choice models show [31]. For the freight transport sector, the shipper might choose air transportation as the preferred mode if he needs a faster link to avoid any delay caused by shipping; however, he might also keep in mind the shipping line as an alternative for network reliability reasons. Recently, there has been research considering network users as non-cooperative selfish players who seek to optimize their experienced network latency [28,17].

4.2 Congestion Game

For the competition among regional ports, zoning techniques can be used to supplement non-cooperative games. The congestion game and the Price of Anarchy are also suitable ways to build pricing policies of associated ports within zones. The congestion game is a game where a player's payoff only depends on its strategy as well as the number of other players choosing the same strategy [46]. On the other hand, shippers are typically viewed as players in a congestion game, and they are assumed to be non-cooperative and to choose routes selfishly. Shippers of a certain zone first choose origins and destinations for their shipments, and then select several carriers as options for fulfilling the shippers requirement. Considering the number of shippers, this game could be regarded as an atomic game with a large number of players. Shippers may have the intention to avoid overloaded links, while carriers have the intention to avoid congested nodes. Shippers might consider the reliability and stability of networks by having more links as options in case that overpayment occurs. So far there is no detailed research on this in the shipping industry. However, similar ideas have been observed in telecommunications including wireless networks (see, e.g., [12]).

Considering appropriate customer relationship management, as network providers, certain carriers give different weights especially to very important shippers so that they have priority to access the required links. This could also be reflected in the graph of the shipping networks.

4.3 Learning Processes

We do not claim that there is no learning process in horizontal relations and principal-agent relations; see [9] on how partners in alliances turn to trust each other and/or control the cooperation based on expectations. Rather we include the learning process here mainly because vertical relations are based on heterogeneous players, and it might be harder to learn and control the expected cooperation among heterogeneous players. For instance, service providers forecast the customers' requirements and never know exactly what customers choose. Therefore, the learning mechanism involved due to business experience, information sharing and exchanging could not reach pure transparency in shipping business reality. Obviously, a liner may learn the performance of a port operator so that he can choose whether to visit. Concerning information sharing among players

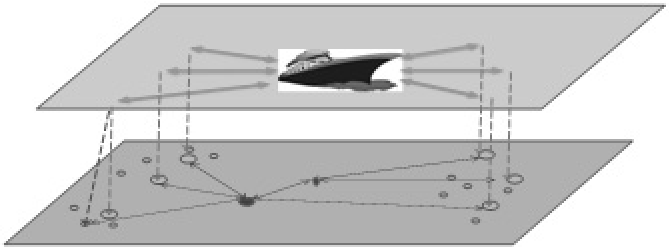

Fig. 2. Two layers of the shipping service network

in shipping, it is not surprising that information is asymmetric. For instance, the owner of the slots gets better access to the information of the costs of slots while the charterer gets less relevant information. The effective transparency of the information sharing among owners and charterers might improve the efficiency of the whole agreements. However, with regard to the published vessel-sharing, slot-exchanging and slot-chartering agreements (see, e.g., [15]), the amount and price of the slots are by no means transparent since they are regarded and protected as business confidentiality. Generally speaking, the liner shipping service cooperation among heterogeneous players can be regarded as stochastic resource allocation problems, usually characterized by "curses of dimensionality."

4.4 Network Dynamics

The node transit capacity and the link weight could change over time, resulting in network dynamics. Shippers own links in a network and sell transport service; at the same time shippers aim to minimize the prices they pay with respect to linkages between origins and destinations taking into account network dynamics. Once the capacity is interpreted as bandwidth of edges, some research done in the telecommunications industry [8] can also be applied to the shipping industry.

The shipping service network is quite dynamic. From the shippers' standpoint, they are atomic, selfish, and non-cooperative, though sometimes shipment consolidations occur. From the standpoint of carriers, they are monopolistic, almost rational, attempt to have more coalitions, which recently resulted in liner shipping strategic alliances and continuously change the capacities of different links. From the standpoint of port operators, they are aggressive, struggling for leadership within nearby zones, which push them towards increasing handling speeds and attract more links to connect them. Furthermore, in case hinterland distribution is included, the schedules of either carriers or shippers turn out to be more or less unreliable [72]. All the above mentioned intentions cause dynamics in the shipping network. The shipping network distinguishes two main layers: the links layer and the nodes layer, as shown in Figure 2. Competition and cooperation games among the liners can be described in the links layer as input and a collection of liners' actions are represented as port-of-call and shipment load of each link. This collection of liners' actions is actually the input of the nodes layer. In addition, given extra investments and encouraging policies, some ports may have extension opportunities. Then, in the base layer of Figure 2, the leader-follower situation of the zones in which promising ports are located, might change. There is valuable research from the perspective of network users. [4] studies reliability of a transport network by constructing a non-cooperative game with two players including a network user and a network provider. The author not only considers link failure of a network, but also the scenario that a connected network fails to provide an adequate level of service. The latter aspect is often faced by ocean sea network service providers, especially when the market is booming and there is not enough capacity available immediately. [5] study the route-choice behavior performed by risk-averse network users by formulating a non-cooperative game. These network users can be transformed to shippers as they can be regarded as ocean sea network users. Such kind of risk-averse users tend to take into account the route costs and their consequent uncertainty on the cost when making decisions on route choice.

5 Mechanism Design

In this section, we start to observe what an industry regulator should do to be better off compared to anarchy. Mechanism design is one of the branches of GT, where protocols are designed for players by regulators. Generally speaking, mechanism design can be viewed as the 'inverse problem' of games, where the input is a game's outcome and the output is a designed game guaranteeing the desired outcome [44]. Regulators in the shipping industry observe the market turbulence and involved players' behaviors from a GT perspective, and later figure out better mechanisms to regulate and motivate shippers, carriers, port operators, etc. Similar ideas have recently been implemented as road pricing policies from the viewpoint of a regulator; see, e.g., [75,77,71].

Ships in our settings usually cause emissions. In this respect a market regulator, e.g. the transport commission of the European Union, regulates the member states in terms of emission quota allocation [20,22]. Once we realize values of cost, profit, emission, slot, and the load share of networks of the same nature, the emission quota allocation problem is actually similar to the cost sharing problem. Regarding profits and the resources sharing problem we refer to [53], where a similar idea could be applied in emission quota allocation, too.

The vital problem of a Principal-Agent incentive game is how the principal could motivate agents to perform as effectively as possible [2] by taking advantage of more information about the agents actual efficiencies. In the shipping industry, a shipping carrier as principal has more information about its own total costs to control the marketing but less information on how effective its related forwarder agents could be. The carrier authorizes forwarder agents to grasp freights on behalf of the principal. As a dominant principal, the carrier can design mechanisms in such manners, e.g., setting bonus of good performance in monetary terms, setting penalty of laziness or ineffectiveness to either motivate or control its agents. Thus, the key points are price setting, contract design based on interdependent players, etc., where the Stackelberg model [55] and a worst-case NE together with the Price of Optimum [32] are vital.

Another application of mechanism design is to harmonize partnerships between public and private sectors of transport projects. One may refer to [45].

6 Algorithmic Game

Algorithmic GT is a promising subfield and experimental method to figure out or simulate the players' behaviors, and later the optimized collective outcome. A NE can be interpreted as the best response of each player so that no other improvement can be better off. While attractive, numerous criticisms of the NE exist. Two particularly vexing problems are the non-existence of an equilibrium and the multiplicity of equilibria. Therefore, what is the complexity for computing and searching the NE? This is a relatively new subfield which captured research interest over the last couple of years. For the computation of network complexity, we refer to [44] as well as, e.g., contributions in [36]. Multi-agent based simulation for the evaluation of container terminal management operations is considered in studies summarized in [27]. The approach aims at planning and coordinating the processes within the terminal by mapping the terminal's objects and resources. The agents strive to complete their specified goal by searching, coordinating, communicating, and negotiating with other agents by means of a market based mechanism such as a series of auctions; see also [67]. In [26], experiments applying multi-agent systems for investigating the impact of different policies for sequencing, berthing, and stacking on the performance of container terminals are proposed. Numerical experiments based upon real data are conducted to evaluate eight transshipment policies. Shorter vessel turnaround times can be achieved with good decisions on yard stacking (e.g., using the stacking-by-destination policy) and berth allocation. [18] propose an integrative cost estimation concept and a multi-agent system approach for managing container terminals. The holistic objective is the minimization of the average terminal-effected costs of container handling. The paper presents different market mechanisms for resource allocation by coordinating the market with bilateral polypolies. Techniques proposed for the container barge handling in the port of Rotterdam by [35,11] may be seen in the spirit of GT approaches, too.

7 Summary and Conclusion

In this paper, we discussed from various perspectives how to observe the shipping industry by means of game theoretical applications. We categorized the link game, the node game and the network game. In addition, we integrated shipping carriers, port as well as consolidation/distribution operators in terms of interdependent network games. Concerning the nature of the shipping industry, horizontal relations among homogeneous players and vertical relations among heterogeneous players were discussed, too. From the supply perspective, once existing carriers make decisions based on cooperative games, overcapacity would not happen so often or severe. In that respect, ideas discussed in this paper propose food for thought for developing liner shipping service in a sustainable manner.

We may further observe transport carriers of other modes than shipping, together with more consolidation/distribution options within associated hinterland instead of only ports at sea. The discussion of this paper can be extended to other means of transport as long as they share the same natures of networks. To conclude, game theoretical concepts can help better understand the liner shipping industry and equally support them in decision making.

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Application of RFID Technology at the Entrance Gate of Container Terminals

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Abstract. Radio Frequency Identification refers to using transponders or tags affiliated with an object for the purpose of identification and tracking by means of radio waves. This paper focuses on container port operations, emphasizing on the current status of these operations and its business bottlenecks. Based on that, we discuss related solutions for improving efficiency from the perspective of orderly balance and seamless connection in different operational processes at the entrance gate of container terminals.

1 Introduction

With the gradual promotion of the concept of the Internet of Things (IoT), its related technologies are expected to have impact on the operational processes of any kinds of logistics, and further promote their efficiency and effectiveness. As one of the technologies that enable the implementation of the IoT, *Radio Frequency Identification* (RFID) is becoming increasingly important and it is used in production, manufacturing as well as supply chain management.

Many RFID applications seem to focus on closed-loop scenarios devised to solve particular problems in real business cases where alternative solutions are not feasible [10]. RFID tools play an important role in supporting assembly lines, medical, logistics, and supply chain management processes. RFID tools can identify, categorize, and manage the flow of goods and information throughout the supply chain. Moreover, RFID brings greater visibility to business processes, e.g., in supermarkets, customs authorities, etc. In an ideal world, it can ensure the necessary data transfer to reach optimal supply chain conditions.

Innovation management and process re-engineering of container terminals may refer to the analysis and redesign of workflows of port operations [18]. Related re-engineering can be used in ports to lower costs and increase quality of service. Information technology may be seen as key enabler for a radical change in ports and terminals. To which extent RFID is an enabler for related change still needs to be investigated. Transportation companies around the world value

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RFID technology due to its impact on the business value and efficiency. Since RFID technology is mature, we can use this technology in the access control systems of container terminals. In this way, we may decrease the workload in the gate of the container terminal and improve the efficiency in receiving the containers. Regarding yard management, shipping and freight and distribution centers are some areas where RFID tracking technology is used.

We first sketch the functioning of container terminal operations in Section 2. In Section 3, the working principles of RFID are introduced. In Section 4 we discuss options to re-engineer selected port operations, together with a discussion on the application of RFID in the container entrance gate for road trucks. The latter section is moderately interleaved with a related literature review. Based on a small case, in Section 5, we reach conclusions on potential benefit of applying the RFID technology as well as summarize some relevant further research topics.

2 Container Terminal Operations

Operation processes at a container terminal can be divided into import and export operation processes. In this paper we focus on the export processes and business bottlenecks. Seaport container terminals may be seen as open systems of material flow with a large variation in size, function, and layout. Basically, they are very similar in structure and related same sub-systems (see Figure 1). The waterside (ship operation or berthing area) is equipped with quay cranes for loading and unloading of vessels. Import and export containers are stocked in a yard which usually is divided into a number of blocks. Special stacking areas may be reserved, e.g., for reefer containers, which need electrical supply for cooling, or for storing hazardous goods. Separate areas may also be used for empty containers. Some terminals employ sheds for stuffing and stripping containers or for additional logistics services. The truck and train operation area links the terminal to the hinterland and outside transportation systems.

The chain of operations for export containers can be described as follows (see Figure 2 and [15]). After arrival at the terminal by truck or train, the container is identified and registered with its major data (e.g., content, destination, outbound vessel, shipping line), picked up by internal transportation equipment, and distributed to one of the storage blocks in the yard. The respective storage location is given by row, bay, and tier within the block and is assigned in real time upon arrival of the container at the terminal. To store a container at the yard block, specific cranes or lifting vehicles are used (e.g., rail mounted gantry cranes RMG). Finally, after the arrival of the designated vessel, the container is transported from the yard block to the berth where quay cranes load the containers onto the vessel at a pre-defined stacking positions. The operations to handle an import container are performed in the reverse order. Scheduling the huge number of concurrent operations with all the different types of transportation and handling equipment involves extremely complex planning problems. Following the discussion in the extensive surveys of [16,14], in view of the ever-changing terminal conditions and the limited predictability of future events and their timing, they often must be solved in an online fashion or even in real time.

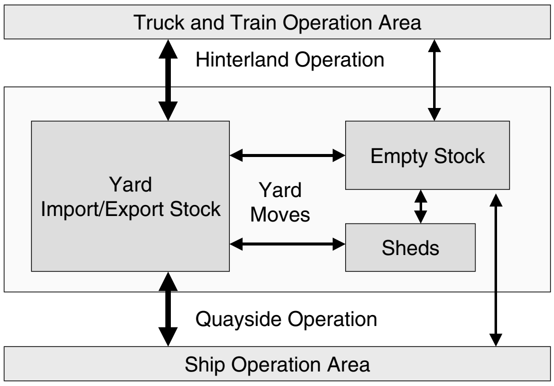

Fig. 1. Operation areas of a seaport container terminal and flow of transports [16, p. 6]

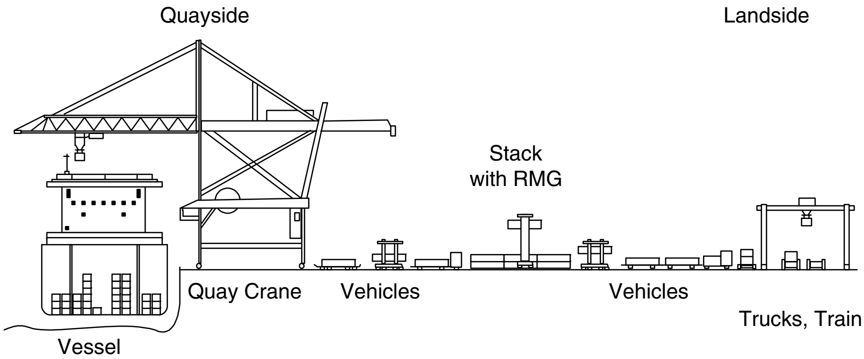

Fig. 2. Transporting and handling procedures of a container [16, p. 13]

Consider a specific example of the container transport chain. When it comes to exporting of containers, the operation processes are as follows.

1. The shipper first consolidates his cargoes in containers.
2. After the commission of the shipper or its freight forwarder, the trucking firm will transport the containers to the yard of the container terminal.
3. Before going into the container yard, the truck has to first check-in at the container entrance gate. During this process, the gate house workers will check the EIR (Equipment Interchange Receipt) and related information of this container, such as the container size, its reference number, etc.
4. After the container has been checked, it will be unloaded, e.g., with a gantry crane, and placed on the yard.
5. When a vessel comes, the port uses related equipment to discharge and load the containers to the vessel.

The procedure of importing the containers is similar to that of exporting containers. When it comes to the transshipment of the containers, the operation processes are shown as follows (including domestic as well as international transshipment containers). When the terminal unloads the transshipment containers, it needs the manifest of the transshipment container or the related EDI information, and the transshipment containers should be transported to a specified transshipment zone. Exporting transshipment containers need the notice certified by the customer. Then the terminal can load the transshipment containers.

Export containers are usually delivered to the ports two or three days before the arrival of related vessels. But at that time the export manifests collected by the shipping agency need not be complete. Still at many ports worldwide only by manually completing data can the terminal collect the containers as there are incomplete (or non-correct) export lists. As there is only one piece of export manifest for one vessel, the terminal gates might even record the information of the containers manually only by referring to the documents, i.e., EIR and packing lists, and after this the containers can pass the entrance gates. It is obvious that this kind of process not only wastes time, but also increases the possibility of including errors [19]. Suppose we record the data completely when containers pass the gates, this will be at the expense of at least 30 to 60 extra seconds. If a vessel carries 2000 containers on average, then this procedure might take 10 to 20 hours to complete the process of moving the containers to the yards or container freight stations, possibly leading to a lower access rate of the gates in the terminal. To improve the recognition accuracy, a container number recognition system needs to identify the reference number at least twice. Finally, the results are based on the integrated complementary information of the container surfaces. Since containers are transferred around the world, the identification number of the containers might be damaged or even disappear. This issue also limits the development of efficient operations of the container terminal.

3 Technical Aspects of RFID Systems

RFID belongs to Automatic Identification (Auto-ID) technologies. This family of technologies includes the famous bar code system, optical character readers and some biometric technologies (like retinal scans). Auto-ID technologies have proved to reduce time and working resources needed and to increase data accuracy. Despite their practical value, the fact that a person is needed to manually scan items is itself a constraint. It is exactly this part where RFID revolutionizes Auto-ID technologies as mentioned in [17]. An RFID system consists of three parts: a scanning antenna, a transceiver with a decoder to interpret the data, and a transponder, the RFID tag, which has been programmed with information. A typical RFID tag consists of a microchip attached to a radio antenna mounted on a substrate. The chip can store as much as 2 kilobytes of data [17] and beyond. For example, information about a product or shipment-date of manufacture, destination and sell-by data can be stored in a tag. Tags can be passive, active or semi-active. An active tag contains some types of power source

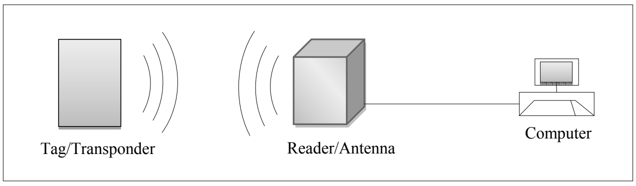

Fig. 3. Working principles of RFID

on the tag, whereas the passive tags rely on the radio signal sent by the reader for power. Semi-active tags use a battery to run the microchip's circuitry but not to communicate with the reader. The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and radio frequency used. The data is interchanged with the monitoring computer for processing after the reader decodes the data encoded in the tag's integrated processing. The working process is shown in Figure 3.

Regarding fundamentals and applications of RFID, Finkenzeller [3] is of value as an introductory reference. Next we review RFID literature with a specific focus on container terminals and logistics and provide a specific application scenario.

4 Application of RFID to Improve the Container Terminal Operation

The intelligent management of container terminals mainly consists of the passive RFID tag with an UHF band between 860-960MHZ, an RFID reader, the communication system, a common data management system and the car software (onboard unit). The passive RFID tag can contain the container information, the cargo information and the information of the logistic chain. The passive RFID tags are attached to the lintel of the container. The container gate house or entrance gate as well as all handling equipment components (e.g., reach stacker, straddle carrier, quay cranes, RMG) are all attached with RFID readers [24]. When a container which is fixed with the passive RFID tags passes any handling or yard equipment, all the information of the container may be checked by the RFID readers in this equipment. The information can be used in the modern management of the container terminal.

There are quite a few more or less conceptual papers on the analysis of RFID technology implementation in container terminals; see, e.g., [1,2,9,13,21,26]. Harder and Voß [6] provide basis and applicable understanding of cost-benefit analysis on RFID application to the shipping industry. RFID usage may envisage several benefits including better "information visibility" allowing for improved tracking and tracing options etc. Another example is better container port security. If sensors are installed inside containers to monitor changes in light, humidity or pressure, indication could be given that someone had interfered with it. A successful test on this issue for Yantian International Container Terminals is mentioned in [22].

Some researchers also observe ways to implementing automatic handling systems in China's container yards (see, e.g., [23]). In addition, [11] describe the research and development of an RFID prototype system that integrates with mobile commerce (m-commerce) in a container depot to enhance its daily operations and support its location management. Wang et al. [20] introduce the application of RFID to Shanghai Port as a case study together with the analysis of future trends of such application to container related transportation.

From the perspective of logistics services, in most cases challenges come from demand sides [7]. Above mentioned technology can be applied not only on cargo transportation but also health care logistics. For example, [27] did a comprehensive observation on framework and evaluation of health care related processes with RFID technology implementation. An example where RFID has successfully been applied to a real-world case in postal logistics is found, e.g., in [12]. The paper deals with the re-engineering and design optimization of a warehouse for package storage operations occurring for a courier express company in Italy. The study considers the use of RFID tags to facilitate identifying items in a package delivery service facility.

4.1 A Specific Application Scenario

The main business of container terminal enterprises is divided into domestic and foreign container trade by providing ships with loading and unloading operations. Other than that, programs are available related to scheduling, billing, clearance after checking, etc. The operation is more complex for exporting containers compared with importing containers, since we must rely on the reliabilities of the information of the containers to load the container on board exactly, including the name of the vessel, the voyage, and the reference numbers of the bill of lading, etc. However, that information is mainly collected by the workers who are assigned to posts for specific container gates. If someone wants to transport an export container to a terminal, the terminal needs to check the paper document with the manual data of the actual container. Only if they match, the terminal can accept the container for further operations. Obviously this kind process dramatically increased the workload of the workers who receive containers, reduced the speed of the traffic flow and prolonged the stopping time of the trucks. Moreover, when several vessels arrive at the same time, the chance of error will be larger.

Currently, when the container is transported through the container gate house it needs to manually check the container size, the container number, the seals, etc. State-of-the-art identification technology in many terminals is a kind of practical method based on OCR (Optical Character Recognition) technology. But as time goes by, the number sticking on containers may become fuzzy, so it becomes not so tangible for the gate house workers to identify containers. The antenna of the RFID on the container gate house is shown in Figure 4. The working principles of the RFID reader of the container gate house are sketched in Figure 5. Related reading regarding the processes at entry gates is provided in [15,4].

Fig. 4. Antenna located at the gate of a container terminal

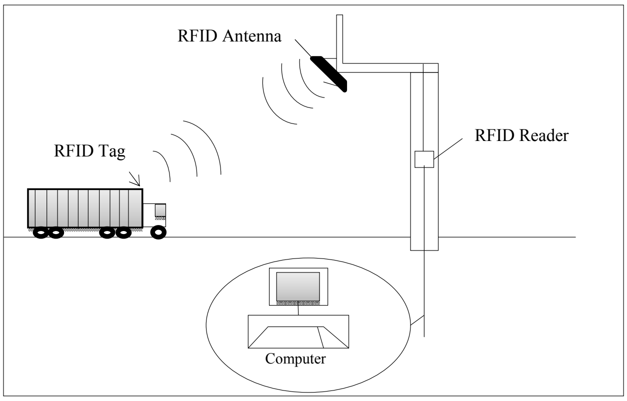

Fig. 5. Working principles of RFID readers

When the container fixed with passive RFID tags goes through the entrance gate, the loadmeter senses there are containers passing. At the same time the loadmeter sends signals to the RFID reader, after that the RFID reader begins to work. It reads the related information of the container recording by the passive RFID tags through locating the RFID tags on the container, thus it can automatically identify the container number. The Container Terminal Management System records the information automatically by the RFID reader. After the information is checked by the information center of the container terminal, the container is allowed to leave the port, at the same time the information center sends the time that the container took in the entrance gate and related information to the Common Data Management Platform. This process needs no human intervention. To compare the efficiency of the entrance gate before

Table 1. Average time (in seconds) taken at the entrance gate

Type	Brake	Check	Start	Total
Without the use of RFID	4	60	6	70
With the use of RFID	4	12	6	22

using the RFID system with the one after using the RFID system, we take the entrance gate of the Shanghai Waigaoqiao Terminal as example with the time as the main index to determine whether the RFID system is efficient. Preliminary investigation of the related gates shows the data provided in Table 1.

4.2 Truck Handling at the Terminal Entrance – Conceptual Aspects

New technology is creating opportunities for an entirely new wave of re-engineering efforts. In [5], re-engineering as a role model was implemented in the back office, the factory, and the warehouse. Later on, it has been applied to the front office and the revenue-producing side of the business: product development, sales, and marketing. In case a port operator is regarded as an enterprise and the port operation process is viewed as workflow within enterprises, re-engineering would most probably have to occur as long as either new demand is increasing or new information technology is about to be applied. From its inception, re-engineering has been a close partner of information technology. Technology enables the processes that are the essence of re-engineering to be redesigned.

The container gate house service system is a typical queuing system, the major processes are trucks passing through the gate. The object in this system is a container truck; According to a large number of internal and external statistical data, most of the container gate house service processes can be considered as a M/Ek/S model [25]. The arrival process of trucks follows a Poisson distribution

$$P_n = P(n) = \frac{\lambda^n}{n!} e^{-\lambda} , \quad n = 1, 2, 3, ... \tag{1}$$

with n being the number of daily arriving trucks, λ the daily average number of arriving trucks, and $P(n)$ denoting the probability of n trucks arriving in a day. After arrival, the passing time of the trucks follows a k-Erlang distribution

$$f_k(t) = \frac{\mu k (\mu k t)^{k-1}}{(k-1)!} e^{-\mu k t} , \quad t > 0 \tag{2}$$

with μ being the number of trucks served in a single gate every day.

In the container gate house service system, service station number is the number of gates owned by the port, we designate it by S. Set the strength factor of system loading according to the M/Ek/S queuing model:

$$P_0 = \left\{ \sum_{n=0}^{s-1} \frac{1}{n!} (\frac{\lambda}{\mu})^n + \frac{1}{S!} \frac{1}{1-\rho} (\frac{\lambda}{\mu})^S \right\}^{-1} \tag{3}$$

$$P_n = P(n) = \begin{cases} \frac{1}{n!}(\frac{\lambda}{\mu})^n P_0, & (n < S) \\ \frac{1}{S!S^{n-s}}(\frac{\lambda}{\mu})^n P_0 & (n \geq S) \end{cases} \tag{4}$$

where P_0 is the probability of no trucks arriving in a day, namely the probability that every gate of the port is idle.

The main performance indicators in a port services system include:

1. The average number of trucks waiting in the container gate house:

$$L_q = \sum_{n=S+1}^{\infty} (n - S)P_n = \frac{(S \times \rho)^S \times \rho}{S!(1-\rho)^2} P_0 \tag{5}$$

2. The average number of arriving container trucks:

$$L_S = \sum_{n=0}^{\infty} nP_n = L_q + S \times \rho \tag{6}$$

3. The average residence time of trucks: $W_S = L_S/\lambda$
4. The average waiting time of the trucks: $W_q = L_q/\lambda$

In the following we consider Daxie Terminal, Ningbo (China), as an example. Table 2 provides details on a sample of 20 trucks between 2:30 and 3:30 PM, May 11th 2011 to calculate related performance indicators. Each truck is transporting one container passing through the gate without RFID technology. Moreover, on May 11th the total number of container trucks entering the port was 1904 TEU. Daxie in Ningbo has eight gates in total, among which five are entrance gates and three are for exits, i.e., $S = 5$. We may denote by t_w the waiting time for each truck when it tends to enter into the terminal. t_p is the processing time for manually processing the EIR documents as there is no RFID. $t_s = t_w + t_p$.

Based on these numbers we may perform the following calculations. Based on 1904 TEU we have $\lambda = 79.33/h$, $\rho = 0.2314$, $P_0 = 0.17$. Moreover, $L_q = 0.0002$, $L_S = 1.157$, $W_S = 226.83s$, and $W_q = 0.04s$.

From these calculations, we can see that the average waiting time W_q is nearly 0, reflecting that the container gates are enough for the Daxie container ports. $W_S = 226.83s$ indicates that the average service time of one truck is less than four minutes. On one hand, if we use RFID technology in the container gates, then the passing time t_p will be decreased, thus the average waiting time can decrease. On the other hand, if the time of the trucks passing through the container gate house decreased, then the container terminal can decrease the number of the gates. For the present data we may conclude the phenomenon of queueing is not frequent. But when building a new container terminal, if the port authorities consider using RFID technology to design the container gate house, one might build a smaller number of gates.

Table 2. Time of container trucks passing through the gate

Container No.	t_w/second	t_p/second	t_s/second
YMLU4956169	90	40	130
INKU6102043	89	152	241
SPNU2879389	78	72	150
YMLU5035019	124	46	170
DFSH6277779	144	57	201
CCLU9233314	87	67	154
YMLU8171209	123	69	192
HJCU4140364	131	71	202
GLDU7464425	56	68	124
CBHU8312882	88	63	151
GCSU6008340	87	49	136
BMOU4783317	75	110	185
GLDU0879225	54	56	110
KMTU7326329	94	68	162
UACU3371086	102	258	360
OOLU8858380	121	75	196
TGHU9799940	197	87	284
GLDU7213760	262	79	341
HUCU1072820	184	92	276
HJCU3205776	88	68	156
average passing time $E(t)$	113.7	82.35	196.05
Variance $D(t)$	2602.43	2308.13	4955.84

5 Conclusions and Further Research

In this paper, we discussed the current status of container port operations as well as the application of RFID in the container gate house and the container yard. For the discussion of the application of RFID in the entrance gate, we can conclude that by using an RFID system we can decrease the passing time of the container trucks. More specifically, from the discussion of Section 4, we can conclude that if we use the RFID technology in the container gate house, then we can improve the efficiency of the turnover of the container trucks, thus decrease the waiting of the trucks and also decrease the parking area of the container trucks. In this sense, we can expand the area of the storage yard.

Due to the limited real world data that has been obtained, the potential re-engineering within the container yard has not been discussed in this paper. However, that would be one of research topics of our interest in the near future. Besides, in the application of RFID in the container yard we have not considered other conveyance when transporting containers from the yard to the terminal apron. This could be another topic for further research. As real business cases on RFID in the shipping industry are still quite rare, related field studies would be of great benefit. This might help to close the credibility gap regarding RFID mentioned in [8].

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General and Modified Slot Chartering Agreements—Performance Comparison Based on Different Mechanisms

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Abstract:

Consignment is a form of business arrangement where a supplier retains ownership of the goods stocked and pays a retailer based on the actual amount that the retailer sells. Similar ideas can be applied to the liner shipping business. A slot-chartering agreement can be designed in such a way that the slot-owner retains ownership of the used slot stocked and collects payment from the slot-charterer based on the actual units sold. The consignment concerns questions on how decision making regarding the inventory stocking level (i.e., who book idle slots) is performed and who is going to take those decisions. Such form of agreement has become popular in the liner shipping business, especially during the Post-Crisis Era, when it became apparent that nobody can forecast market dynamics exactly. With consignment, how or who to make decisions on the selling price of the used slot as well as the payment transfer between the slot-charterer and the slot-owner can have significant impact on the overall performance as well as individual liner carrier's commercial performance. In this paper, we study a specific consignment arrangement, called slot-chartering agreement, based on what the leading slot-owner has recently launched for managing its business relationship with many of its slot- charterers. Under the slot-chartering agreement, a slot-owner charges a slot-charterer a pre-specified percentage of the 'list price' of loaded slots sold to the market by the slot-charterer, where the slot-owner is allowed to choose the list price for its loaded slot while the slot-charterer in return decides the final retail/selling price and order quantity for the used slot.

According to the slot-chartering agreement, there are two kinds of contracts to be analyzed in this paper, namely, a general slot-chartering contract and a modified slot-chartering contract. We build a game-theoretic model to demonstrate that managed under such a general slot-chartering contract, the overall performance incurs a minimum loss in efficiency or profitability, compared with a centralized overall, and depending on cost parameters and the nature of demand uncertainty, the actual loss can be significantly higher than the minimum value. Second, we show that the slot-chartering agreement leads to a 50-50 split of the realized overall profit between the slot-charterer and the slot-owner, and in equilibrium the combined choice of the percentage charged by the slot-charterer and the list price itself by the slot-owner is largely a non-influential factor both to the overall performance and to individual firm's performance, i.e., the 50-50 split of overall profit. We then propose a simple modification to the above mentioned general slot-chartering agreement, where the only change is for the slot-charterer to delegate the decision on stocking quantity to the slot-owner. We show that such a modified slot-chartering agreement guarantees a loss in efficiency of just or no more that a minimum value for the overall, while keeping the 50-50 split of overall profit unchanged. As a consequence, the modification program on the slot-chartering business, if implemented, has the potential to create a guaranteed win-win environment for the slot-charterer and its slot-owners in the liner shipping industry.

Keywords: Slot, Slot agreement, Liner Shipping, Mechanism Design

Section 1 Introduction

Service retailing in liner shipping business has created an unprecedented market place for the slot-owner (supplier of slots) and slot-charterer (buyer of slots and competitor of the slot-owner simultaneously) to cooperate on distributing as well as offering their slots as service to final consumers, i.e., shippers in the liner shipping market. These business structures have entailed the continued creation of innovative forms of contracting arrangement between liner shipping business partners, i.e., slot-owners and slot-charterers, for managing their commercial relationship. Understanding the effectiveness or efficiency of these contracting arrangements has in turn become a major interest of practitioners as well as academic researchers.

Regarding contemporary liner shipping service, the existing pricing scheme can be categorized into three different types, i.e., capacity-based pricing, time-based pricing, and service-based pricing.

1) Capacity-based pricing means the price of using a slot depends on the capacity constraints given by the liner carriers. An apparent example is the soaring freight rate retained to upcoming peak season, i.e., when supply falls short of demands. Despite the carriers being competitors all the time, they might build up a temporary pricing partnership so that each of these carriers can obtain a freight rate increment simultaneously.
2) Time-based pricing means the price of using a slot depends on the Total Travel Time (TTT) of this specific voyage. When a service ordered by a shipper cannot be performed by one single voyage, one or more transshipments occur. Generally speaking, the more transshipments are involved, the longer TTT can be expected. However, the liner carrier might offer some priority to certain carriages so that even if transshipment is involved, these carriages can still enjoy quite efficient connections, which results in shorter TTT. Obviously, such time-saving service as fast-lane or quick-connection, no matter how to name it, costs more to the shipper.
3) Service-based pricing means the price of using a slot depends on the service quality offered by the carrier. For instance, in case a reefer container is to be carried, the price of providing carriage of such cargo is expected to be relatively high.

Above mentioned pricing scheme is set between the seller of slots and the buyer of the slots. The seller of slots can be owner of a container ship and/or operator of container ships. The buyer of the slots, in most cases, can be a shipper and/or consignee. However, taking into account the cooperation among liners, the buyer of slots can then also be a liner who rents slots, i.e., buys service from her business partner based on designed slot-chartering agreements.

Among these three pricing schemes, the capacity- based pricing more likely happens during highly congested season or geographical regions. One of the objectives of adopting slot agreement is to have a best possible interplay between covering much of a service network as possible and deploying the smallest capacity (or handling volume) as possible, and obtain maximal expected profits. Therefore, the pricing scheme also plays a vital role as one aspect of general principles of slot agreements, which build up the main research scope of this paper.

For years the slot-charterer has been using a simple consignment contract with revenue sharing to manage its relationship with its numerous slot-owners for selling slots at the marketplace and nowadays even by means of online auctions through the internet. Such online auction as a newly designed business can be seen, e.g., through Maersk Lines' webpage (www.maerskline.com) since the beginning of 2009. Ignoring many of the details of minor importance, the contract can be described as follows: A seller of slots can choose the retail price and listing quantity for selling his loaded slot at the slot-charterer online marketplace, and the slot-owner collects a fee from the slot-charterer based on the slot-chartering agreement only when a slot related service is sold. The slot-owner calculates the fee to charge based on a predetermined percentage of the list price of a loaded slot.

Very recently, however, the slot-charterer started to offer a different contract, called the modified slot-chartering agreement, the essential part of which states as follows: There is an annual fee for being a member of a slot-chartering agreement. The fee includes unlimited title enrollment, access to the slot-owner services association, and access to the slot-owner protocol to manage the account. The standard term of slot-chartering agreement slot-owners is 55% and the slot-charterer keeps 45% of the list price. That means that slot-charterer is entitled to 55% of the list price for each slot that sells to shippers- final customers in the liner shipping service market.

The slot-owner, receives 55% of the list price. The slot-owner sets the list price, also known as Suggested Retail Price of the liner service, of loaded slots, and all payments made to slot-owners are calculated based on the list price. If the slot-charterer decides to further reduce the retail price to the final customer at a lower price than the list price, the shipper's discount is derived from the slot-charterer's percentage.

Furthermore, under the modified slot-chartering program, it is the slot-charterer who makes the decision about the amount of slots that are to be chartered. The slot-charterer continuously adjusts the amount of slots he orders from slot-owners based on the recent sales performance of slot-charterer's business, with the goal of keeping a few weeks of estimated demand in stock by holding even some spare slots. Provided as one of functions of the managerial information system of the slot-charterer, he himself will be notified on how many chartered slots were actually sold to his final customer, i.e., making revenue.

The purpose of this research is to study the decisions and performance of slot related business under the above mentioned slot-chartering agreements.

1) How do the slot-charterer and the slot-owner each make their respective decisions in equilibrium under such contracts?
2) How does the non-cooperative behavior perform, compared with a cooperative behavior? How does each individual liner company perform?
3) Can we propose alternative contracts to improve the collective benefit as well as individual benefit?
4) Who, including slot-charterer and slot-owner will or will not benefit when switching from its previous revenue-sharing contract to a newly designed slot-chartering agreement?

Towards gaining managerial insights on these issues, we consider building a slot related business consisting of one slot-owner and one slot-charterer. The slot-owner incurs a constant unit cost to offer a slot with unlimited shipping capacity, and the slot-charterer incurs a constant unit cost for chartering and later selling the slot to the liner shipping market. Market demand for the liner shipping service during a selling season is uncertain and depends on the freight rate offered.

Prior to the selling season, the slot-owner announces a revenue share, as the percentage of the list price for the slot (e.g., 55% in slot-owner's), that he wants to charge the slot-charterer for each slot sold. In response to this revenue share, the slot-owner chooses the list price for chartering out a slot. Based on this list price and the predetermined revenue share, the slot-charterer then decides the final freight rate for selling the slot to the market and a corresponding slot-chartering order quantity. This final freight rate chosen by the slot-charterer is the actual price that the shipper will pay for using the slots, and it does not have to be equal to the list price set up by the slot-owner. The calculation of the slot-charterer's fee payable to the slot-owner on each unit sold, however, is always based on the list price.

We assume that demand information, about the service price-sensitivity and its nature of uncertainty, is common knowledge to both parties. All decisions, i.e., the revenue share, the list price, the final freight rate and the slot order quantity, have to be made before the start of each selling season (i.e., every year or every half year). In addition, for simplicity, we assume that there is no salvage value or disposal cost for any unsold slot at the end of voyages, and there is no shortage penalty beyond the loss of profit margin for any unmet demand.

We model the above decision-making procedures as a 3-stage Stackelberg (leader-follower) game. At the first stage, the slot-charterer, acting as the Stackelberg-leader, offers the Slot-owner a take-it-or-leave-it contract, specifying the percentage allocation of the revenue between these two parties. At the second stage, the slot-owner, acting as the follower, chooses the list price, which is actually the unit cost of this specific slot-charterer of using the slot. At the third stage, the slot-charterer determines the freight rate per unit as well as the slot-chartering order quantity.

With some weak conditions on probability distribution of the demand function, this game has a unique Nash equilibrium and the following sections characterize explicitly its equilibrium solution. Equilibrium decisions determine performance of agreement as well as individual liner company's performance as represented by the split of the collective profit between the slot-charterer and the slot-owner.

Second, the research shows that the collective profit is always evenly (50-50%) shared between the slot-charterer and the slot-owner. The model analyses and reveals that in equilibrium the combined choice of the percentage charged by the slot-charterer and the list price chosen by the slot-owner is largely a non-influential factor both to the performance of collective profit and that of an individual liner company. That is, the slot-charterer will simply compute his list price in such a way that his unit net revenue on each sold slot stays as a constant.

We then propose a simple modification to the slot-chartering agreement, where the only change is for the slot-charterer to relinquish his decision on stocking quantity to the slot-owner. That is, at the second stage of the game, the slot-owner now decides the list price together with a quantity of idle slots, i.e., based on the stocking factor, while at the third stage, the slot-charterer now chooses only the final freight rate per unit. We derive the Nash equilibrium for this model and prove its uniqueness. We show that such a modified agreement guarantees a net improvement over the previous agreement, leading to a loss in collective revenue. The share of collective revenue between the slot-charterer and the slot-owner, however, stays unchanged. As a consequence, the modified agreement creates a guaranteed win-win environment for both parties.

The subsequent parts of this paper are divided as follows. Section 2 provides a brief review of related literature. Section 3 details the model assumptions and derives decisions based on cooperative behavior. Section 4 provides the analysis for the non-cooperative behavior under two different kinds of mechanisms regarding slot-chartering agreements, respectively. Section 5 concludes the research and discusses future research directions.

Section 2 Literature Review

This research contributes to the broad literature on joint production-pricing or service-pricing decision problems under market uncertainty. In the classic newsvendor setting of pricing scheme for centralized decision-making, Whitin (1955), Mills (1959, 1962) and Karlin and Carr (1962) are the earliest researchers who formulate and solve such problems. Petruzzi and Dada (1999) provide a review and extensions to problems under the single-period newsvendor setting, while Federgruen and Heching (1999) and Chen and Simchi-Levi (2004 a,b) study production-pricing problems under multi-period settings. Yano and Gilbert (2002) provide a comprehensive review that covers a much broader range of production-pricing decision problems.

Extending the newsvendor framework to decentralized supply chains, Emmons and Gilber (1998), Granot and Yin (2005), and Song et al. (2006) consider a setting where a slot-owner wholesales a product to a slot-charterer who makes pricing-procurement decisions. These papers explore how the slot-owner of a product or service can improve the overall performance by using an inventory-return policy for items overstocked by the assembler. Cachon and Lariviere (2005) explore how a slot-owner can use a combination of wholesale-price and revenue-sharing contracts to achieve cooperative behaviors of involved parties. Granot and Yin (2007a,b) study the effect of postponement of determining retail prices or order quantity decisions on overall performance. Other papers dealing with joint production-pricing decisions of decentralized supply chains include Federgruen and Heching (1999), and Ray et al. (2004), etc. The papers that are most relevant to our research here are by Wang et al. (2004) as well as Ru and Wang (2010), who analyze the consignment contract with revenue sharing methods.

With respect to the broad literature on contract design, this research seeks to characterize the equilibrium, and to measure the performance of the slot-chartering agreement when operating under a given set of designed contracts. This is in contrast to many other literatures whose goal is to design a contract form of achieving cooperative behaviors from all involved parties, in the sense that when the cooperative behavior is performed under such a slot-chartering agreement, it achieves the first-best agreement performance. For readers interested in papers with such a focus, Cachon (2003) provides a most comprehensive review with extensions.

Section 3 Decision Making Procedures and Performance under the General Slots-Chartering Agreement

In this section the equilibrium decisions are analyzed in subsections, respectively. Later on, the comparison between the performances of a decentralized decision making procedure with that of the centralized decision making procedure is demonstrated.

We will characterize the solutions of non-cooperative behaviors under the two kinds of agreements in Sections 3 and 4, respectively. In order to provide a brief framework on these two kinds of agreements, i.e., the General Slot-Chartering Agreement and the Modified Slot-Chartering Agreement, players and their decisions are listed in Table 1.

Table 1 General and Modified Slot-Chartering Agreements

Player	**General Slot-Chartering Agreement**	**Modified Slot-Chartering Agreement**
Slot-owner	• provide list price	• provide list price • quantity of slots to sell to the slot-charterer
Slot-charterer	• quantity of slots to buy • selling price of the slots to market • stocking factor	• selling price of the slots to the market

Section 3.1 Model Assumption based on Collective Decision

Consider a liner shipping service where a slot-owner provides slots and sells slots through a slot-charterer to the market. The slot-owner, i.e., the carrier, produces the service at a constant unit cost of C_s, and the slot-charterer incurs a unit cost of C_R for handling and selling the service to the market.

Define $C \equiv C_s + C_R$ as the total unit cost, and $\alpha \equiv C_R/C$ as the share of the collective cost that is incurred by the Slot-charterer (or by the slot-agreement based business).

Market demand for the service, denoted by D, is price-dependent as well as uncertain. We use the following multiplicative function form to model demand:

$$D(p) = y(p) \cdot \varepsilon \quad (1)$$

p is the freight rate offered to the final customer, i.e., shipper, $y(p)$ is a deterministic and decreasing function of p, and ε is a scaling factor, representing the randomness of demand. Let $\varepsilon \in [A, B]$

Assume $y(p)$ takes the following form: $y(p) = ae^{-bp}$ with $a, b > 0$ (2)

Before the implementation of the slot-chartering agreement, the slot-owner provides Q units of slots and delivers them to the slot-charterer who consequently tries to sell them to the liner shipping market at selling price (i.e., a freight rate) p. The Slot-charterer and the slot-owner operate according to a slot-chartering agreement that specifies who makes which decisions and how payments are transferred between the parties. We will consider and compare two different contractual arrangements, to be labeled as the General Slot-Chartering Agreement and the Modified Slot-Chartering Agreement, respectively.

When operating the slot-chartering business under the General Slot-Chartering Agreement, the slot-charterer and the slot-owner negotiate sequentially in three stages, which can be shown as follows.

Negotiation Stage 1: the slot-charterer sets up a payment schedule which states that for each unit of the product he sells to the market, he pays $(1-r)$ percent of a list price p_L to the slot-owner.

Negotiation Stage 2: the slot-owner chooses the list price p_L to determine the final payment he will get back from the slot-charterer for each slot sold.

Negotiation Stage 3: the slot-charterer decides the quantity Q for the Slot-owner to deliver and the final freight rate p of selling the slot to the liner shipping market.

Then, in order to derive solution to such agreement, a backward-induction procedure is applied for analyzing these stages.

For the rest of this section we derive the optimal solution for a cooperative behavior, which will serve as a benchmark for comparing the performance of the Slot-Chartering Agreements. In the case of a slot-chartering business based on cooperative behaviors from both parties, the slot-chartering agreement between the slot-seller (i.e., slot-owner) and the slot-buyer (i.e., slot-charterer), the decision is to simultaneously choose the selling price p and the quantity Q with the objective to maximize the expected collective revenue which can be written as:

$$\prod_c(p,Q) = pE\{min\,(D,Q)\} - cQ = pE\{min\,(y(p)\varepsilon, Q)\} - cQ \tag{3}$$

Following Petruzzi and Dada (1999), we define $z \equiv Q/y(p)$ and name it the 'stocking factor' of unused idle slots, which to some extent reflect service level of the slot-owner. Then, due to the one-to-one correspondence between (p,z) and (p,Q), for maximizing $\prod_c(p,Q)$, choosing (p,Q) is equivalent to choosing (p,z). Furthermore, based on the demand function form (1) that for given (p,Q), the stocking factor is computed as:

$$P_s\{D(p) \leq Q\} = P_s\{\varepsilon \leq Q/y(p) = z\} \tag{4}$$

For given distribution of ε, each z value corresponds to a unique stocking factor, and thus choosing a value for z is equivalent to setting up a service level for the slot-owner. Substituting $Q = y(p)z$ into the formula, the objective function can be rephrased as:

$$\prod_c(p,z) = y(p)\{pE[min(\varepsilon,z)] - cz\} = y(p)\left\{p\left[z - \int_A^Z (z-x)f(x)\,dx\right] - cz\right\} \quad , \tag{5}$$

where $\wedge z \equiv \int_A^Z (z-x)f(x)\,dx.$ (6)

To find the optimal solution, denoted as (p_c^*, z_c^*), which maximizes $\pi_c(p,z)$, we first find the optimal price $p_c^*(z)$ for any given z, and then maximize $\pi_c(p_c^*(z)\,, z)$ with respect to z to find the optimal z_c^*.

Theorem 1: For any given $z \in [A, B]$, the unique optimal freight rate $p_c^*(z)$ is given by

$$p_c^*(z) = \frac{cz}{z-\int_A^Z (z-x)f(x)dx} + \frac{1}{b} \quad (7)$$

And, if the probability distribution function $f(\cdot)$ satisfies the property of increasing failure rate (IFR), the optimal z_c^* that maximizes $\pi_c(p_c^*(z), z)$ is uniquely determined by

$$\frac{cz}{z-\int_A^Z (z-x)f(x)dx} + \frac{1}{b} = \frac{c}{1-F(z_c^*)} \quad (8)$$

Then, $$\prod_c^* = ae^{-b\{\frac{cz_c^*}{z_c^*-\int_A^Z (z-x)f(x)dx}+\frac{1}{b}\}} \frac{z_c^*-\int_A^Z (z-x)f(x)dx}{b} = ae^{-b\{\frac{cz_c^*}{z_c^*-\Lambda(z_c^*)}+\frac{1}{b}\}} \frac{z_c^*-\Lambda(z_c^*)}{b} \quad (9)$$

Section 3.2 Equilibrium Decisions

At Stage 3 of the decision procedure, for a given revenue share r, allocated by the slot-charterer at the Stage 1, and a given list price p_L, chosen by the slot-owner at Stage 2, the slot-charterer's problem is to simultaneously choose the selling price p and the order quantity Q to maximize her own expected profit which can be calculated as

$$\prod_{d,R}(p, Q|r, p_L) = [p-(1-r)p_L]E\{\min(D, Q)\} - c_R Q. \quad (10)$$

As before, stocking factor $z \equiv \frac{Q}{y(p)}$. Then, for the slot-charterer, choosing (p, Q) is equivalent to choosing (p, z). Hence, the above profit function can be rewritten as

$$\prod_{d,R}(p, z|r, p_L) = y(p)\{[p-(1-r)p_L][z-\Lambda(z)] - c\alpha z\}, \quad (11)$$

Where $y(p)$ and z are defined as given in Table 2, respectively. Other Notations are also summarized in Table 2.

Table 2 Notations

Expression	**Meaning**	**Memo**
α	Slot-charterer's share of the collective cost	$\alpha \equiv \frac{c_R}{c}$
b		
z	Stocking factor of idle slot as inventory	$z \equiv \frac{q}{y(p)}$
p	Selling price of slot to market	
$y(p)$	a deterministic and decreasing function of p	$y(p) = ae^{-bp}$, with $a, b > 0$
p_L	list price that slot-owner provides	
ε	a scaling factor	$\varepsilon \in [A, B]$
r	Revenue share	
$\prod$	Profit function	
IFR	Increasing failure rate	
C_s	a constant unit cost	
D	Market demand for the service	
Q	quantity of slots that the slot-owner provides	

Although selling price p to market is decided by the slot-charterer, it should be close to or almost the same as the slot-owner's offer to the same market in case the slot-owner would like to sell directly these slots to the market (shippers) by him. It should be noted that in the liner shipping market, a slot-owner and a slot-charterer can be liner shipping carriers at the same time, which means that generally speaking, they simultaneously are competitors besides the fact that slots are chartered from one player to the other on some specific voyage.

Section 3.2 Decision Making Procedures under General Slot-Chartering Agreement

Backward-induction is applied in this section so that stages of decision making procedures are analyzed. The decision making procedure 1 is applied during Stage 3. In other words, the decision making procedures follow reversed sequence of the negotiation stages.

Decision making procedures are listed as follows:

Decision making procedure 1: Slot-charterer decides the selling price

Decision making procedure 2: Slot-owner decides list price

Decision making procedure 3: Slot-charterer Decides Revenue Share

3.2.1 Slot-charterer decides the selling price

In order to find the optimal solution, denoted by (p_d^*, z_d^*), for maximizing the output of the profit function $\prod_{d,R}(p,z|r,p_L)$, the optimal selling price $p_d^*(z)$for any given z needs to be derived. And then figure out the optimal z_d^* that maximizes $\prod_{d,R}(p,z|r,p_L)$ with respect to z.

The results are summarized as follows:

Theorem 2: For any given $z \in [A,B]$, list price $p_L > 0$, and revenue share $r \in (0,1)$, the unique optimal selling price $p_d^*(z)$ is given by

$$p_d^*(z) = (1-r)p_L + \frac{c\alpha z}{z-\Lambda(z)} + \frac{1}{b} \tag{12}$$

And, if the demand distribution satisfies the property of IFR, the optimal z_d^* that maximizes $\prod_{d,R}(p_d^*(z), z|r, p_L)$ is uniquely determined by

$$\frac{c\alpha z_d^*}{z_d^*-\Lambda(z_d^*)} + \frac{1}{b} = \frac{c\alpha}{1-F[z_d^*]} \tag{13}$$

The IFR, i.e., $\mathrm{h}(x) \equiv \frac{f(x)}{1-F(x)}$ being increasing in x , as required by Theorom 1, is a relatively weak condition satisfied by most commonly applied probability distributions like Normal, Uniform, and Exponential distribution, etc. Equation (13) implies that under this condition about the demand distribution, the optimal stocking factor z_d^* is in fact independent of the list price p_L and revenue share r; rather it is uniquely determined by the demand distribution and other system parameters.

Furthermore, equations (12) and (13) indicate that the slot-charterer's optimal selling price p_d^*

consists of two main parts, i.e., the amount paid to the slot-owner, namely, $(1-r)p_L$, and for each unit sold plus a constant revenue margin for herself, namely, $\frac{c\alpha z}{z-\Lambda(z)}+\frac{1}{b}$.

Note that the slot-owner provides the slot-charterer a list price according to z. Later on in the following analysis, we will further discuss whether z and the list price really affects the expected revenue.

3.2.2 Slot-owner Decides List Price

At this stage of decision making procedure, namely stage 2, knowing that the slot-charterer choose according to (12) and (13) at stage 3, the slot-owner aims to set the list price p_L to maximize his own expected profit, for any given revenue r proposed by the slot-charterer at Stage 1. The slot-owner's profit function, denoted by$\prod_{d,s}(p_L|r)$, is expressed as

$$\prod_{d,s}(p_L|r)=(1-r)p_L E\{min(D,Q_d)\}-c_s Q_d \tag{14}$$

After integrating $D=y(p_d)\varepsilon$ and $Q_d=y(p_d)z_d$ into (14), the following equation can be obtained:

$$\prod_{d,s}(p_L|r)=y(p_d)\{(1-r)p_L[z_d-\Lambda(z_d)]-c(1-\alpha)z_d\} \tag{15}$$

Since $y(p_d)=\mathrm{a}e^{-bp_d}$ and (p_d^*,z_d^*) are determined in (12) and (13) during Stage 3, (15) can further be rephrased as

$$\prod_{d,s}(p_L|r)=ae^{-b\left\{(1-r)p_L+\frac{c\alpha z_d^*}{z_d^*-\Lambda(z_d^*)}+\frac{1}{b}\right\}}\{(1-r)p_L[z_d^*-\Lambda(z_d^*)]-c(1-\alpha)z_d^*\} \tag{16}$$

Theorem 3: For any given revenue share $r\in(0,1)$, the slot-owner's unique optimal list price $p_L^*(r)$ is given by

$$p_L^*(r)=\frac{1}{(1-r)}\left\{\frac{cz_d^*(1-\alpha)}{z_d^*-\Lambda(z_d^*)}+\frac{1}{b}\right\} \tag{17}$$

From (17) we can see that the optimal list price p_L^* is increasing in slot-charterer's revenue share r. Since the optimal z_d^*does not depend on the revenue share r, (17) further implies that the amount earned by the slot-owner on each unit sold, namely, $(1-r)p_L^*$, is a constant. For instance, if the slot-charterer raises her share r of the revenue, the slot-owner would accordingly increase the optimal list price p_L^* to ensure the amount that he gets from each sold unit is not affected, which is very realistic in liner shipping business. This is as expected, since from the slot-owner's point of view, given that all money transfers are based on the units sold, what matters to himself is how much he earns on each unit sold. This also indicates that the slot-charterer does not create any real bargain power by moving first, as a leader of this game, to set up the revenue share scheme, as what can be seen based on Stage 1 of this Section of the analyses. Incorporating (17) into (12), we then have

$$p_d^*(z_d^*) = \frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b} \tag{18}$$

Therefore, the slot-charterer's bargain power might superficially been reflected as revenue share. However, slot-charterer's optimal selling price does not really depend on that revenue share allocation r. This is a vital finding of this research as food for thought for the slot-charterer, which is beyond the slot-charterer's first instinct over the slot-agreement based business.

3.2.3 Slot-charterer Decides Revenue Share

At Stage 1, the slot-charterer knows not only her own choice on (p_d^*, z_d^*) according to (12) and (13) at Stage 3, but also the slot-owner's best response at Stage 2, the slot-charterer is going to choose revenue share r, to maximize her own expected profit.

However, as what is going be shown next, in equilibrium the slot-charterer's profit does not depend on her choice of r. Consequently, the slot-charterer can choose any $r \in (0,1)$ and achieve the same profit.

Now by substituting (17) for p_L and (18) for p_d into (11), we can derive the slot-charterer's profit as

$$\prod_{d,R} = ae^{-b\left\{\frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b}\right\}} \frac{z_d^* - \Lambda(z_d^*)}{b} \tag{19}$$

Where z_d^* is determined through (13) in which r does not appear as a parameter. Consequently, the slot-charterer's final profit indeed does not depend on her choice of r.

Similarly, after substituting (17) for p_L and (18) for p_d into (15), we obtain the slot-owner's profit as shown below, which does not depend on the slot-charterer's choice of r either.

$$\prod_{d,S} = ae^{-b\left\{\frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b}\right\}} \frac{z_d^* - \Lambda(z_d^*)}{b} \tag{20}$$

It is interesting to observe from (19) and (20) that in equilibrium the slot-charterer and the slot-owner always earn equal profit. In other words, the slot-charterer and the slot-owner each obtain 50% of the collective profit which is given as

$$\prod_d = \prod_{d,R} + \prod_{d,S} = 2ae^{-b\left\{\frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b}\right\}} \frac{z_d^* - \Lambda(z_d^*)}{b} \tag{21}$$

Briefly speaking, for the decentralized decision making process under the General Slot-Chartering Agreement, the slot-charterer can choose any revenue share $r \in (0,1)$; the slot-owner then decides his corresponding list price according to (17). In equilibrium the slot-charterer chooses the selling price and stocking factor as given by (18) and (13), respectively, which leads to the total channel profit of (21). This total collective profit is shared equally between the slot-charterer and the slot-owner.

Section 3.3 Performance under General Slot-Chartering Agreement

The expected profit of the channel depends on nothing but the choice on the final selling price p and the production quantity Q, or equivalently, the selling price p and the stocking factor z. We know from the centralized collective profit sharing problem, the pair of selling price and stocking factor (p_c^*, z_c^*) that maximizes the collective profit is determined through (7) and (8). While if follows the decentralized decision making process, (p_d^*, z_d^*) is determined through (18) and (13). In general, the decentralized decision making process reaches a different output from that of centralized decision making process, and hence a lower collective profit. We are interested in measuring the difference between outputs derived from the decentralized decision making process and the centralized decision making process. In the following, we show that these measures of difference are monotone functions of a key system parameter, namely, the slot-charterer's share of channel cost $\alpha \equiv \frac{c_R}{c}$. In order to accomplish that goal, we need the following Lemma about the property of any general probability distribution function $F(.)$:

Lemma 1. Let $G(z) \equiv \frac{1}{1-F(z)} - \frac{z}{z-\Lambda(z)}$ with $\Lambda(z) \equiv \int_A^Z (z-x)f(x)dx$. If the failure rate function $h(x) \equiv \frac{f(x)}{1-F(x)}$ is increasing in x, then $G(z)$ is increasing in z.

With Lemma 1, we can prove the following set of properties when comparing the decentralized decisions with the centralized decisions:

Proposition 1. $z_c^* - z_d^*(\alpha)$ is increasing in α, and $z_c^* - z_d^*(\alpha) = 0$ when $\alpha = 1$.

Proposition 2. $p_c^* - p_d^*(\alpha)$ is increasing in α, and $p_c^* - p_d^*(\alpha) = -\frac{1}{b}$ when $\alpha = 1$.

Propositions 1 and 2 show that as the slot-charterer incurs a bigger share of the collective cost, the production quantity and selling price reached in the decentralized channel get closer to, but never equal to, the collective quantity and selling price.

The explanation to this phenomenon is that, under the most extreme situation, the cost of the slot-charterer would get closer to the cost of the slot-owner. Eventually, these two costs turn to be equal to each other. Therefore, the performances of two types of decision making processes, i.e., collective quantity and selling price deducted by centralized and decentralized decision making process, get closer to each other, respectively.

This discussion based on aforementioned propositions indicates that as the slot-charterer incurs more of the collective cost, the performance based on the decision making process gets improved, given $e = 2.718$, as shown text.

Proposition 3. $\frac{\Pi_c^* - \Pi_d^*(\alpha)}{\Pi_c^*}$ is increasing in α, and reaches $1 - \frac{2}{e} \approx 26.4\%$ when $\alpha = 1$.

That is, under the General Slot-Chartering Agreement, the loss of collective profit as a percentage of the centralized decision making process' collective profit is at least 26.4%. the 26.4% loss in collective efficiency is of course the best case scenario for a decentralized decision making process. In addition to the parameter α, the actual loss of a given decision making process will be dependent on other system parameters, for instance b in the demand function and the uncertainty nature of demand. We can easily generate examples to demonstrate that in the worst cases, the loss can approach up to 100%.

Therefore, the upper bound of performance is 26.4%, and the lower bound is 100%.

Briefly list the factors that affect performance of slot chartering agreements as follows.

1) Parameter α
2) Parameter b
3) Uncertainty nature of demand

Alternatively, if managed under the Modified Slot-Chartering Agreement to be analyzed in the next section, a decentralized decision making process always achieves the best scenario of 26.4% loss of the current contract, independent of system parameters or demand distribution, as listed above.

Section 4 Decision Making Procedures and Performance under the Modified Slot-Chartering Agreement

The utmost advantage of the Modified Slot-Chartering Agreement lies in the fact that the output of the decision making process is no longer dependent on the system parameters. In this section, the stages of the decision making process under the Modified Slot-Exchange Contract are introduced and performance is analyzed. Under this Modified Advantage Agreement, the slot-owner chooses the list price together with the delivery quantity in the second stage of the overall decision sequence, followed by the slot-charterer who chooses the selling price to the final shipper in the market.

Section 4.1 Decision Making Procedures under the Modified Slot-Chartering Agreement

4.1.1 Slot-charterer's Pricing Decision

At the third stage, for a given revenue share r, announced by the slot-charterer at the first stage, and for a given list price p_L and quantity Q or stocking factor z, chosen by the slot-owner at the second stage, the slot-charterer's problem is to determine the selling price p

appropriately so that her own expected profit is maximized. Defining the stocking factor of inventory as $\equiv \frac{q}{y(p)}$, the slot-charterer's expected profit can then be written as

$$\prod_{d,R}(p|z, p_L, r) = y(p)\{[p-(1-r)P_L][z-\Lambda(z)]-c\alpha z\} \tag{22}$$

Where $y(p)$ and $\Lambda(z)$ are defined in (2) and (5), respectively.

Theorem 4. For any given $z \in [A, B]$, list price $p_L > 0$ and revenue share $r \in (0,1)$, the slot-charterer's unique optimal selling price $p_d^*(z, p_L, r)$ is given by

$$p_d^*(z, p_L, r) = (1-r)P_L + \frac{c\alpha z}{z-\Lambda(z)} + \frac{1}{b} \tag{23}$$

Same as under the General Slot-Chartering Agreement, (23) indicates that slot-charterer's optimal selling price p_d^* consists of two parts: the amount that the slot-charterer has to pay to the slot-owner for each slot (unit) that she books, and a mark-up for herself.

4.1.2 Slot-owner's Decision

At the second stage, knowing the slot-charterer's best response p_d^* of (23), the slot-owner aims to set the list price $p_L$and the stocking factor z optimally to maximize his own expected profit, for any given revenue share r, proposed by the slot-charterer at the first stage. The slot-owner's profit function is given by

$$\prod_{d,S}(p_L, z|r) = y(p_d)\{(1-r)P_L[z-\Lambda(z)]-c(1-\alpha)z\} \tag{24}$$

Since $(p_d) = ae^{-bp_d}$, (22) can be rewritten as

$$\prod_{d,S}(p_L, z|r) = ae^{-b\left\{(1-r)P_L+\frac{c\alpha z}{z-\Lambda(z)}+\frac{1}{b}\right\}}\{(1-r)P_L[z-\Lambda(z)]-c(1-\alpha)z\} \tag{25}$$

We denote the optimal solution for the slot-owner by (p_L^*, z_d^*), which maximizes the profit function of (25) for a given revenue share r .

Theorem 5. For any given $z \in [A, B]$, and revenue share $r \in (0,1)$, the slot-owner's unique optimal list price $p_L^*(z)$ is given by

$$p_L^*(z) = \frac{1}{(1-r)}\left\{\frac{cz(1-\alpha)}{z-\Lambda(z)} + \frac{1}{b}\right\} \tag{26}$$

And, depending on market structure, if the demand distribution satisfies IFR, his optimal z_d^* that maximizes $\prod_{d,S}(p_L^*(z), z|r)$ is uniquely determined by

$$\frac{cz_d^*}{z_d^*-\Lambda(z_d^*)} + \frac{1}{b} = \frac{C}{1-F(z_d^*)} \tag{27}$$

From (27), the optimal stocking level z_d^* chosen by the slot-owner under this modified agreement is lower than that chosen by the slot-charterer under the original agreement as given in (13). Moreover, it can be observed that the decentralized stocking level z_d^* here in (27) is, in fact, exactly the same as the centralized stocking level z_c^* given by (8).

Incorporate (26) into (23), and we get the selling price chosen by the slot-charterer in equilibrium as

$$p_d^*(z_d^*) = \frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b} \tag{28}$$

4.1.3 Slot-charterer's Revenue Share Decision

We next derive the equilibrium expected profits for the slot-charterer's and the slot-owner, respectively. Same as under the General Slot-Chartering Agreement, we will again see that their profits actually do not depend on the choice of revenue share r. Consequently, the choice of a revenue share becomes a non-decision, or can be chosen arbitrarily by the slot-charterer. Incorporating the equilibrium list price of (26) and selling price of (28) into the slot-charterer's profit function of (22) and the slot-owner's profit of (25), we obtain their expected profits as follows, where the stocking factor z_d^* is determined through (27).

$$\prod_{d,R} = \prod_{d,S}^* \quad = ae^{-b\left\{\frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b}\right\}} \frac{z_d^* - \Lambda(z_d^*)}{b} \tag{29}$$

Therefore, as under the General Slot-Chartering Agreement, here the slot-charterer and the slot-owner again earn equal profit, or they evenly split the realized collective profit of

$$\prod_d = 2ae^{-b\left\{\frac{cz_d^*}{z_d^* - \Lambda(z_d^*)} + \frac{2}{b}\right\}} \frac{z_d^* - \Lambda(z_d^*)}{b} \tag{30}$$

The 2 in this equation means it is actually the sum of both profit of slot-charterer and that of slot-owner.

Section 4.2 Performance under the Modified Slot-Chartering Agreement

The following conclusions on performance under the Modified Slot-Chartering Agreement can then be drawn, as summarized in Table 3.

Table 3 Comparison on Factors Affecting Performances of General and Modified Slot-Chartering Agreement

Factors	General Slot-Chartering Agreement	Modified Slot-Chartering Agreement
Formula	• parameter α	Independent of system parameter α or b
	• parameter b	
Demand side	• uncertainty nature of demand	Independent of demand distribution

Based on Table 3 together with equations in Section 4.1, we explain the performance under the Modified Slot-Chartering Agreement as follows.

1) From (26) and (17) we see that under the two contracts, for a given stocking factor z, the slot-owner chooses exactly the same list price. In particular, the slot-owner sets up, still, the list price in such a way that the revenue he gets paid $(1-r)p_L$ keeps at a

constant, independent of the choice of r chosen by the slot-charterer.

2) From (27), the stocking factor chosen by the slot-owner under the Modified General Slot-Chartering Agreement is, however, different from that chosen by the slot-charterer under the General Slot-Chartering Agreement as given in (13).
3) It is interesting to observe that the decentralized stocking factor here in (27) is, in fact, exactly the same as the centralized stocking factor of (9).
4) Note that although the expression of the selling price here in (28) is the same as that of (18) under the General Slot-Chartering Agreement, since the stocking factor z_d^* here is different from the z_d^* under the General Slot-Chartering Agreement, the equilibrium selling prices under the two contracts will be different.

Section 4.3 Difference between the General Slot-Chartering Agreement and the Modified Slot-Chartering Agreement

The Modified Slot-Chartering Agreement differs from the above General Slot-Chartering Agreement only in one respect: it shifts the quantity decision of the Slot-charterer in Stage 3 to the Slot-owner in Stage 2. That is, in Stage 2, the Slot-owner now chooses the list price p_L together with the quantity Q to provide and deliver to the Slot-charterer, and in Stage 3 the Slot-charterer only decides the freight rate p to the final customers, i.e., shippers. The decision making procedures for two mechanisms, respectively, are summarized in Table 4.

Table 4 Decision Making Procedures of the General and Modified Slot-Chartering Agreements

Stages	**General Slot-Chartering Agreement**	**Modified Slot-Chartering Agreement**
Stage 1	The slot-charterer decides • revenue share	Same as that of the General Slot-Chartering Agreement
Stage 2	The slot-owner decides • list price	The slot-owner chooses • list price together with • delivery quantity
Stage 3	The slot-charterer decides • selling price of the slot to the market together with • order quantity of the slot	The slot-charterer decides • selling price of the slot to the market

The performance of the decentralized decision-making procedure is compared with that of the centralized decision-making procedure and the result of such comparison provide food for thought for the slot-owner, slot-charterer for obtaining better benefit from the slot-agreement related business.

In this section, a modified slot-agreement contract is proposed as suggestion for the slot-charterer to make better decision.

Recall that under the General Slot-Chartering Agreement, collective decision made and performance gained both critically depend on slot-charterer's share α of the collective cost. In a sharp contrast, with the Modified Slot-Chartering Agreement, collective decision and profits are all independent of α.

Comparing the decentralized decision making procedure based decision (z_d^*, p_d^*) of (27) and (28) with their centralized decision making procedure based decision (z_c^*, p_c^*) , following propositions are readily got.

Proposition 4. Under the Modified Slot-Chartering Agreement, $z_d^* = z_c^*$ and $p_d^* = p_c^* + \frac{1}{b}$.

Since$z_d^* = z_c^*$, a simple comparison of two output based on centralized and decentralized decision making procedures leads to the following proposition Y.

Proposition 5. Under the Modified Slot-Chartering Agreement, the overall always incurs the profit loss of, as a percentage of the collective profit, $\frac{\Pi_c^* \ \ -\Pi_d^*(\alpha)}{\Pi_c^*} = 1 - \frac{2}{e} \approx 26.4\%$

Briefly summarize, under the Modified Slot-Chartering Agreement, the slot-agreement business is guaranteed to always achieve the best performance of the previous business under the General Slot-Chartering Agreement.

Section 5 Conclusions and Further Research

In this paper we have built a game-theoretic model to analyze the decentralized decision-making procedure and performance operating under two different agreements. The model developed in this paper indicates that operating under such a contractual regime, the slot-owner and slot-charterer would evenly split the net profit with each other; the overall contractual based profit, however, would incur a loss in profit of at least 26.4%, compared with the first-best collective profit achievable under centralized decision-making procedure. Then a slightly modified contract is proposed and it shows that it would guarantee a loss in collective profit of just 26.4%.

As discussed at the beginning of this paper, in the past decade, most slot-owners have been operating either under scheme of liner conferences during last century or under scheme of liner strategic alliances in the past decades. Recently, slot-owners have started to apply slot-chartering agreement, where a slot-owner is entitled right to choose price and quantity of the slots he would offer to the market.

Regarding further research that to be done, sensitivity analyses may be further carried out to analyze the impact of different pricing strategies. The utmost aim of the whole paper is to study a win-win solution for either of the players. The win-win situation can also be interpreted as acceptable solution for all the involved players, i.e., the slot-owner, slot-charterer and NVOCCs (Non Vessel Operating Common Carrier). We have discussed the slot-owner and slot-charterer as players in this paper. However, NVOCCs can to some extend be regarded as a buyer of the slot and its related service as well. In this sense, there is some similarity between slot-charterer and NVOCCs. The only difference between these two kinds of players might lies to the way how they decide the selling price of the slot, which might deserve more research based on the analyses has been done in this research.

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RFID TECHNOLOGY AND ITS APPLICATION TO PORT-BASED CONTAINER LOGISTICS

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Radio frequency identification (RFID) technology is among the Internet of Things (IoT) technologies that have been proposed for substantially improving performance of container port operations. In addition, more implementation is to be expected in the field of container yard and depot as well as in logistics-related activities. Seaports, especially container terminals, are expected to become one of the efficient nodes among all logistics activities with the help of IoT technology in the operation practice of sea port, which plays an essential role in transportation; there is a trend that IoT technology, including RFID technology, is to be adopted to fulfill future electronic identity verification and remote location and control over cargo. A goal of this article is to critically evaluate RFID application for operational procedures in port-based container logistics. Based on that, some previously used technologies are briefly introduced with their effectiveness and efficiencies so that comparison can be made. We also discuss current application of RFID technology in the field of container logistics. Furthermore, RFID application trend from wider perspectives is also observed. That is to say, applications derived from cargo demand side and supply chain/network management side can also be triggers that lead to increase in the number of application in the near future.

Keywords: *container; port operation; RFID*

1. INTRODUCTION

1.1. Overview on RFID Technology

RFID has been successfully used in transportation and manufacturing since the mid-1980s and its use is growing rapidly as costs come down and benefits are recognized. The primary advantage to RFID in a port/terminal application is that it is an "automatic" data collection technology.

There are two types of RFID tags that are of primary interest: active and semi-active. Active RFID tags contain a battery to boost reading range. Active tags can have a range of up to 100 m. These tags have a relatively large memory capacity to store relevant data that is typically encrypted to prevent unauthorized reading of, for example, a shipping manifest. Active tags may contain sensors, global positioning (GPS), satellite links, or other enhancements. Semi-active RFID tags contain a battery but this is not used to enhance reading

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range. The battery is used to power sensors or volatile memory. Read range depends on the frequency and type of tags.

Also of interest are RFID identification cards, which may be contactless smart cards. These are passive since they contain no battery and have a more limited range. Currently, passive RFID tags may also be found on pallets and other load devices within shipping containers.

A barcode is an optical machine-readable representation of data, which shows data about the object to which it is attached. Originally, barcodes represented data by varying the widths and spaces of parallel lines, and may be referred to as linear or 1-dimensional (1D). Later they evolved into rectangles, dots, hexagons, and other geometric patterns in 2-dimensions (2D). Although 2D systems use a variety of symbols, they are generally referred to as barcodes as well. Barcodes are scanned by special optical scanners.

Machine-to-machine (M2M) refers to technologies that allow both wireless and wired systems to communicate with other devices of the same ability. M2M uses a device (such as a sensor or meter) to capture an event (such as temperature, inventory level, etc.), which is relayed through a network (wireless, wired, or hybrid) to an application (software program) that translates the captured event into meaningful information (for example, items need to be restocked).

However, scenariorn M2M communication has expanded beyond a one-to-one connection and changed into a system of networks that transmits data to personal appliances. The expansion of wireless networks across the world has made it far easier for M2M communication to take place.

Recently, SMS has become an increasingly important transmission mechanism for M2M communication, with the ubiquity of GSM and the relatively low cost of SMS being cited as advantages. Concerns have been raised over the reliability of SMS as an M2M channel; however the rise of direct Signaling System 7 (SS7) connected SMS gateways, which can offer increased reliability and the ability to confirm delivery, have allayed many of these fears.

The RMM+ is a remote communication device designed for refrigerated containers. The RMM+ combine communication industry standard ISO10368 with wireless technologies for fast data transfer, long distance communication, and tracking. It is further the key component in ISO 10368 power-line communication to monitor and control reefer containers onboard vessels or terminals. Each container equipped with an RMM+ is able to send data on its operating conditions and alarms to a local monitoring system, such as the REFCON system. Besides monitoring, the RMM+ can be used to remotely control various reefer container functions, which is discussed in the forthcoming sections in this article.

The previously mentioned technology can be applied not only for cargo transportation but also in health care logistics. For example, Zhou and Piramuthu (2010) developed a comprehensive framework and evaluation of health care–related processes with RFID technology implementation. A similar idea also has been analyzed by Pamela, Nabil, and Dominique (2011) for optimizing infectious medical waste collecting by using RFID technology. Finkenzeller (1999) is of value as an introductory literature on fundamentals and applications to different fields.

Based on RFID technology, no operator intervention or action is required. Whereas other forms of data collection, whether bar code or manual methods, depend on employees to record information, RFID relieves them from this time-consuming and error-prone process.

Some of these applications offer benefits to the terminal/port operator, either directly or as added services for shippers. Other benefits must be seen more as a means of simplifying compliance with increasing governmental security regulations and record keeping requirements.

While many of the applications cited in this article will require the cooperation of ship owners, shippers, carriers, and terminal operators in employing RFID and may, therefore, seem to be excessively forward-looking, the regulatory environment will likely encourage adoption in a much shorter timeframe than might be evident at this moment.

1.2. Overview of Container Terminal Operation

By the international financial crisis, the first decline in China's port container throughput appeared in 2009, while in 2010, driven by rapid growth of economy and trade, port-based container throughput increased in an expected rapid speed. Moreover, seaport hubs together with land transport links have already shown its remarkable significance. Port-based logistics therefore is an integrated system of scenariorn logistics in shipping scenario, which has achieved fundamental support of material flow logistics and additional value-added services in the overall system.

In such international environment, it's an important issue to enhance the competitiveness and influence of port logistics, including developing strategies to build a scenariorn port logistics systems supported by IT, network, and IoT technologies so that the logistics service industry companies tap new sources of profits, as well as helping third-party logistics companies to expand market and approach to economies of scale.

For a general and updated literature review on container terminal operations, readers may see Stahlbock and Voß (2008). Harder and Voß (2011) provide basis and applicable understanding of cost-benefit analysis on RFID application to the shipping industry.

In addition, some researchers (e.g., Xie et al. 2007) also observed ways to implement automatic handling system in China's container yards. Ngai and colleagues (2007) described the research and development of an RFID prototype system that integrates with mobile commerce (m-commerce) in a container depot to enhance its daily operations and support its location management. This RFID system integrated with m-commerce architecture first is introduced as a framework for research and the viability of the RFID integrated m-commerce framework is tested in a container depot.

With the progress of computer information technology, network technology, and global economic integration, the trend of seaport development is set to become an integrated logistics center with the convergence of commodity flow, capital flow, and information flow, as well as a logistics information center. Therefore, traditional port logistics business is no longer capable to meet current needs of the growth of logistics in today's environment, and information technology, especially RFID as one of the IoT technology in business process reengineering of many companies is playing an increasingly important role in order to meet competition. Logistics companies, which based themselves on port-related business, then need to use these technologies.

2. CONTAINER TERMINAL OPERATION PROCEDURES

2.1. Existing Terminal Operation Procedures

2.1.1. Documents Pre-recorded. A packing list is a specific document of container transportation and is also an essential one in the whole shipping transportation process. It is filled based on the goods that have been loaded inside, together with trade terms, stowage order, and related information of certain container ships. Packing lists are very important in container transport business they are one of the original documents used during shipping process and the basis for follow-up documents, such as Bill of Lading (B/L). Previously, a paper copy of the packing list is carried by lorry drivers when crossing into a gateway and is then manually input into port operation system. Since the terminal cannot receive this information in advance, the arrangements of container operation and gateway traffic speed were terribly impacted. Now, terminals using EDI transmission allows for electronic packing list input in advance, and the driver could just make a simple confirmation of the serial number as long as the container truck arrives, which greatly speeds up the clearance capacity and accumulates economic benefits.

2.1.2. Entrance gateway. By using RFID, vehicle and driver information through the RFID tag on the truck's front window can be collected. The information of containers will be recorded through image recognition system by container number and checked with the container shipping companies' report as well as the extent of container damage. If the software fails to accurately identify the container number, staff will again conduct artificial recognition and type it into the port operation system. Truck drivers are just required to enter the reservation number instead of getting off, and the machine automatically prints out a small note, written to remind the driver to put the required number and location of container. At the same time, control instructions issued to the relevant box area facilitates the cable car to move quickly in place to do a good job working at the fastest speed.

2.1.3. Landside operation area. Independent from the selected terminal operations system, specific processes are performed at different areas. On the apron area the ship-to-shore operations (loading and discharging of vessels) are carried out. In the beginning of container shipping the cargo handling on this area was mainly carried out with on-board lifting gear of the vessels or a regular quay crane. Nowadays this type of handling is only used on terminals with a comparatively low container throughput. On medium- and large-sized terminals the ship-to-shore handling of containers is usually carried out with gantry cranes specialized for this purpose. Container vessels are the only ships that can theoretically be loaded and discharged at the same time. The Ship-To-Shore gantry Crane (STS Crane) discharges a container moving landwards, and on its way back loads a container on to the vessel. This handling procedure requires good planning of the terminal equipment for container delivery as well as for container stacking in the yard and on the vessel.

The configuration of the area for landside operation is determined by hinterland transport scenarios or related interfaces, respectively. In case of predominant truck operations, this functional area is often integrated in the yard area. The trucks are loaded and unloaded on dedicated spaces at the end of the stacking yard or in the middle of the yard, for example, by straddle carriers or yard cranes. In case of railway transport, loading/unloading should take place outside the stacking area to avoid the crossing of rail tracks by the yard equipment. This would increase the terminal efficiency and performance as well as the safety on the terminal. The loading/unloading process is carried out directly by the yard equipment or by gantry cranes being combined with appropriate vehicles for horizontal transport between railway station and terminal yard.

2.2. Current Technologies Applied in Container Terminal Operation

2.2.1. Electronic devices in container terminals. Providing reliable service to the interacting elements of the transportation chain is a major objective of any container terminal. Within a port community, the effective flow of information is considered to be an important variable. For example, in an eight-berth terminal where eight ships are berthed for loading/unloading some 6000 containers simultaneously, a highly sophisticated information technology is required to provide reliable and timely information for hundreds of people within the port/transport community. Among them are freight forwarders, transport companies, rail operators, crane operators, and container carriers in terminals. To carry out an effective data interchange, appropriate electronic devices must be used. However, despite the fact that several devices are available in the market, they are not employed in every container terminal. While they can operate as individual devices in ports and outside terminals (e.g., rail track), they should be integrated to the port and transport network communications via a computer system. Only a few international ports have taken maximum advantage of existing devices to improve their operational efficiency, minimize terminal congestion, and establish a fully integrated system. A brief description of the following devices aims to explain their importance in container tracking, recording, movements, and segregation of imported/exported containers.

2.2.2. Microwave technology. At present, material handling systems are generally manually operated. One of the few US terminals (e.g., Long Beach, Los Angeles) has gone beyond the experimental stage in advancing the state of material handling practice. Some have employed computer process control to minimize crane travel time from ship's hull to the quay. Microwave technology is simply employed to track the placing and pick-up of containers by recording relevant data on tags installed on the containers. In ship-to-rail direct loading at the terminal, for example, this method would reduce the crane's waiting time when the spreader is in the ship's hull.

2.2.3. Tagging technology in rail transport. Recent advances in microwave technology include a tag that allows data read or write. The tag can contain up to 4000 characters of data that can be updated by radio signal broadcaster installed in the terminal or alongside of the train track (e.g., automated wagonload operations on the New Zealand railway system). The tags can be read while the train is moving at up to 110 km/hr. This system must be modified when the fast freight trains (160 km/hr operate in Japan and Germany) are used for freight transportation. The antenna used in this system creates an inductive radio frequency field to activate and receive data from tags. It contains a transmit-coil with associated tuning and matching components and a receive-coil. When a consignment is loaded on the train, the computer will be able to provide relevant information on content of containers loaded on the train, wagons, and destinations. Information is then passed to the yard staff. Based on this information, a work order is passed to the crew of the train. As the train leaves the yard, an Automated Vehicle Identification (AVI) reader reads the tags on each wagon and sends a message to the central computer to compare the manifest with information in the central computer. At the same time, the wagons are weighted to check for load discrepancies. Both sets of data are then sent ahead of the train to the next stop so that the freight forwarders can be advised of arrival.

2.2.4. Barcode scanner. A barcode scanner would help the customs decide whether physical inspection of containers is required particularly when several vessels simultaneously unload thousands of containers. Barcode and optical character recognition are basically two automatic identification systems. They are environmentally sensitive and application restrictive. The scanner is easy to use where the ambient light environment in the container terminal is high. A barcode is ideal, especially for shipping manifests and outer packing cases or other exposed surfaces. This system is capable of providing prompt information required by customs when vessels are at berth. It operates most effectively in a controlled environment particularly when relatively small amounts of data need to be captured.

2.2.5. Radio frequency microcircuit system. Radio frequency microcircuit system (RF) is developed to identify the containers when traffic at terminals reaches the peak. It is not easy to check and control the traffic at a terminal where thousands of containers are stacked and hundreds of containers are on the move. Container carriers deliver the stacked imported containers to the quay area and the newly unloaded containers occupy their slots. The system is ideally suited for operation in a harsh and outdoor environment. Nonconductive materials such as grime, snow, and rain that intrude between the interrogator and transponder do not appear to affect operation of the system. The system consists of the reader or antenna (that is buried in the pavement of the terminal to keep it free from vandalism, accident, and weather) transponders (tags), an interrogator and computer interface tag. RF system offers high-speed and remote electronic identification of equipment. The heart of the system is the tag, powered either by a battery or by an RF beam from the antenna. Each tag can have a unique code that is related to the object to which the transponder is attached. The electronic components of the transponders are enclosed in rugged packages that may be as small as a credit card. One application for RF systems is in monitoring the movement of containers and their status in the terminal. This is the area that assists the terminal operator to produce prompt reports for importers/exporters and other relevant agencies. The system can also track containers entering and leaving the terminal through the gate or as they pass the scanning points in the yard.

2.2.6. Voice recognition technology. Voice recognition technology provides communications between the crane operator and the ground personnel. This system could be used either as a standalone or it can be integrated with other technologies.

Voice systems use pattern recognition similar to that in barcode systems. Instead of an image, the computer recognizes words in a preprogrammed vocabulary. When it is activated, crane operators speak into a microphone; the machine recognizes words or phrases and then converts them into electronic impulses for the micro- or host computer. The high-performance units operate at an accuracy rate of 99.5%. One of the advantages of the system is message recording. This would assist the terminal operator in providing the final report on the position of containers loaded on to the ship. When properly integrated, the system can assist in the automatic capture and processing of marine terminal data.

3. APPLICATION OF RFID TO CONTAINER TERMINAL OPERATION

3.1. RFID Container E-Seal

Port operators are striving to increase efficiency through effective supply chain management, while focus is being placed on security, visibility, and control. The problem is caused by the highly complex environment in which thousands of containers need to be handled at high speeds without automated business processes. Many shippers still use manual methods, which can lead to tracking errors and mishandling. The modules that can be applied in port operations are listed next.

3.1.1. Module

1. RFID Container Seal—RFID Container Seal records every single lock or unlock event performed and when it is performed. Unauthorized lock or unlock will tamper the seal and triggers the alarm when the container passes through the check point. RFID Container Seal comes with large memory, allowing detailed information to be stored in the seal. The information stored in the seal can be used for faster customs clearance, e-document for port, etc. RFID Container Seal is reusable and it is environmentally friendly.
2. Handheld PC with RFID Reader—Handheld PC with RFID Reader is used to initialize, write, issue lock, or unlock command to the RFID Container Seal. Lock or unlock RFID Container Seal without command issued from the Handheld will tamper the seal.
3. Desktop RFID Reader—Desktop RFID Reader is used to initialize and write information into the RFID Container Seal in the convenience of office environment.
4. Readers at Check Points—RFID Readers are installed at a check point to read the information in the RFID Container Seal affixed to the container. Information collected is uploaded to the Smartrack^{TM} EPCIS or other repository, allowing shipper, freight forwarder, ports, etc. to know the status of the container online. Container with RFID Container Seal intact is allowed to pass through without the need to physically check, which helps in faster clearance. Only a container with tampered RFID Container Seal will be inspected.
5. Readers at Quay Crane—Readers at Quay Crane capture the status and information in the RFID Container Seal when a container arrives. The status and information will then be uploaded to Smartrack^{TM} EPCIS or other repository. It allows the shipper to know when the container is loaded or offloaded from the vessel. On top of that, if the seal is tampered, the shipper can easily identify when the seal was tampered and whether it happened before or after the container was loaded or offloaded from the vessel.

3.1.2. Standards. Electronic Seals (E-Seals) present a very simple and at the same time very strong defense against different weaknesses in safety of containers in worldwide trade. By implementing various types of E-Seals it is possible to enhance container security as well as improve efficiency of container logistics processes throughout the whole supply chain.

According to the current ISO 18185 dentition, an E-Seal is a “Read-only, non-reusable freight container seal conforming to the high security seal defined in ISO/PAS 17712 and conforming to ISO 18185 or revision thereof that electronically evidences tampering or intrusion through the container door.” At present, there are no global standards for frequencies and technical specification for electronic seals. The International Standards Organization’s (ISO) Technical Committee 104 is trying to specify data protection technology, and as a result, ISO 18185-4 Gen 1 was released in August 31, 2005. However, the ISO 18185-4 Gen 1 did not satisfy requirements for the data protection and device authentication for E-Seals.

An E-Seal provides not just physical security but also can contain a set of useful information such as seal number, container number, user data, security, battery, and environment status and some different data useful for supply chain management. An electronic seal has the great advantage of maintaining visibility en route and allows for real-time event reports using satellite or cellular communications. With high-end capability it becomes more attractive for security and business applications.

Finally, the adaptation of E-Seals is connected with additional expenses for container business providers and for government in particular. The problems of investments in such security devices on containers are evaluated in the article.

3.2. Scenarios and Development

In correspondence with the four hierarchies illustrated previously, the application of RFID to container transportation could also be classified into four scenarios.

1. Scenario one—quasi closed loop application:
   A container terminal or a container yard or container freight station is more likely to implement this RFID application scenario in the first place within the container transport industry. As the container terminal is the most dynamic node full of container logistics activities, the implementation of RFID within the terminal or yard could result in substantial benefits including but not limited to the following aspects:
   - Facilitating gatehouse operations through better container identification efficiency
   - Keep improving the container storage management via real-time data updates
   - Check container logistics operations to minimize operation errors
2. Scenario two—container shipping route application:
   This scenario can come into being only when at least two terminals have implemented RFID systems so that the container shipping routes between the ports can be integrated into their systems, forming lines of RFID application routes. It is expected to bring about the following benefits:
   - Facilitating the liner companies with their container scheduling and management
   - Better container tracking and tracing functions
3. Scenario three—RFID container application clusters:
   Based on well-implemented RFID within the shipping/port realm, other operators related to container logistics within the multimodal transportation systems can be further integrated into the existing container RFID application clusters. This step is essential to the whole container transportation system's efficiency improvement since the information of the containers within the clusters can be transmitted efficiently and in a timely manner. Information distortion can be eliminated significantly in intermodal container transportation chains:
   - Satisfying container tracking and tracing functions
   - Comprehensive and prompt statistics
4. Scenario four—comprehensive application:
   Along with the roll out of RFID application to container transportation, under proper international standards, the internationally compatible application can be expected in container transportation. This is the ultimate application of container RFID. If it is going to happen in the future, the following extended functions of container RFID system may be realized:

- Public container data platform implementation for international customs organization to monitor the container transportation and international trade security
- The efficiency perfection of the entire container transportation system

3.3. Improving workflows of the container terminal operation. The existing RFID application to the entrance gate process of a container terminal can be found in Figure 1, where time taken for EIR can be dramatically shortened. As for processes that happen inside of a container terminal, a flowchart is illustrated in Figure 2. Each activity unless it is container related, for example, EIR activity, can then turn to be more efficient in the case of RFID application.

3.4. Advantages and Disadvantages

The advantages of the large-scale application of RFID are analyzed next.

1. Overall improvement in operational efficiency, reduce clearance time, achieve paperless transportation.
   When the speed of operation and transportation is in the RFID tag's signal range, data exchange automatically ensuring seamless operation. It will completely change the flow of container transport operations, so there is no longer a need to approach EIR, which is a completely paperless operation.
2. Accurate and timely data collection rate.
   The current way of data collection is single, and controllability is not high and the data source does not guarantee real-time updates. Although the accuracy and timeliness of the arrival rate satisfies the current management but can still be improved to enhance the management of all containers to reduce lost container rate, goods damage, and theft losses.

Figure 1 RFID application at entrance gate of container terminal (color figure available online).
Source: Photo by Authors at Waigao Qiao Container Terminal in Shanghai, Apr. 2011.

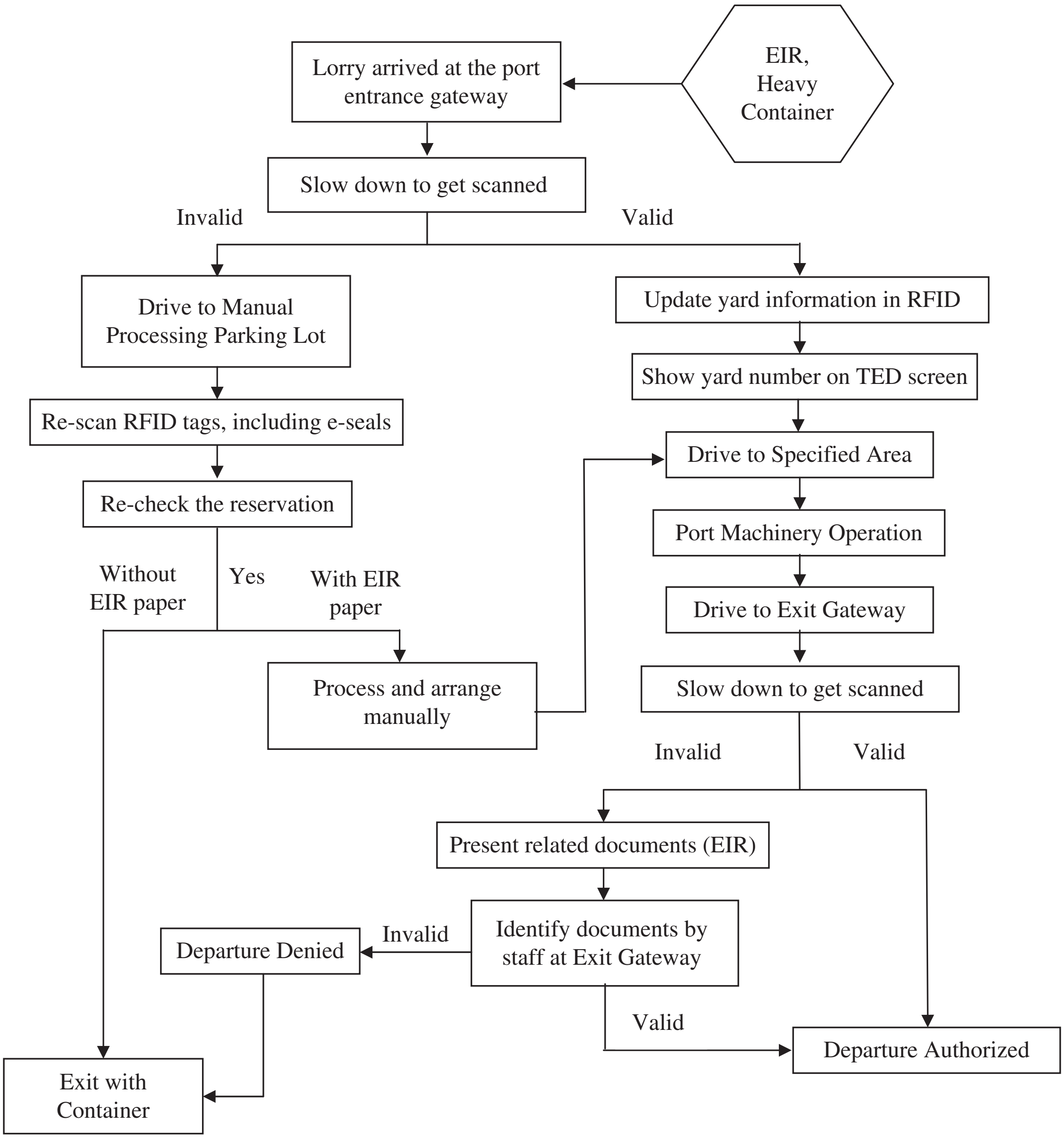

Figure 2 Flowchart of container related port operations.
Source: Authors own composition based on Xie et al. (2007).

3. Slash labor costs.
   Automation of electronic yard management will replace a large number of managers to achieve centralized and efficient management, reduction of labor costs, and costs of the logistics of cargo owners reduced accordingly.
4. Integrate the entire supply chain optimization from a strategic perspective.
   The current logistics costs are often unclear for lack of control based on position, but the demand of data collection is especially very strong. Effective management of the supply chain means to successfully control every aspect of logistics costs, reduce shipping circulation, and increase owner of business interests. Information must therefore be to achieve effective integration of RFID, mobility, and use only the most of its value.

The disadvantages of large-scale application of RFID are analyzed next.

1. Container transport is a global business.
   The circulation of each container is in a global range. If RFID electronic tags are planned to be implemented, it needs to be promoted by the entire shipping and port industry, together with related companies or associations to promote an integrated implementation. Currently, there are no plans to set up new organizations. Even if the national policy supports, it is still difficult to advance in international business, while allowing for development of pilots only for domestic transport.
2. Within the container shipping company, data acquisition and transmission has reached standards of accuracy and completion.
   Data are collected in the form of electronic telegraph messages, from the port, ship yard, and operating ships, updated regularly through the company's EDI system for data integration summed to form a complete container information feedback. The current electronic message accuracy rate is more than 99% (according to the interview with staff working in China Shipping Container Line), with all operations contained in the report. In addition, operating items reported on a daily routine.

4. TREND OF RFID APPLICATION TO LOGISTICS OPERATION

4.1. Practical Industry Views

Logistics and transportation are major areas of implementation for RFID technology. For example, yard management, shipping, and freight and distribution centers are some areas where RFID tracking technology is used. Transportation companies around the world value RFID technology due to its impact on the business value and efficiency. From the perspective of logistics services, in most cases challenges arise from the demand side. The interested reader may refer to Kapoor, Zhou, and Piramuthu (2009).

4.2. From Perspective of Shipping Company

Some liner shipping company has carried out bar code label applications, where bar code labels are attached to the top of a corresponding container EIR, and has survey applications and found that EIR in practice suffers the consequences due to improper care and other reasons. Therefore, scanner read information is often not timely, the greatly reduced efficiency of customs clearance, which is even slower than a skilled manual input speed. Ultimately such inconvenience leads to failure of multiple scan container station to give up bar code scanning. How to ensure the speed of customs clearance and port reading accuracy will be important in considering the adoption of RFID technology.

RFID technology gains little visible economic profits. Although the electronic tag on the container port operations and management control will be fully optimized to enhance, but from the economic point of view, the huge initial investment (the specific numbers needed to be collected later in the survey data) and operating and maintenance costs in the process is unknown, and future income is not directly visible, we cannot directly address the main issues in the current operation. Only the lower labor costs have a certain role. Meanwhile, the investment costs of new technology will eventually be transferred on to shippers, causing increased shipping costs, which may affect the choice of the owner of the carrier thus causing loss of the customer base.

The quality of the current mechanisms for monitoring and alarming of reefer-container has been improved. CSCL chips and refrigerators are supported by Daikin, the ambitious coproduction of such well-known air-conditioning manufacturer; every tiny change of the temperature of reefer-containers is meticulously recorded. As one of the most leading monitoring and alarm systems, its temperature monitoring has reached Europe's and the United States' stringent requirements for various types of imported food. It is not clear whether the temperature monitoring and alarm systems are networked. All that has been learned is that the alarm system can still be in the yard field application.

Lack of demand on app level limits new breakthroughs. RFID is just one of the means of data exchange, namely an alternative to existing technologies at physical level, while at the application level it still needs to explore new areas. To find RFID technology in the logistics chain services to meet the new demands and the corresponding RFID tag technology breakthrough is an important breakthrough in application.

In sum, the attitude of the interviewees to some extent represents that of the shipping companies, that current RFID technology in existing systems and technologies can meet business needs, and application of new technologies seems immature, without any obvious visible benefit cases, shipping companies are powerless when it comes to implementing RFID tag technology. Of course, considering the interviewee positions and angle of individual characteristics, this conclusion does not fully represent the views of the decision-making board in shipping companies.

4.3. From the Perspective of Emerging Market

The RFID technology can not only enable item-level retail pricing as studied by Zhou and colleagues (2009) but also facilitate logistics service designed for specific cargo, for example, those packaged in reefer containers. Keeping real-time tabs on fresh food supply helps guarantee the quality of perishable goods.

In this niche market—the reefer-container market—Maersk Shipping Line Co. (hereinafter referred to as Maersk) has been leading the industry, and its technology and service solutions are able to fully meet customer demand for transport of different commodities such as ultra-low temperature freezing and constant temperature refrigeration. In cooperation with cooling technology companies, an exclusive agreement is often signed to purchase expensive container refrigeration technology in order to ensure its technological leadership. In addition, Maersk also generates great emphasis on its R & D and Q1 service improvement, invested heavily in R & D and technical personnel in the new reefer-container technology to ensure meeting the new demands of customers in a timely manner.

At present, the reefer-container transportation of Maersk shipping company is no different from other shipping companies. In the terminal yard, Maersk signed agreement with appropriate local agencies, requiring at least two patrol checks a day to ensure the normal operation of reefer-containers, and downloading temperature data artificially with cable devices. On board transport, the Maersk container ships have a special placement for reefer-containers, where there is the power and data transmission interface, and the temperature data can be received directly in the ship control room and returns the corporate data center.

Reefer container transport has a relatively higher requirement on refrigeration technology and status monitoring system. Reefer-container transport ship at the current stage provides basic power supply and can ensure the timely transmission of data, but in the terminal stage of yard and road transport, shipping companies and cargo owners are unsatisfied of the control of status information, as a result of inefficiency to confirm whether its agents' services are in place. Moreover, all temperature data recorded on reefer-containers have to be manually downloaded, which means a heavy workload. Various data information of reefer-container is transmitted in real-time via wireless network carriers, ensuring real-time monitoring of information in a timely manner for both shipping companies and cargo owners, particularly to deal with emergency situations and achieve preparation for ship maintaining before docking. Thus, the data can be downloaded without having to manually work but also avoid cargo damage caused by the absence of timely inspections and the practical realization of the container real-time transmission of data, a higher level of service to shippers. Since the market is not much demanding for such technology, relevant shipping companies that had originally intended only to develop have not yet entered the commercial stage.

RFID tag technology has also been tested in the Maersk planned updates, but its physical security and data transmission limitations caused no large-scale application. In addition, RFID tag information is stored in relatively fixed form mainly designed for dry containers, with the main information being the container number. But for the past few years, image-recognition technology has developed faster than the application of RFID tag technology, mostly by which dry-containers identification is carried out instead of RFID tags. Furthermore, the transmission limitations of large transmission networks need to be solved by accepting large-scale deployment. Compared to the service of mature network providers, the cost is too expensive.

At the entry gateway of ports, even if RFID tags were globally applied, it still may not be achieved without stopping by. Because the plan of the container stacking yard is not pre-established, instead it is arranged according to the order of on-site container arrival, and the computer system is only secondary. When crossing the gateway, truck drivers have to collect a small ticket printed with the yard information and then know their own loading and unloading position. Therefore, unless there is further updating of communications equipment on trucks, it cannot be achieved without stopping clearance just relying on RFID tags.

In short, from the perspective of these emerging markets, RFID may help the decision maker to identify where the bottleneck exist. In this case, the aim of such application of RFID is to better fit the Standard for Work designed by a manufacturing enterprise, better managing of key elements and spare parts, and better implementing of storage and delivery service.

4.4. From the Perspective of Device Manufacturer

RFID tags are divided into two types: passive and active. Passive tag is relatively simple, generally thin in shape, suitable for short-range signal transmission within 1 meter or less, and usually operates in high-frequency. The main transmission scenario is to issue a changing magnetic field transmitter to activate reverberation within the loop current so as to provide energy for data processing chip and data transmission. A passive RFID tag costs about 1.5 RMB, of which the cost of individual electronic chips at 0.15 RMB, and in the case of the scale of demand to reach tens of millions, a single electronic chip production cost can be reduced to 0.1 RMB.

Active electronic tag chip and the memory itself are the same as passive ones, but they require their own access to power devices. Its signal transmission distance is about

1–30 meters, and the main transmission scenario for the electromagnetic waves are high frequency signal, usually 900 mHz. The cost level of the power supply devices varies but will be much higher than the cost of passive tags.

There is a signal blind area that requires multiple signals to simultaneously read the transmitter address, or by reading the physical location of mobile objects when active electronic tags initiate long distance signal transmission, causing reflection of electromagnetic waves by obstacles, etc. Therefore, the practical deployment of long-distance transmission needs to be analyzed in container yards. Besides, there is no blind area for RFID devices to read if container trucks are within the prescribed speed. The foil inside electronic tags suffers from signal reception barriers, so it needs to be transformed into three-dimensional shape, which may give rise to the cost of the container RFID tags to some extent. In addition, due to the same signal frequency section shared by both ultra-high-frequency RFID and GSM (Global System for Mobile Communications, originally Groupe Spécial Mobile, is a standard set developed by the European Telecommunications Standards Institute to describe technologies for second generation digital cellular networks), there exists interference, but it can be resolved if reading times are increased.

RFID technology update interval is generally 2–3 years, and now it is a second generation technology, while the third generation has not yet applied. An RFID tag production line is generally 10–20 million size of capital investment. So if a large number of tags are needed, investing in an independent production line is worth consideration and even the founding of an appropriate company.

Currently, imported RFID read-write devices are about 1–2 million, while domestic one enjoys a price of 5–6 thousand RMB, and a single reader module is only 200–400 RMB, which can be combined with other data readers or sensor equipment. The handheld reader devices are generally more expensive.

5. CONCLUSIONS

As we observed, the container transportation industry is still in the elementary stages of its RFID applications. RFID applications in container transportation are not exactly the same as the RFID applications to the customs requirement. In transportation and logistics realm, information management accuracy and efficiency is more important with a relatively low system cost. Meanwhile, customs require more security guarantees. That is why the customs are working on smart container E-Seals to achieve their goals. Given the gap between the container transportation industry and the customs, as discussed in pervious sections, it is very likely that two types of RFID applications will coexist: one is a logistics tag for transportation applications and the other E-Seal, which when necessary, would be added to the exporting container.

So far, for the RFID tags in container transportation field it seems that the container manufacturer is one of the most suitable parties for container RFID tag installation because the manufacturer is the source of containers, which has the precedence to gain economies of scale and technical standards establishment and implementation.

This article does not only give a detailed explanation of RFID application but also provides the reader with the fundamental principles and a critical review of potential solutions as well as the bibliography to be checked in case someone wishes to deepen their knowledge on some aspects of this topic.

Last but not least, further research topics such as confidentiality protection, deactivating waste tag, legal framework of RFID application deserved detailed research in the near future.

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ACTIONS APPLIED BY CHINESE SHIPPING COMPANIES UNDER GHG EMISSIONS TRADING SCHEME

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Abstract

With the convening of the COP15 United Nations Climate Change Conference Copenhagen 2009, the reduction of Greenhouse Gas (GHG) emissions has once again become a popular topic. All countries present at the meeting have discussed on the standard of emissions, but failed to reach an agreement as one might ever have expected.

Although the shipping industry has not been included in the mandatory emission reduction list in the "Kyoto Protocol", as the global climate problem turns to be severe, countries in Annex I in the "Kyoto Protocol" and the EU begin to put pressure on the International Maritime Organization (IMO). As a result, IMO has put the issue of reducing GHG emissions in the shipping industry on the agenda and committed to introduce a specific standard for emissions reduction by 2011.

Moreover, in March 2009, the State Council of the People's Republic of China has issued a strategic policy on the promotion of transforming Shanghai into an international financial and shipping centre. Under such circumstance, an in-depth study of a carbon emission reduction model is far-reaching not only for the development of the Chinese shipping industry, but also for shipping companies to gain a favourable position in the carbon credits exchange market.

In addition, the Cost-Benefit-Analysis is applied to get a cost - benefit ratio in GHG emissions trading. It is compared with the cost - benefit ratio resulting from GHG emissions reduction through technical methods in the shipping industry, thus showing the feasibility of GHG emissions trading.

In this paper, an in-depth study is carried out, aiming to enhance the professionalism and technical knowledge of the Chinese shipping industry regarding GHG emissions reduction. In addition, proposals for corresponding actions are raised for shipping companies' reference, so that they will have an advanced position in the GHG emissions exchange market in the near future.

Keywords

GHG, emissions reduction, international GHG emissions trading scheme, shipping

ACTIONS APPLIED BY CHINESE SHIPPING COMPANIES UNDER GHG EMISSIONS TRADING SCHEME

1 Introduction

With the convening of the COP15 United Nations Climate Change Conference in Copenhagen in Dec 2009, developed and developing countries have argued on their duties of GHG emissions, but failed to reach an agreement. People from all areas of life have discussed on the reaction plans to the standard of emissions that will be set in 2011. While in March 2009, the State Council issued a national strategic plan regarding further promoting Shanghai as an international financial and shipping clustering city by 2020. Under such circumstance, an in-depth study of the modes to reduce carbon emission is not only far-reaching but also urgent. The main focus of this paper is two-fold. One concern is to improve the professional qualities and technical knowledge of GHG emissions in the Chinese shipping industry, thus providing proposals at the time of making decisions. The other is to propose a corresponding program under GHG emissions trading scheme from the shipping companies' perspective through an in-depth analysis. In our research, the following actions are taken:

1.1 Research Outline

(1) International organizations, historical agreements and conventions about GHG emissions standard is studied, through which knowledge is gained about the allocation of emission credits.

(2) The overall level of emissions in the domestic shipping industry and in China is analyzed. Moreover, we explore what role shipping companies would play in China in the GHG emissions trading market.

(3) Measurement indicators, such as EEOI (Energy Efficiency Operational Index) are discussed to have a quantitative analysis on greenhouse gas emissions, indicating our capability to win profits from GHG emissions trade.

(4) Current solutions to reduce GHG emissions are studied like improvement of engines and hull, grease brushing, slow-steaming sailing, fuel consumption saving, minimizing waiting time when loading and unloading containers. In addition, other feasible solutions are discussed on this basis for future application.

(5) The CDM (Clean Development Mechanism) projects which are carried out in the current market situation are studied, including foresting projects in Guangxi, hydropower projects, so as to offer suggestions for Chinese shipping enterprises when investing in CDM projects. Besides, the GHG emissions trading market is introduced for a better understanding of the existing carbon trading scheme and its future developing trends.

1.2 Research Procedures

(1) Information Collection

Regarding research methodology, we first focus on collection of information. Through a relevant literature review, including the review of "Kyoto Protocol", "Copenhagen agreement", etc. and the information on the internet, the policies carried out by the government and the Carbon trace tracking devices in all countries should be acknowledged.

(2) Survey to Enterprises

Survey of targeted shipping companies and related institutions are carried out to understand the level of Chinese carbon emissions, current corresponding actions of shipping companies and future development in GHG emissions trade.

(3) Mathematical Modelling

Some alternative Carbon Trading Programs are analyzed by applying mathematical modelling, using an integrated method to estimate their cost, cost - benefit analysis to examine their feasibility thus finding out the most reasonable program.

2 GHG and GHG Emissions Trading

GHG means those gases that can absorb solar radiation reflected from the ground, and re-release the radiation, such as water vapor, carbon dioxide and most of the refrigerants. They can make the earth's surface warmer, similar to the greenhouse's interception of solar radiation, then heat the air inside the greenhouse. This kind of effect is called "greenhouse effect."

Currently GHG mainly include water vapor (H2O), ozone (O3), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), hydrogen CFCs class (CFCs, HFCs, HCFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6),etc. [1] As carbon dioxide account for the largest proportion in GHG, it gives the largest contribution to global warming, for about 55% [1]. Nowadays carbon dioxide is usually regarded as the research objective in the international study of GHG, and other GHGs are converted to carbon dioxide equivalents.

2.1 IMO Regulations and International Conventions on GHG Emissions in the Shipping Industry

The United Nations Intergovernmental Negotiating Committee has reached an agreement on UNFCCC on May 22, 1992 and approved in the Environment and Development Conference held in Rio de Janeiro on June 4, 1992.

The goal of the UNFCCC is to reduce GHG emissions, thus reducing human activities' damage to the climate system, mitigate the climate change, thus enhancing ecosystem resilience to climate change and ensuring food production and sustainable economic development.

The 3rd session within the Parties of UNFCCC was held in Kyoto, Japan on December 11, 1997. Representatives from 149 countries and regions adopted the "Kyoto Protocol" and took effect on February 16, 2005, requiring developed countries to take the obligations from 2005 while developing countries from 2012. [2]

In 1997 the IMO adopted a new protocol of The International Convention for the Prevention of Pollution from Ships (MARPOL), namely, prevention of air pollution (Annex VI). It has taken effect on May 19, 2005 and its main purpose was to limit the emissions of Ozone, sulfur oxides, nitrogen oxides, hydrocarbons and particulate matters, etc. [3] As the emissions of CO2 account only 2.7% of total GHG emissions, the IMO did not consider it an urgent task limiting its emissions.

With the climate issues becoming severe, countries listed in Annex I of "Kyoto Protocol", EU and some developed countries began to put pressure on the IMO to take the issue of reducing emissions on to its agenda. However, in shipping practice, it is always difficult to allocate the responsibilities and emissions regions [4]. And in the recent two years, the IMO has been trying to reach a breakthrough in standardizing CO2 emissions.

In April 2008, all parties discussed and reached an agreement on the principles to regulate the GHG emissions in the shipping industry in the 57th session of the MPEC: 1) It should effectively reduce GHG emissions on the global basis; 2) It should be compulsorily and equally applied to all flag States; 3) The reduction measures should be based on the cost- benefit analysis; 4) It should at least make the minimum distortion of competition; 5) It should be a sustainable development to the environment without compromising the development of global trade; 6) It should be a target-oriented approach, not just providing a certain method; 7) It should stimulate technological innovation, research and development in the shipping industry; 8)It should consider advanced technology; 9) It should be practical, transparent, fraud free and easy to be supervised. [5]

In the 58th session of the MEPC in October 2008, the principled consensus on the regulatory of GHG emissions was approved, which was pointed out in paragraph 2 in that the mandatory emissions reduction was equally applicable to all flag States. [6]

In the 59th session of the MEPC in July 2009, the "EEDI Calculation Provisional Guidance," "EEDI Voluntary Certification Interim Guidance," "Ship of Energy Efficiency Management Plan (SEEMP)" and "Guidelines to EEOI Voluntary Use" were adopted.

In the 60th session of the MEPC in March 2010, the guidelines to EEOI voluntary use were further promoted, applied to ships of different sizes, including unconventionally designed ships and ships not using the existing exponential equation in propulsion systems. By far, GHG emissions reduction has become an inevitable responsibility to Chinese shipping companies.

2.2 GHG Emissions Trading Scheme

2.2.1 Definition of GHG Emissions Trading

With the Kyoto Protocol coming into force in 2005, Annex I listed countries have to face the obligations to reduce emissions by 5.2% [7] compared with that in 1990 during the period 2008 to 2012. In the specific implementation process, emissions quota will be allocated to enterprises. If they surpass the quota, they have to face with a high fiscal penalty and be deducted the corresponding amount of emissions quota next year. The “Kyoto Protocol" regulated that countries can exchange extra quota through GHG emissions trade to meet the standard, which is called the GHG emissions trading scheme, thus shaping the market mechanism.

2.2.2 Carbon Trading Mechanism

The overall carbon market is divided into quota trading market and voluntary market. Quota trading market provides emissions trading places for developed countries to complete its obligations. While the voluntary market is available for countries or enterprises to carry out the voluntary carbon trading to take responsibilities regarding protecting environment, to cumulate brand reputation, to accomplish social responsibilities and economic benefits.

(1) Quota Trading Market

Carbon quota traded in such market is bound by law or agreement. "Kyoto Protocol" provides three types of market mechanisms to promote the trade. They are, Emissions Trading (ET), Joint Implementation (JI) and CDM.

According to Article XVII of "Kyoto Protocol", ET refers to the trading among national registries in Annex I countries, including the transfer or acquisition of "emission reduction unit", "emission reduction warrants ", "assigned amount Units "(AAUs)," removal units "(RMUs),etc.

According to Article VII of "Kyoto Protocol", JI refers to the exchange of "emissions reduction units "(ERU) among Annex I countries under the supervision of Supervisory Committee.

Under the Article XII of "Kyoto Protocol", CDM regulated the trade between Annex I countries and non-Annex I countries in CDM Registry. The purpose is to let non-Annex I countries reduce the emissions under the premise of sustainable development and Annex I countries get "certified emission reductions" (CERs) to reduce the costs of implementing the commitment of UNFCCC. [7]

(2) Voluntary Market

Voluntary trade includes personal or business-specific activities to compensate their GHG emissions, mainly out of marketing, environmental responsibility, brand building. Voluntary transactions not only take place in exchanges, but also over the counter. As there are no laws or regulations, OTC transactions usually cost low and provide a wider variety of trades, including the Verified Emission Reductions (VERS), Unverified Emission Reductions (NER) and Prospective Emission Reduction (PR) and so on.

2.2.3 Main Trading Markets

(1)International Exchanges

Up to 2010, there were four international GHG emissions trading exchanges in the world, i.e., European Union Greenhouse Gas Emission Trading Scheme (EU-ETS), UK Emissions Trading Group (ETG), Chicago Climate Exchange (CCX), National Trust of Australia (NSW) [8], etc.

EU-ETS was a framework for reducing emissions founded by the EU on October 25, 2003. It is a multi-national GHG emissions trading system with the most participation countries, primarily in the areas of high energy-intensive heavy industry sectors, including energy, mining, smelting, steel, cement, glass, paper and other industries.

CCX is the world's first platform for voluntary emissions trading. It has about 300 member companies, concerning aviation, electricity, environment, automobile transportation, energy and other areas. Five of the member companies are from China. And its trading products include CO2, CH4, N2O, NFCs, PFCs, SF6, etc.

As for the four exchanges, the US and Australia are not "Kyoto Protocol" member states, therefore, only the EU-ETS and the ETG are truly international exchanges. In addition to the above four exchanges, there are other small-scale but fast-growing markets. For example, Regional Greenhouse Gas Initiative (RGGI) in East America aims to maintain the level of emissions during 2009 to 2014 as the current level, and to cut the emissions during 2015 to 2018 by 10% compared with that in 2009. [9] There is also New South Wales GHG emissions trading system which was officially launched in January 2003 and Canada's first CO2 emission quota trading market: the Montreal Climate Exchange.

Moreover, in Asian, Hong Kong HK Exchange is preparing for a GHG emissions trading floor. Also another 20 exchanges including BlueNext Exchange in France, ACX-CHANGE, and the European Energy Exchange are all operating in different business modes.

(2) Exchanges in Mainland China

There are also several Exchanges in China, such as Wuhan Optics Valley United Assets and Equity Exchange, Changsha Environmental Resource Exchange, Tianjin, Shanghai, Beijing Environment Exchange. Xiamen is also planning to launch an international exchange in the coming years. However, lacking of relevant laws and supporting measures, there's not a single regulation carried out by China to standardize the voluntary trading market and audit the carbon trading transaction system. Because of this, China always stays in an unfavourable situation when doing transactions in the international exchanges

Along with Copenhagen 2009, China Beijing Environment Exchange launched the so-called "Panda Standard", which is regarded as the first voluntary emission reduction standard of China. While no specific measures were announced, the "Panda standard" established voluntary emission reduction standards and testing principles and provisions of the voluntary emission reduction processes, assessment bodies, and such rules limit the content to improve China's carbon emissions trading market mechanisms. The introduction of this standard also indicates that China's carbon exchange in a more standardized step on the road, but also for the future implementation of China's carbon trading mechanism to provide favourable conditions.

Moreover, in order to obtain favourable position during negotiation in the future international GHG emission trading market, China has carried out the first voluntary emissions standard set by China: the "Panda standard" in Copenhagen Conference, which indicates that the GHG emissions trading will become more standardized and more initiative in China. The "Panda Standard" Version 1.0 was drafted by four organizations, Beijing Environment Exchange and the BlueNext Environmental Exchange as the initiator, and the Chinese forest rights organization exchanges and Winrock International Agricultural Development Center as the co-sponsors.[10] It is learnt that "Panda standard" is to establish a standard for voluntary emissions reduction processes, assessment institutions, etc.

3 GHG Emissions in China and the Chinese Shipping Industry

3.1 Overall GHG emissions in China

Due to the large number of GHG emissions, global warming became more and more severe in China. According to the statistics issued by the Chinese Meteorological Administration, over the past century (1908-2007) China's average surface temperature has increased by 1.1˚C. Since 1986 China has had 21 warm winters. In the past 30 years, surface temperature of coastal sea has increased by 0.9˚C, while the coastal sea level has a rise of 90 mm [11]. To some extent, the climate phenomenon is caused by the greenhouse effect. Therefore, it is time that the Chinese government takes actions to prevent the harm of GHG.

According to BP Global Energy Statistics Yearbook 2009 data, China's GHG emissions in 2008, s accounted for 21.8% of global emission, with an increase of 6.4% compared to 2007. Seen from Figure 1, China's CO2 emissions volume is increasing year by year, and the growth rate is also on the climbing trend.

In the Copenhagen meeting, China proposed to complete the reduction of 40% -45% by the year 2020. [13] China has always taken the voluntary responsibility to reduce the emissions before the "Kyoto Protocol" effect ends in 2012. According to the discussion in the Copenhagen meeting, there is little possibility that developing countries will bear mandatory responsibilities in a short period. Therefore, if in the near future China does not need to take the mandatory responsibility, under current CDM mechanism, Chinese shipping companies can buy emissions quota from other industries in China.

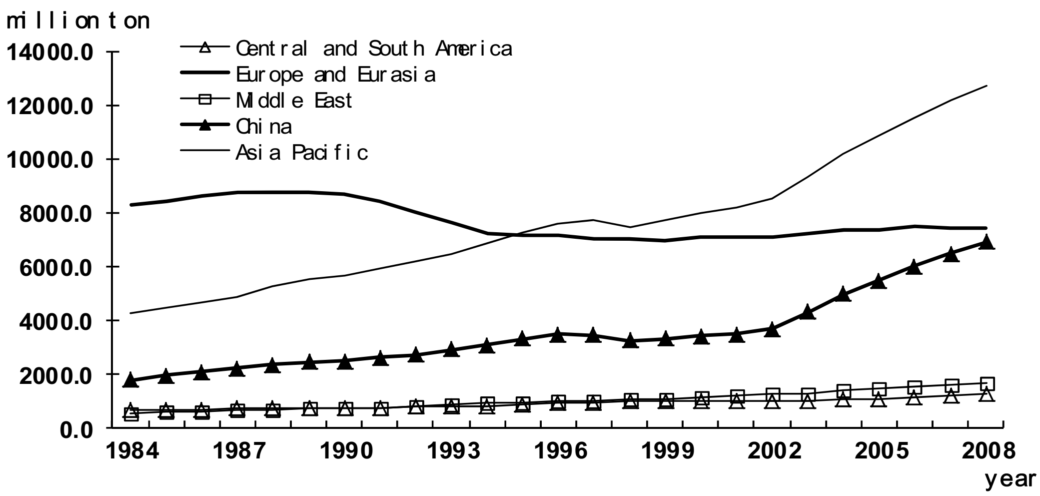


Figure 1 CO2 emissions over the years (details in Appendix I [12])

Source: Authors own composition

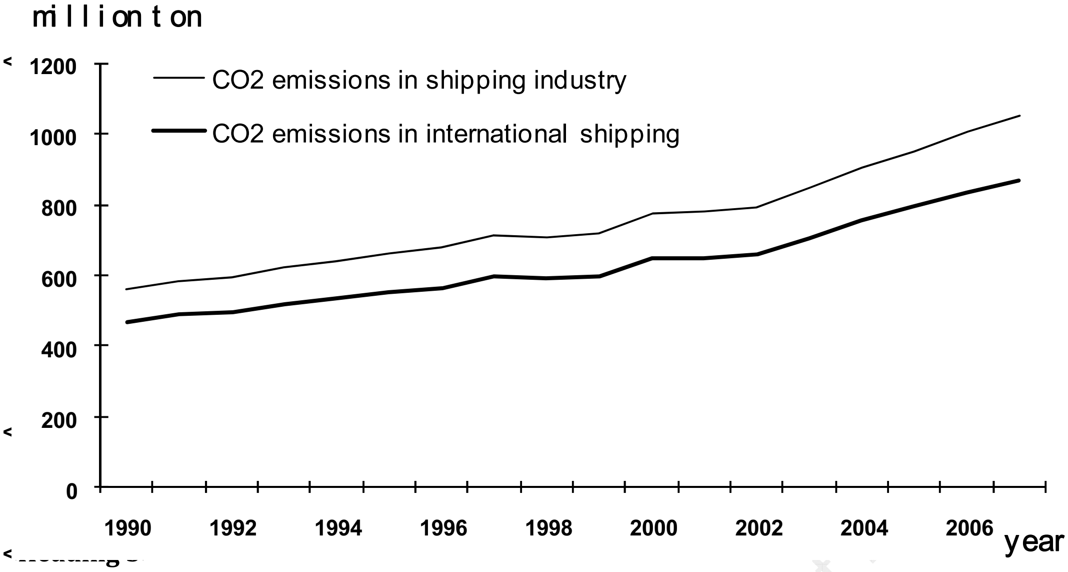
3.2 GHG emissions of Chinese Shipping Companies

The CO2 emissions in international shipping account for the majority in shipping. MARINTEK research Centre from Norway, CE DELFT Research Centre from Europe, Dalian Maritime University and other institutions cooperated and edited "IMO GHG Study Second", through which collected and calculated the CO2 emissions from 1990 to 2007. It is the world's most recognized authority statistics. The data are given in Table 1.

Table 1 1990-2007 CO2 emissions and fuel consumption in the shipping industry (from [14])

year	CO2 emissions in the shipping industry (million t)	include：international shipping (million t)	Fuel consumption in the shipping industry (million t)	include：international shipping （million t）
1990	562	468	179	149
1991	587	488	187	155
1992	598	498	191	159
1993	624	519	199	165
1994	644	535	205	170
1995	663	551	211	176
1996	679	565	216	180
1997	717	596	228	190
1998	709	590	226	188
1999	722	601	230	191
2000	778	647	248	206
2001	784	652	250	208
2002	794	660	253	210
2003	849	706	270	225
2004	907	755	289	240
2005	955	795	304	253
2006	1008	838	321	267
2007	1054	870	333	277

Figure 2 1990-2007 CO2 emissions in the shipping industry



According to the data above, in 2007, CO_2 emissions from the shipping industry accounted for about 3.3% of the global CO_2 emissions. And international shipping emissions account for 2.7% of total emissions. According to the forecast in this literature, if there's not any reduction measures taken, by 2050, the international shipping emissions will grow by 2.4-3.0%, account for about 6% of overall emissions. [14]

The European Committee (EC) issued that it will create a regional shipping system to regulate CO_2 emissions if the IMO continues not to take actions. [4] In any case, the IMO is facing great pressure to reduce emissions.

In the 58th convention of the MEPC, the IMO has already reached a consensus that mandatory responsibility should be equally allocated to all ships, but the detailed allocation is still in discussion, hoping to differentiate the responsibility between developed and developing countries though schemes like carbon taxes and emissions trading. While up to the 60th convention of MPEC, it is still a deadlock.

Although the emissions of in the shipping industry account for a small portion of the overall emissions, the growth rate is high. As China's total emissions are exceedingly large, in accordance, the emissions in the Chinese shipping industry are also very large. Once taken a mandatory responsibility, Chinese shipping companies must face severe pressures.

4 Difficulties of Chinese Shipping Companies Implementing GHG Emissions Trading

4.1 Forecast of Future Emissions Reduction Policies

In recent years, the IMO has discussed the guidelines of GHG emissions reduction, looking for a consensus of GHG emission reduction mechanism in the industry. According to the recent discussion, there are several options as follows:

(1) Market-based instruments (MBI)

a) Levying Marine fuel tax, which is raised by Denmark, is the simplest and most detailed program of MBI, but there are still many controversial issues, such as who will manage the fund, how much fuel tax should be levied, whether the fuel tax levied should be spent on CDM projects, etc.

b) Emissions trading, which has strong support of the EC, EU governments and some industry groups, is considered as the most appropriate option of MBI. While there is not a single standard operational process, it still remains controversial.

c) Other programs

There are other programs, such as levying less fuel tax if the ship formula is optimized, but there are also objections that it will be easier for old ships to reduce fuel duty.

The United States raised a program that can trade EEDI index between efficient hull and low efficient hull, instead of carbon emissions trading. But there is no clear standard for ship coefficient, especially "which kind of ship is below the standard". [15]

Among MBI, GHG emissions trading scheme, despite many disputes, shares the most support and is considered the most suitable option.

(2) Technical Program

The IMO has encouraged the voluntary use of parameters such as EEDI to optimize the design of new ships. Fuel consumption can be reduced by 20- 30% through such method, thus saving the fuel cost.

However, this method also has some limitations. For example, for a number of existing vessels, it costs too much to achieve the optimization. In addition, with the "NOx Technical Code" coming into effect, many of the existing ship engines' efficiencies have been improved [16], it is difficult to be further improved.

(3) Operating Program

Operating program refers to the emissions reduction through the means of using shore power, slowing down, making use of large ships, etc. However, the effect is not that significant as that of the other two programs because it will affect normal operation of shipping companies.

According to the "Discussion Paper of GHG" by the World Shipping Council (WSC), Copenhagen Conference might not overturn the current agreement on controlling emissions; instead, it only further regulates the existing agreement. The shipping industry is now concerned about what rules it will carry out, such as: 1) whether it will reach a consensus reduction target, 2) whether it will levy carbon tax to establish the UNFCCC funds, 3) whether a cross-regional emissions trading will be shaped. [15]

Once a consensus is reached, the solutions will be introduced no later than 2011. Most likely the solution will be a combination of several programs.

4.2 Present Disputes and Difficulties of International GHG Emissions Trading

Among various programs of MBI, there is one about GHG emissions trading, which still remains controversial and cannot be approved.

There exist difficulties and stress to implement GHG emissions trading with a uniform standard and the controversies are predicted in the following subsections.

4.2.1 Allocation of Emissions Quota and the Setup of Emissions Baseline

It is difficult to determine emissions reduction credits; even if determined, there are still problems to remain, such as how emission credits will be allocated? Whether it should be for free? Who should do the distribution? What criteria should be taken?

Another important problem is determining the emissions baseline. However, as developed countries have emitted a lot of carbon dioxide in the previous stage of development, which developing countries have not experienced, it will be unfair using the same baseline to limit emissions.

4.2.2 Allocation of Obligations

Whether the obligations should be allocated to ship owners or operators remains controversial, as the two sides have quite close relationship.

It was suggested that the obligations can be distinguished by registration country or flag State, but it is easy to shirk obligations by changing flags.

There are also views to distinguish obligations according to the destination of the voyage to achieve "common but differentiated obligations." But there is a problem for liner shipping, because the liner is not a point to point transport and it is hard to determine the responsibility of intermediate or transhipment ports.

4.2.3 Completion of Emissions Reduction and Punitive Measures

The IMO should take the audit of completion of emissions reduction into account, whether audit it by fuel consumption or by other means. If monitored by fuel consumption, it will come across the problem of inter-regional audit.

Meanwhile, if ships cannot meet the target, whether to give a fiscal penalty is also a problem. Assuming that giving a fiscal punishment, then how to set up the amount? And who is going to keep that account?

4.2.4 Transaction Mode

Even if the above problems have been solved and it comes to GHG emissions trade, there would inevitably be the following problems encountered.

Where can the trade take place and how to set the price, whether it should be fixed or unfixed? What should be the transaction mode? Should they trade by annual quota or several-year quota? Should there be a limit to the trading quota? Is there a regulation that is only part of the companies that can take part in the transaction?

Most of the participating countries supported that the shipping industry can buy emissions quota from other industries, while the precondition is that there exists a global trading system. However, the difficulty lies in who is going to set up such a system, the governments or the UN? Even if the system is set up, how to guarantee that it is in consensus with the Copenhagen agreement?

Also, how to ensure the enforcement of GHG emissions trading is a difficulty. It is easy to shirk responsibility if there is no clear-cut punishment.

All the above aspects are still in discussion, and they are questions that cannot be solved within a short period. Currently we can only wait for the policies carried out by the IMO, predicting and doing early preparation for these policies.

5 Corresponding Programs of GHG Emissions Trading

5.1 Mathematical Modelling

In the following we introduce several sets of programs for Chinese shipping companies' reference in the future emissions trading, and compare them with operating and technical programs to judge whether they are economical and practical. A comprehensive estimation method is used to calculate the cost of the following programs.

The comprehensive estimation method includes three basic components:

A. Work Breakdown Structure (WBS). WBS is a clear definition of the work elements in a project and the relationship between them. And the cost and revenue of the project is estimated through WBS.

B. Cost and revenue classification. In order to estimate the cash flow of all levels in WBS, there is a classification of costs and revenues.

C. Estimation. Mathematical models are selected to estimate the costs and revenue during the research period. [18]

The WBS chart is shown in Figure 3.

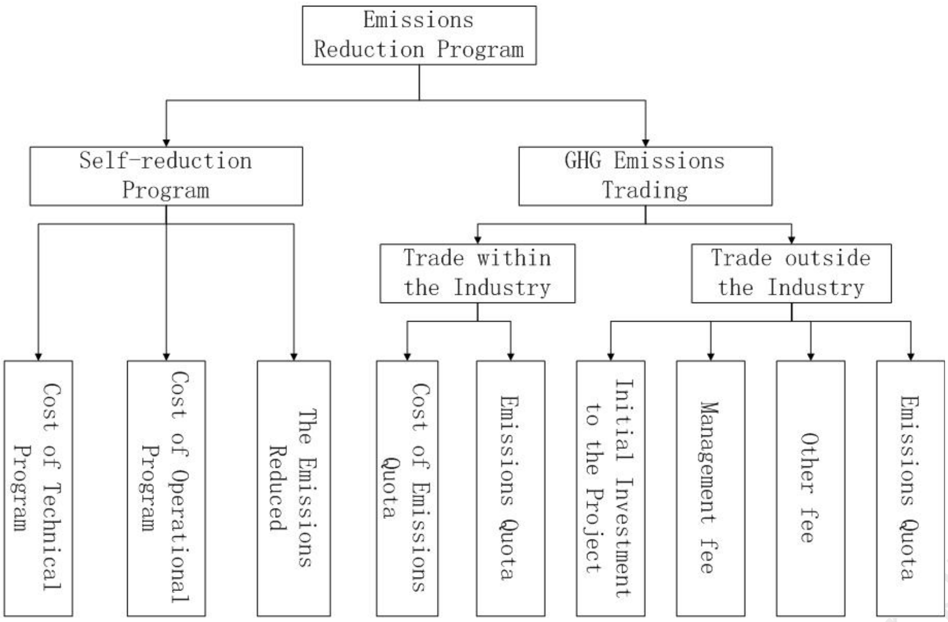


Figure 3: WBS Chart of Emissions Reduction Program

5.2 Emissions Reduction Examples

The corresponding actions are divided to two programs, self-reduction program and emissions trading program. And emissions trading can be inside and outside the industry. And there will be a cost - benefit analysis between the two programs to state the feasibility of emissions trading.

5.2.1 Self-reduction Program

According to a survey, Chinese shipping companies now have their own way in the implementation of emissions reduction, among which the "Ship Adding and Slow-Steaming Sailing" is the most economic and commonly used temporary solution as it can also deploy the extra capacity on the market.

Figure 4 is the cost-benefit analysis of various international shipping routes when adding one ship and two ships. The calculated operating costs and carbon emissions scatter. When adding one ship, the speed will be decreased by about 3 and when adding two ships, the speed will be decreased by about 6, so the cost saving equals (annual fuel cost saved – annual fixed cost increased).

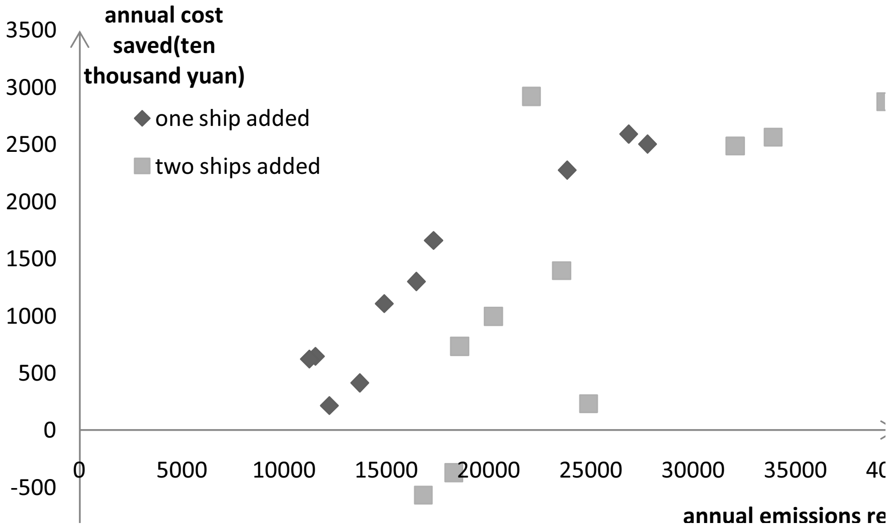


Figure 4: Cost-benefit analysis of "slow-steaming sailing"solution in various routes of international shipping

(Source: survey to shipping companies)

5.2.2 Trade inside the Industry

(1) Transactions among shipping companies of different countries

If the audit of the emissions reduction implementation is differentiated in different countries, then developed countries will take more responsibilities and there is a possibility to have transactions between developing and developed countries.

(2) Transactions between different types of shipping companies

Operating under the IMO Energy Efficiency Index, according to the following equations:

$$EEOI = \frac{\sum_i FC_i \times C_{Fi}}{m_{cargo} \times D}$$

Where:

i - fuel type;

FCi - ship sailing in the total consumption of fuel i, unit: t;

CFi - CO2 emission factor, refers to consumption of 1 ton per fuel i CO2 emissions quality, unit: t (CO2) / t (fuel);

mcargo - cargo capacity, unit: t, TEU, or people (for passenger ships), as the case may determine;

D - navigation mileage, that ships in the transport operation in the actual sailing distance, unit: nm.

EEOI units need to be determined by goods species, can be: t / t • nm, t / TEU • nm, t / person • nm, etc.

The smaller EEOI value is, the higher the energy efficiency of the ship is.

According to "Index of ships operating efficiency," selecting normal operating status for a variety of ships (assuming the standard container ship operating status: Vs0 = 22kn, D0 = 6000nm, R0 = 70%, tp0 = 96h; tanker standard operating status : Vs0 = 12kn, D0 = 6000nm, R0 = 70%, tp0 = 96h; bulk carrier standard operating status: Vs0 = 12kn, D0 = 6000nm, R0 = 70%, tp0 = 96h), get the result of typical ship EEOI index as follows:

Table 2 Typical Ship EEOI index

Source: Reference [20]

Dwt(t)	Container Ships	Bulks	Oil Tanks
15563		16.36	
29049		11.41	
34748			8.48
38521		5.89	
41983			7.43
45541			7.34
50137	18.92		
52242	17.84		
57596		5.84	
62127			7.02
68635			6.04
69229	16.57		
73937		4.15	
75493			4.86
98500	15.09		
102453	14.99		
111572	13.64		

Dwt(t)	Container Ships	Bulks
15563		16.36

The calculation results are as follows:

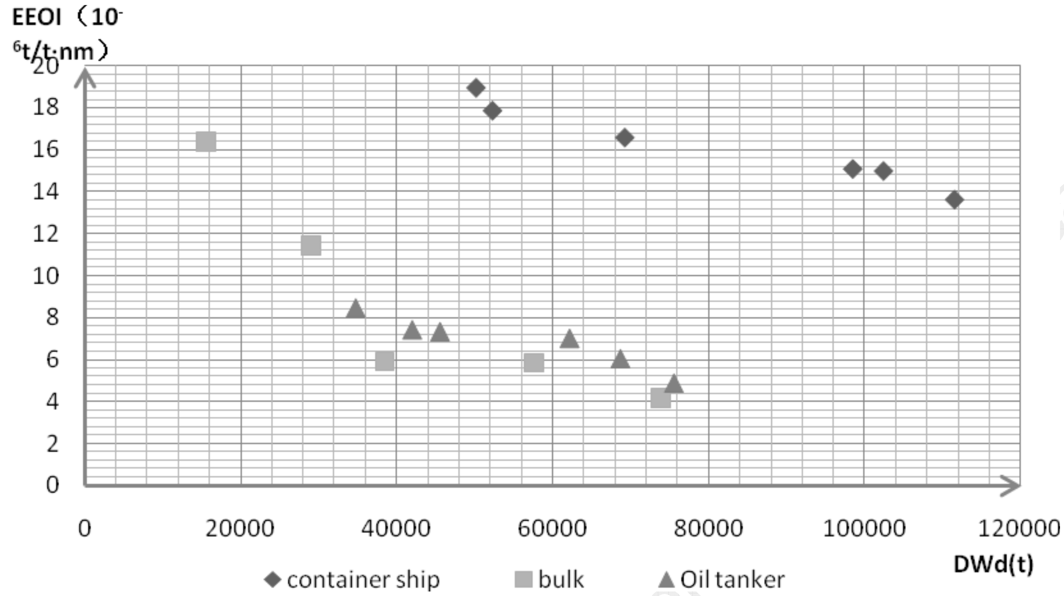


Figure 6: EEOI index of different types of ships

According to the calculation results, in normal operation, container ships share the most CO2 while bulk cargo ships emit the least. Therefore, it is possible that different types of shipping companies can have transactions, particularly, subsidiaries of some shipping companies can easily exchange emissions quota in internal coordination.

Since whether the transaction is taken place among shipping companies from different countries or among different types of shipping companies, the transaction price and scope can only be fixed after the IMO has set the emissions standard. Therefore, this article will not calculate the cost-benefit of trade inside the industry, just clarify its possibility.

5.2.3 Transactions outside the Industry

(1) Collaboration with other modes of transportation

The results show that in normal operation, different transportation modes emit different amounts of CO2. As shown in Figure 7, CO2 emissions of shipping mode is relatively low and is undoubtedly the most environmental-friendly one.

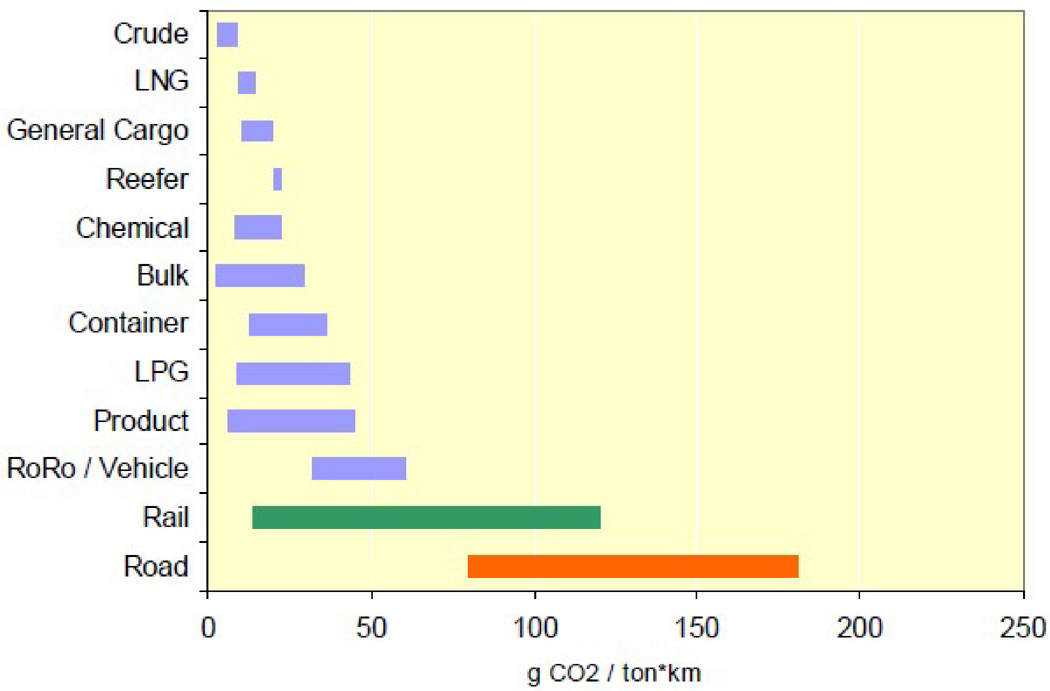


Figure7: Typical range of ship CO2 efficiencies compared to rail and road

Therefore, it is possible for Chinese shipping companies to work together with other transport companies to set up CDM projects and get emissions quota.

Rarely have domestic literatures concern about this issue, but foreign scholars have studied on multimodal transportation. For example, Kim and Van Wee [19], combined with the actual condition in China, state the feasibility of this program.

Select Chongqing - Shanghai route, based on truck-only and trucks - shipping - truck model, assuming the goods is a 20-foot standard container (weighing about 22 tons), and give out the cost-benefit result of this program.

1) Route

A. Chongqing - Shanghai truck-only program

The route is from Chongqing to Shanghai via State Road 318, for a mileage of about 1949 km. B. Chongqing - Shanghai truck - shipping - truck model

The sailing route from Chongqing to Shanghai is along the Yangtze River, passing ports or cities including Yueyang, Wuhan, Jiujiang, Wuhu, Nanjing, Zhangjiagang. The total length of the route is about 2399 km, of which 648 km is from Chongqing to Yichang, 626 km is from Yichang to Wuhan, 1125 km is from Wuhan to Shanghai. It is assumed that both ends of trial are 50 km. The basic parameters of these two modes are assumed according to the data of [19], listed in Table 3.

Table 3 Basic parameters of two nodes

Mode	Energy	Distance（km）	Average speed（km/h）	Time consumed（h）
Truck-only	Diesel	1949	60	32.5
Truck-shipping-truck	Diesel	2399(Shipping)+100（Truck）=2499	20nm/h/ship 60/truck	66.4

In 2008, the cost of a normal truck transport is 10 RMBs / km * box, so the total cost of truck transportation is 10 * 1949 = 19,490 RMBs / case. While the multimodal model costs 4663 RMBs / case, 14,827 RMBs / case cheaper than truck-only mode. The specific cost is shown in Table 4.

Table 4 Cost of truck-shipping-truck multi-modal transportation

	Item		Cost
I	Truck cost	Yuan/case	630
II	Sail cost		
1	Chongqing to Yichang	Yuan/case	1126
2	Yichang to Wuhan	Yuan/case	997
3	Wuhan to Shanghai	Yuan/case	1110
III	Port fee	Yuan/case	400*2
Total			4663

Emission Reductions

Based on the data of "Second IMO GHG Study", calculate the emissions reduction quota. Generally, trucks emits 90-190 g CO2 / t˙km, take an average of 140 g CO2 / t˙km; container ship emits 7-50 g CO2 / t˙km, take an average of 28.5 g CO2 / t˙km.

Total emissions of truck-only mode = 1949 * 22 * 140 = 6002920 g = 6 t CO2, Total emissions of truck - Shipping - Truck mode= 100 * 22 * 140 +2399 * 28.5 * 22 = 1812173 g = 1.8 t CO_2,

Compared to truck-only mode, multimodal transport mode emits about 4.2 tons CO_2 less.

Cost-Benefit Analysis

Using the multimodal transport mode can not only get a certain amount of CO_2 emissions quota but also save the transportation cost. If Chinese shipping companies take a mandatory emissions responsibility in 2011, then they can work together with logistics companies to realize the reduction and pay them fees to get the emissions quota. The minimum cost = (transport loss of logistics company - transport fees get by shipping companies) = 14,827 Yuan / box, the CO_2 emissions reduction = 4.2 tons, that is for 1 ton CO_2 emissions reduction required for about 515 U.S. expenses.

According to the above results, it is possible to realize the GHG emissions trade through cooperation with logistics companies while there are still some limitations:

First of all, this kind of reduction can only be practiced in inland waterway shipping as international transportation rarely uses truck-only mode. However, inland waterway shipping emissions accounted little for the total emissions of shipping companies. Secondly, because of the geographical constraints, it is not easy to conduct multimodal transport in mainland China. Lastly, the Chinese political environment determines that the China Ministry of Communications, Ministry of Railways and shipping companies work separately. Therefore, multi-party negotiations and efforts are needed to achieve cooperation.

Investing in CDM Projects of Other Industries

According to data given by the Chinese Bureau of Statistics, the operating costs of various industries to manage the waste each year is listed below in descending order (including carbon dioxide, carbon disulfide, hydrogen sulfide, fluoride, nitrogen oxides, chlorine, hydrogen chloride flower, carbon monoxide, sulfuric acid (fog), lead, mercury, beryllium compounds, production of soot and dust); see Figure 8.

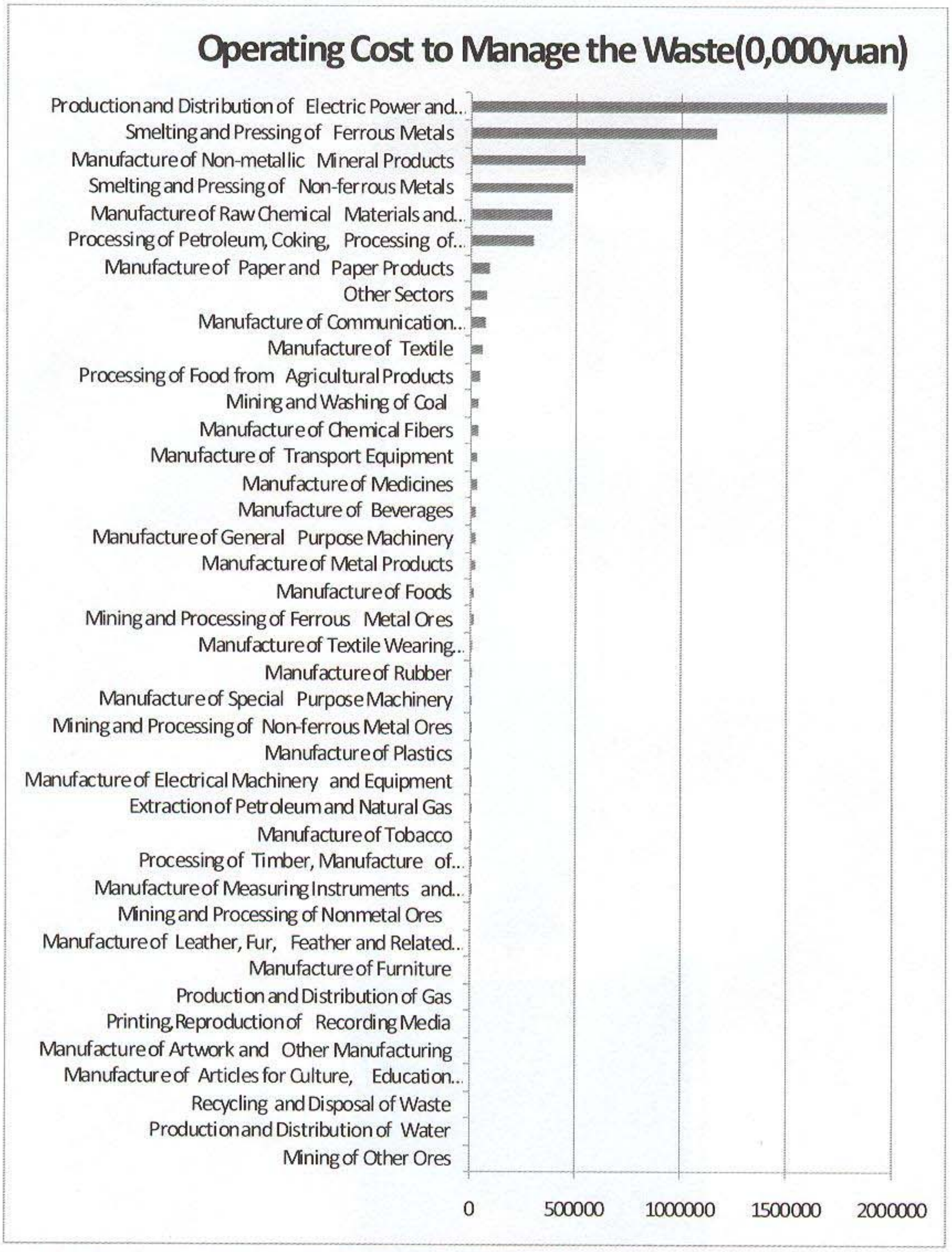


Figure 8: Operational cost to manage the waste in various industries

The cost of the transportation industry is higher than average. Therefore, as part of the transport industry, shipping companies can purchase emissions quota from lower-cost industries, thus saving the cost of their emissions.

The CDM projects in developing countries can be generally divided into three modes: single mode, bilateral and multilateral mode. Unilateral model refers to the independent implementation of CDM projects by developing countries, then selling the CERs in the market; bilateral model means developing and developed countries cooperate and develop CDM projects or all invested by developed countries, and developed countries get the CERs; multilateral mode refers to several developed countries to establish a foundation to invest in the CDM projects, and the CERs are owned by the Foundation.

If in 2011 the Chinese shipping industry was given mandatory responsibility to cut in emissions, then the shipping industry buy CERs in international emissions transactions or invest in CDM projects of other industries. However, there is a precondition that Chinese shipping companies should spend less to purchase CERs from other industries than reduce emissions through operation and technical programs so that the investment is meaningful. A CDM project developer, in general, should bear the cost as shown in Table 5.

Table : Costs C pro ects

Cost to develop a CDM project
Project screening
Develop/select methodology and estimate the emissions reduction
Prepare relevant technical documents
Permission of the host, consultation from stakeholders, environmental impact assessment
CER purchase agreement
DOE approval of the project
Registration fee
Monitoring
Verification and certification costs
Adaptation costs (2% of the total CERs)

Source: Authors' own composition

To further explain the feasibility of shipping enterprises investing in CDM projects of other industries, "Hydropower CDM Project case study" by [24] is applied as follows:

In the hydropower CDM project case, the project can get an electronic capacity EGy = 1.09 × 105MWh, based on the emissions formula, the available emissions reduction: ERy = EGy × EFy = 102.95 × 106kg (EGy for the electronic capacity; EFy for the comprehensive emission factor of Central China Power Grid)

The parameters for the project are stated in Table 6.

Table : Parameters of hydropower C pro ects

Source: Reference [24]

Serial	key parameter	values
1	An installed capacity / MW	35
2	line capacity / MWh	93170
3	Tariff / (dollars · kWh-1)	0.301
4	years generating revenue / million RMB	2804
5	project life cycle / a	30
6	unit price reductions (CO_2) / (dollars · t-1)	9.5
7	rate / (USD / RMB)	1/7.95
8	hydropower industry benchmark yield /%	8
9	Tax - VAT /%	17
	Tax - surcharge for education /%	8
10	investment in fixed assets of / 0,000RMB	29229.15
	Of which: Capital /0,000RMB	5976.69
11	operating costs / 0,000RMB	254.8
12	construction period interest rate /%	6.84

Despite the value-added taxes and time effect, annual earnings of the project = annual energy revenues - (fixed assets investment + operating costs) / project life cycle = 2804 - (29229.15 +254.8) / 30 = 18.212 million Yuan, that is when invest in the project can get the maximum profit of about 18.212 million Yuan, while get about 102,950 tons of CO_2 emissions reduction, equivalent to a profit of about 26 U.S. dollars for1 ton reduction per year.

This section has listed several possible programs of GHG emissions trade, the cost-benefit result of all programs are shown in Table 7.

Table 7: Cost- benefit of all programs

	Self- reduction program	Trade inside the industry	Trade outside the industry (cooperate	Trade outside the industry

			with other logistic companies)	(invest in CDM projects of other industries)
Cost-benefit	Annual operating cost savings of -34 to 132 U.S. dollars per CO_2 emissions reduction	No specific calculation	A pay for 515$/ carton operating cost per CO_2 emissions reduction	Maximum annual profit of 26$ per CO_2 emissions reduction

Source: Authors' own composition

From the economic point of view, investment in CDM projects of other industries is quite economic, not only able to achieve some economic benefits, but also get emissions reduction credits. Although it is not as economic as the self-reduction program of shipping companies, it has no limited amount of reductions while the self-reduction program has.

If shipping companies exceed the IMO emissions standard a lot, they have to purchase emissions quota from other companies or countries. Regardless of its economy, the cooperation with logistics companies has certain practical limitations and is complicated, trade inside the industry is simple while its economy is unknown, and investment in CDM project of other industries can be seen as a quite simple and economic program, recommending shipping companies to have practices in the future.

6 Conclusions and Further Research

Under the background of the Copenhagen Conference, the IMO forced to carry out criteria for emissions made by the shipping industry. As Shanghai is accelerating itself to be an international financial and shipping centre, this research has predicted the potential programs taken out by the IMO, market-based instruments, from both the technical and the operational perspective.

Whatever programs the IMO would introduce, it is necessary for Chinese shipping companies early involved in GHG emissions trade to gain an advantage place in the market, reacting better in 2011 in case there is a mandatory responsibility coming up.

An integrated estimation method and a Cost-Benefit-Analysis are introduced in this article to compare all the possible trading programs , among them, investing in CDM projects of other industries is the most economic and practical, which is recommended for practitioners.

This article aims to enhance professionalism and technical knowledge of Chinese shipping industry to emissions reduction and have better corresponding actions to 2010 IMO policies.

So far, there are no specific emission reduction standards, the corresponding actions in this article are based on predictions of the IMO policies. With the IMO proceeding the discussion the responding actions will change accordingly. Moreover, with the market becoming mature, the economy and practice of GHG emission trade will gradually become more feasible. This article just proposed the feasibility, looking for further standardization and amendments.

Because of time constraints, part of the quoting data is not shown in detail. In the forthcoming study, further research can be obtained to get more specific results for certain CDM projects.

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LOCATION PLANNING OF DRY PORT BASED ON LOGIT-THE CASE OF SOUTHWEST CHINA

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Abstract

In the face of increasing international trade and subsequent transportation demand, dry port is positively being considered as one good solution to not only relieve problems at seaports like congestion, service in short supply, etc. What's more, it's one kind of way to improve inland cities through facilitating local import and export transportation and forming advantages to attract other investment. With this respect, governments of inland cities are competing to attract more transshipment in order to achieve economic balance between the profits and large cost spent in the process of constructing dry port. Multinomial Logit model, standing from shippers' preferences, provides particular prospective for decision makers in an much intuitive form, according to which, different influence factors and respective coefficients can be discerned on the base of demand from dry port users, and then by taking measures to exert strength and enhance weakness of candidate locations, relatively large probability of being chosen as dry port construction location is available. This paper forms a location planning model with combining multinomial logit and objective optimization and then a case from southwest china is given to verify such model.

Keywords

Dry Port, Multinomial Logit, Customer Preference, Objective Optimization

Location Planning of Dry Port Based on Multinomial Logit

1. Introductions

With international trade increasing among countries all over the world, container shipping surged and also give rise to two kinds of main situations: onerous burden of containers for seaport to deal with, and emerging seaports conforming to such trend exacerbate the competition among them.

Regarding the first situation, from reported delays, seaport is facing with capability not high enough in handling those containers resulted by increasing trade turnover across international countries; Together with this situation seaport is at risk of losing the opportunity of attracting more ships' berthing. Besides, carbon dioxide emission produced in the waiting hour from vehicles caused by congestion in the inner seaport station should be seriously taken into consideration in the environmental friendly focused age.

For another situation, due to the internationally economic development and growing trade volume across countries, governments paied vigorous attention on developing seaports including efficiency improvement by ameliorating seaports' operation environment, and new seaports' building to add service supply. All these policies and activities from administration have made seaport industry a much intensely competitive area. Besides, seaports have actively joined in the trend of developing into the fourth generation, for which, the competition among ports is substituted by the competition among ports' supply chain originated from hinterland. Broad hinterland denotes strong support to connected seaport in the form of huge commodity supply, hence that's guaranteed the seaport get more chance to win in such fierce competition.

Given these two situations, dry port is gradually approached, one inland inter-modal terminal directly connected with a seaport by rail, with shippers (consignees) can leave and/or collect their goods in intermodal loading units as if directly at the seaport (Woxenius, 2004). Firstly, dry port exactly make up for those shortages faced with seaports. Efficiency can be enhanced in the seaport for the inland terminal with much similar functions has shared large workload and responsibility, like Customs clearance, etc. Simultaneously, a dry port in inland area can gather more source of goods from more cities for the connected seaport, which would not reach that far into inland by itself. In addition, except those benefits gotten by seaport, inland cities does not earn less: rail access strengthening inland-seaport communication, close trans-modal terminal facilitating import and export transportation of both local and adjacent cities, dry port construction attracting more business and investment for better development. Finally, for shippers and governments, benefits are also available. An inland constructed terminal save land cost to a great extent compared to expanding seaport area along the coastline. And it's more environmentally efficient and expense cutting with resource integration from delivering cargos to the seaport respectively by shippers to large volume of cargoes delivery by one actor (Roso, 2009).

Since the benefits of dry port construction are so obvious, and several local governments are dedicated to justify its reliability before building due to its great exspense. This paper is focused on analysing such situation from the prospective of demand of dry port's users with Multinomial Logit model in order to identify key factors in affecting probability of cities being chosen as dry port. In this paper, a background introduction above in Section 1 is followed by a literature review about dry port researches mainly in the aspect of location selection in Section 2. Section 3 describes the core methodology: Multinomial Logit model, and then one example is given to better illustrate the application of such analysis. In Section 4, a model combining multinomial logit and objective optimization is proposed to fix location selection problem of dry port. Finally, conclusion is given as Section 5.

2. Literature Review

Dry port, also called inland port (Rodrigue et al., 2010) , can be understood as an inland seaport except berthing facilities. The same as seaport, it allows several functions to be performed, including consolidation and deconsolidation, distribution and temporary storage, customer clearance, transshipment between two different traffic modes, etc.

About dry port, lots of study have been done by former researchers, ranging from qualitative terminology definition (Andrius Jaržemskis, 2007; Woxenius, 2004; Sciomachen, 2005; Roso, 2007; Rodrigue et al., 2010), functions discerning (Xu and Lu, 2006; Ye, 2005; Jaržemskis, 2007; van Klink and van den Berg, 1998; Parola and Sciomachen, 2005; Dadvar and Ganji, 2010; Dadvar, 2010), to quantitative research, like the effect made by dry port on reducing carbon dioxide emission (Roso, 2009).

Among those researches, location selection of dry port is stressed for its practical significance in supporting decision making. The location planning of a dry port is the critical issue for the whole supply chain and its relationship with seaports, shippers, transportation operators and the hinterland. As for the methods used to locate dry ports, studies show several representative models, as followed:

Hua (2005) developed a Multiple-Attribute Decision Making (MADM) method based on the TOPSIS dedicated to change fuzzy data into crisp data for selecting the most acceptable inland port from a set of candidate sites under multiple potentially conflicting objectives in a group decision-making environment, and then Multiple-Objective Decision Making (MODM) method is added with consideration of investment.

DEA is used by Yang (2006) to plan dry port location. Narrow the location scope firstly with keeping the locations that meet the main factors which take great influence in choosing dry port location, such as transportation cost, time length, shippers' satisfaction, etc, and simultaneously filtering out failed ones, in which way the locating process is much simplified. Then AHP-F is cited to list the priority sequence of the rest cities, which consider many factors that influence the competitive strength of each candidate location, like governmental policy, living culture of local citizen, transport infrastructures and facilities, etc, within which governmental policy takes a great proportion.

Government attitude toward the development of dry port always accout for the most disparities among high and low-developing cities.

Mansour Rahimi(2008) designed one model called location- allocation to locate inland ports for 5 counties served by two sea-ports in California. Location- allocation is a mathematical model to find the optimal location for more than one inland port. This model, based on a set of candidate locations obtained by using the simple facility location model for each of the five regions, not only determines the optimal number as well as the location of each inland port (i.e., a location problem), but it also determines which transportation nodes will be served by which inland port (i.e., an allocation problem). The main characteristic of the research lies in letting the evaluation of truck VMT(Vehicle-Miles Travelled) as the platform of the basic work, which considers the availability of data as well as environmental pollution. And a combined set of homogeneous traffic analysis zones (TAZs) are adopted to form new regional boundaries differing from the geological boundaries, which can be called transportation nodes (TN).

Lv and Li (2009) applied ANP, kind of like AHP, to chose dry port for Tianjin port from 4 candidate cities. A two-tier evaluation indicator system is constructed, including traffic convenience, cost, labour resource, etc. And the calculation process is done by software named super decision, the result is also verified with reality.

Fuzzy-C clustering is the most common seen method among prior researchs in location planning for dry port, the application of which is based on the uncertainty of describing local economic development and geographical location, as a result the evaluation index is of fuzziness when quantified. Zhong et al. (2008) used fuzzy c-means clustering algorithm to find the most suitable location as candidate dry port for Dalian port among 34 inland hinterland cities. It validates the adaptability and rationality of applying a fuzzy c-means clustering algorithm into the location planning of a dry port. A comparison with the existing development and layout of the dry port provides the government with a theoretical underpinning for an inland dry port location. Besides, Fuzzy Factor Rating System and Fuzzy Logic(Ou and Chou, 2009; Kuo et al., 2009) are also proposed to locate international distribution center. A fuzzy multi-objective model is developed to optimize fire station location through genetic algorithm (Yang et al., 2007).

Seen from the literature review of location planning methods, most of them have to decide the factors affecting such choice firstly, and then methodology can be carried out. However, most of related factors are added only from an subjective prospective without any data support, and location result from applied methods can not conversely verify those factors' rationality. As described in Section 1, governments or other institutions eager to make policies based on reliable analysis to perfectly make sure their decisions are feasible and profitable. Given this condition, factors' identification like those making effect to dry port location outcome forms great effect, according to which, decision makers can take measures to exert strength and enhance weakness in related fields. In some way, literatures help in suppling original factors, like distance between production base to seaports (Ng and Gujar, 2009), transportation expense and logistic spending (Wang, 2004), economy development (Zhong et al., 2008), interests conflict of different partners (Dadvar, 2010), policy regulation, infrastructure, environment, and land cost (Roso, 2008), etc. Most of those factors are going to enter the the initial step of multinomial logit model in Section 4 of this paper.

After factors are laid down, standpoint of this study needs to be clear. There's no doubt optimal service, fine transportation environment and other offerings from dry port are used to attract potential shippers using their services. Even when partners' interests are not in a line, cooperators have to acknowledge that customer is the first part who should be satisfied by co-efforts without negotiation. Considering such requirement and prerequisites of dry port implementation, an appropriate model is necessary to help decision makers find ways to satisfy customers' demands. In this paper, Multinomial Logit model (Wang, 2004; Cao, 2008) is proposed to offer one decision support, based on taking customers' preference about transportation into account. And then a model combining multinomial logit and objective optimization is raised to plan location of dry port.

3. Methodology

3.1 Logit Model

Logit model, one kind of discrete model, is generally used to analyse coefficients before factors and then evaluate probability of individual choice behaviour if relative data are available (usually through questionnaire survey). It derives several forms, like multinomial logit, conditional logit, nested logit, mixed logit, exploded logit, and ordered logit, etc, and each has its special characteristics and corresponds to appropriate situation.

Nested logit can deal with situation which violates IIA (independence of irrelevant alternatives) hypothesis while multinomial has to comply with. Mixed logit arises from the limitations of the standard logit model by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time. Ordered logit regression is used in cases where the dependent variable in question consists of a set number (more than two) of categories which can be ordered in a meaningful way (for example, highest degree, social class) while multinomial logit model is used in similar cases but with a set of categorical (not ordianl) dependent variables.

All of these kinds of logit model are extensively employed in economics, transportation, social and marketing researches, like bank credit risk prediction (Fang and Zeng, 2004), financial prewarning (Jiang and Han, 2004), enterprise growth forecast (Qiao and Zeng, 2009); path selection (Liu and Wu, 2008), traffic modes allocation (Yi and Deng, 20009), freight distribution into different routes (Zhao and Zhang, 2010); like transport charges evaluation (Wang, 2007; Hu and Xu, 2001), factors' identification influencing local farming companies' export (Zhang, 2004; Ye, 1998); market research (Huang and Shen, 2002), etc.

Among them, few found related to solving location planning problem. Cao (2008) cited logit model in his dissertation locating competitive stores, in which he expressed utility of one store as the function related to distance from a certain demand area to each store, and this function has been proved as logit model. Demand is then put into the final goal function as one factor to compute profits. Wang (2004) calculate income via multinomial logit model with consideration of transportation cost and logistic activities spending as two main influencing factors, from which the probability of one candidate inland port being chosen by single shipper can be gotten and put into income forecast related to transportation demand.

Accurately, logit model can also be used in location selection area as its application in traffic route choosing behaviour, based on deciding factors' coeffcients. Regarding its convenience (software support) and its general employment in researches, this paper is going to cite multinomial logit model to analyse the problem of dry port location selection, hence elements and respective coefficients related to which can be discerned to help governments form active regulations and measures to construct local dry port.

3.2 Modelling

In this section, this paper proposes an model based on multinomial logit to choose location for dry port, in which the transshipments one dry port collect is the key.

In this model, we assumes:

1)Both the logistic cost of each freight category and the profit each one brings are assumed to be the same;

2)And each candidate place spend the same to construct and run a dry port;

3)This model in this paper will choose dry port according to the amount of transshipment it attracts.

According to the logit model, probability of individual choice and transshipment amount can be computed through the formula:

1) $V_{ij}=0.34x_{ij1}+0.4x_{ij2}+0.26x_{ij3}$ means the contribution of candidate city j to city i; the value of x_{ij1}, x_{ij2}, x_{ij3} can be found in the above table;

2) $P_{ij} = \frac{e^{v_{ij}}}{\sum_{j=1}^{5} e^{v_{ij}}}$ i indicates choice behaviour, i=1,2...16; j=1,2,...5, means candidate city;

3) $M_j = \sum_{i=1}^{16} T_i * P_{ij}$ means the summed freight that probably will be processed by candidate dry port j;

4. Case Study——The Southwest China

In order to demonstrate the application of multinomial logit model in dry port problem, this paper will illustrate an case study in this section.

4.1 Case Description

Yunnan province, lied in the inland southwest of China, is famous in exporting products like electromechanical, tobacco, biomedical, tourism, etc, to the contiguous countries such as ASEAN, Europe, Peru, India, Australia. Most of the exports are completed by shipping through Guangzhou port. Such export, in the strongest way, supports the full development of Yunnan province which now just awares local government to form a dry port in one of its cities. On one side, with the increasing trade amount, guangzhou port is challenged by pressure of long waiting cargos which cannot be processed in time due to lack of enough land resource and port facilities. On the other side, shippers are bothered with the high cost caused by time waste, which may harm companies' reputation and eventually the commercial profits. Current transport pattern can not satisfy emerging requirements any more. Dry port, in this case, located in one city of Yunnan, can offer an solution with better service to save cost for shippers. At the same time, dry port gives an perfect opportunity for Yunnan province to develop as an regionally international logistical hub, an portal open to the whole south Asian. Third-party logistics suppliers including freight forwarding, shipping agency, will offer "one-package", "door-to-door" solution to imports and exports with their freight, that is, freight will be processed with multimodal transport. And dry port in inner land can facilitate freights' declaration and inspection, hence congestion in Guangzhou port will be relieved effectively since freights are ready to be loaded onto ship directly rather than waiting for customs declaration activities.

Regarding the practical requirement for building dry port in Yunnan province, this paper is going to deal with the issue of location selection from all of the administrative cities in Yunnan. In such case, 5 candidate cities(Kunming, Jinghong, Hekou, Ruili, Qujing) have been selected from the whole 16 cities, and then multinomial logit is employed to choose the best candidate city, from above, it's known that the best city should be the one most attactive to collect transfreights.

4.2 Data Description

Through literature review and investigation in Yunnan, railway container hub(yes-1;else-0), accessibility, import and export trade are considered as the three influencing factors in logit model. Each factor implicates specific meaning, explained in table 2.

Table 1: Factors Connotation

Factors	Connotation
f1:wether railway container hub(yes-1;else-0)	Most dry ports built in our country base on the 18 railway container hubs construct by the railway ministry; container transportation from dry port to seaport is mainly completed by railway, in this way, a railway container hub contributes to such transportation to an extreme extent.
f2:accessibility	The number of city each candidate can reach in the same period of time. It's measured by road transport which is mostly applied in the transportation from inner shippers to dry port. Accessibility is calculated by summed distance from one candidate to all of the rest cities divided by average velocity(Cao et al., 2005).
f3:import and export trade	Import and export trade of one candidate indicate its economic vitality and future development, which just support the effective operation of dry port.

Value of three factors are defined as below:

1)According to the plan of railway ministry, Kunming belongs to one of 18 railway container hubs, hence the value of this factor is 1, and the value of other cities in this case is 0;

2)Table 2: Accessibility value of candidate cities(units)

Candidate cities	Accessibility (Time period=8 hours(normal working hours)); velocity=100km/h)	Normalization(divided by the maximum)
Kunming	15	1.000
Jinghong	10	0.667
Hekou	9	0.600
Ruili	9	0.600
Qujing	14	0.933

Source:composed by authors

3)Table 3: Import and export trade value of each cities in Yunnan(10,000$)

	Cities	Trade(Ti)	Normalization		Cities	Trade(Ti)	Normalization
1	**Kunming**	563,030	1.000	**9**	**Lijiang**	8,544	0.015
2	**Jinghong**	20,270	0.036	**10**	**Puer**	11,449	0.020
3	**Hekou**	44,152	0.078	**11**	**Lincang**	6,176	0.010
4	**Ruili**	76,279	0.135	**12**	**Chuxiong**	6,403	0.011
5	**Qujing**	15,201	0.027	**13**	**Wenshan**	7,703	0.014
6	**Yuxi**	15,652	0.028	**14**	**Dali**	14,405	0.026
7	**Baoshan**	10,403	0.018	**15**	**Nujiang**	551	0.001
8	**Zhaotong**	998	0.002	**16**	**Diqing**	696	0.001

Source:Yunnan statistical yearbook 2010

4.3 Data Processing

According to multinomial logit, each candidate has its own utility towards different behaviour, in this paper, that means the 16 cities. Utility function can be written as $U_{ij}=V_{ij}+\varepsilon_{ij}$, while visual part $V_{ij}=b_1x_1+b_2x_2+b_3x_3$, $b_{1,2,3}$ mean the weights of 3 factors, which are defined as the average evaluation of different experts. In this paper, $b_1=0.34$, $b_2=0.4$, $b_3=0.26$.

The value of x_1, x_2, x_3 in the utility function depends on each of 16 city. Factors in logit model has two kinds of characteristic, one describing nature of candidate, like f_1, f_2, f_3, the other reflecting the feature of individual behaviour. Standing from the point of choice individual, logit model includes former factors as the contribution each candidate city makes to choice behaviour, that is, satisfaction. As a result, 50 shippers in each of 16 cities will evaluate the contribution from value of f_1, f_2, f_3, scoring from 1-5, and the average evaluation in each city will be put into final utility function as the value of x_1, x_2, x_3 to calculate the corresponding probability. For example, if the average evaluation score from Yuxi city to f_1, f_2, f_3 of candidate Kunming city are 5, 5, 4, the utility of candidate Kunming relative to Yuxi will be 0.34*5+0.4*5+0.26*4=4.74.

Table 4: Average evaluation of factors' value

	Kunming			Jinghong			Hekou			Ruili			Qujing		
	x1	x2	x3	x1	x2	x3	x1	x2	x3	x1	x2	x3	x1	x2	x3
Kunming	5	5	5	1	2	1	1	2	1	1	2	1	1	3	1
Jinghong	5	4	5	3	4	2	1	1	2	1	1	2	1	2	2
Hekou	5	4	5	1	3	2	2	4	2	1	2	2	1	3	3
Ruili	5	4	4	1	2	1	1	3	2	2	3	2	1	4	2
Qujing	5	3	5	1	2	2	1	2	3	1	3	3	2	5	3
Yuxi	5	3	5	2	2	3	2	2	2	2	2	4	2	4	2
Baoshan	4	4	5	2	2	2	2	2	3	2	2	3	2	4	3
Zhaotong	5	5	5	2	3	3	2	3	2	2	3	4	1	4	4
Lijiang	5	3	5	3	2	3	1	2	3	3	2	3	2	3	4
Puer	5	4	4	2	1	2	1	1	2	2	1	4	2	2	2
Lincang	5	4	5	1	1	3	2	1	3	2	2	3	2	3	3
Chuxiong	5	3	4	2	2	3	1	2	2	2	1	4	2	3	3
Wenshan	5	4	5	1	3	2	2	3	3	2	3	4	2	4	3
Dali	4	3	4	1	2	2	1	2	2	2	2	3	2	3	2
Nujiang	5	4	5	2	2	3	2	2	2	2	3	4	1	3	4
Diqing	5	4	5	2	2	3	2	3	3	2	2	4	2	3	3

Note: 1-quite unsatisfied, 2-unsatisfied, 3-normal, 4-good, 5-excellent

Source: Questionnaire survey, Aug, 16, 2011, Kunming

4.4 Result Analysis

Table 5: Probability of each choice(Pij) and summed trade of each candidate dry port(Mj)

i i	Ti (10,000$)	Kunming	Jinghong	Hekou	Ruili	Qujing
Kunming	563,030	1	0	0	0	0
Jinghong	20,270	0.387	0.262	0.106	0.106	0.139
Hekou	44,152	0.342	0.153	0.208	0.124	0.173
Ruili	76,279	0.343	0.111	0.163	0.190	0.193
Qujing	15,201	0.310	0.122	0.142	0.171	0.255
Yuxi	15,652	0.305	0.164	0.145	0.183	0.203

Baoshan	10,403	0.308	0.145	0.163	0.163	0.221
Zhaotong	998	0.313	0.167	0.150	0.183	0.187
Lijiang	8,544	0.295	0.183	0.135	0.183	0.204
Puer	11,449	0.367	0.145	0.114	0.192	0.182
Lincang	6,176	0.357	0.118	0.144	0.175	0.206
Chuxiong	6,403	0.312	O.179	0.131	0.168	0.210
Wenshan	7,703	0.301	0.135	0.174	0.191	0.199
Dali	14,405	0.311	0.143	0.143	0.195	0.208
Nujiang	551	0.320	0.157	0.139	0.203	0.181
Diqing	696	0.313	0.154	0.181	0.171	0.181
Mj (10,000$)		643258.396	33875.452	37828.749	39887.869	45915.397

Source: composed by authors

From table 4 in the above, it's apparent that Kunming is probable to collect the most freight if dry port is developed there, while other 4 candidate cities are far cry behind. In fact, this result is reasonable since Kunming scores much higher than other cities on the value of selected factors. Firstly, Kunming is one of 18 railway container hubs issued by railway ministry, which takes significant role in facilitating distribution of freights from all cities in Yunnan province. In addition, Kunming lies in the center of provincial road transport web, for which it almost connects all of other cities in Yunnan and and it also will take much less time to reach destinations where shippers are. Finally, larger amount of transportation demand based on import and export trade, relatively to its counterparts, strongly sustains the city in the way that dry port built there will be fully feed and effectively used. From the prospective of shippers, cost saving is commonly concerned at the first. Freight forwarders or other Third-party logistic suppliers in Kunming are able to offer much cheeper but better service. Their advantages lie in being close to railway container distribution, hence transportation on road between shippers and dry port is shorten, so is the road transportation cost; the same cost reduction can also be possibly realized when logistic providers find an easy way to get shippers or dry port; cheeper logistic cost also comes with scale economy when local land can produce large amounts of import or export trade. For these reasons, Kunming, selected by most of shippers, is appropriate to develop a dry port, and this is also in line with recent plans of Yunnan government, who intends to develop Kunming toward an international portal in southeast Asian.

5. Conclusions

In this paper, logit model is applied to fix the traditional location selection problem, and then an case study from southwest China is employed to verify such application. Firstly, the characteristics of logit model are specifically studied, that is it's an tool mainly targeted to investigate preferences of choice behaviour while other tools like AHP or Clustering algorithm(Li, 2011) only concern features of candidate in location selection field. In addtion, location selection of dry port counts mostly on the transshipment it can collect and distribute, if the portal service can not been well used, the original intention of building a dry port will just waste resources. Enough freight source guarantees the effective operation which will support future development of a dry port, and even a whole city where dry port lies. In this way, what shippers think about dry port deserves consideration of decision makers. Only the dry port meets most of shippers' preferences will accumulate most transshipments, therefore create highest profits. From these two prospects, logit model is quite appropriate to deal with location selection of dry port, which is also the goal completed in this paper. However, lots of work in this paper still deserves further research. For instance, transportation demand in this paper is set off by administrative district, but more specific division can be set by freight category. The weight in utility function is decided by average evaluation of experts, and if data is available, weights should be given by MLE. Other problems like operation pattern of dry port is also an hot topic in this area.

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Verifying liner Shipping Alliance's stability by applying core theory

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Stability

ABSTRACT

The core is a vital concept in cooperative game theory and has been widely used in analyzing alliance's stability. It is especially interesting to apply core theory in liner shipping market due to the latter's exceptional characteristic of non-homogeneous cost curves as well as divisible and fluctuant demand. Having observed some new phenomena and trends in the industry, this paper studies the economic performance and stability of liner shipping alliance by applying core theory where business cooperation is partly realized by delivering joint-service with mega container ships. To demonstrate the core situation in liner shipping alliance, a cost function is first identified on the basis of two assumptions regarding cooperation: 1) sharing or pooling vessels and 2) deploying mega container ships if needed. Taking cost functions as basis, two conditions of approaching core may be groomed, i.e., collective rationality and individual rationality. The first condition is discussed from the perspective of market, while the second condition is studied within the alliance. Stability of liner shipping alliance is then observed based on these two conditions. An illustrative case study is conducted in order to show some implications and explicitly clarify the theory.

1. Introduction

One of the most significant developments in liner shipping industry over the past decades is the formation of strategic alliances. Since mid-1870s, the liner conference system has already been developed in an attempt to deal with excessive capacity and cut-throat price competition. Over the following century, numbers of agreements on freight rates, numbers of services, ports served, goods carried and acceptable mechanism of revenue sharing have been constantly developed. With the trend of containerization, standardization and global competition, liner conference system was almost exempted from anti-trust legislation step by step until the end of 2008 (Stopford, 2009). As alternative strategy of cooperation, various alliances appeared that aimed to achieve lower unit costs.

Since 2008, the financial crisis put enormous strains on the once booming global economy. Shipping industry benefits from globalization more than almost any other sectors, but has also been made more vulnerable to the economic slowdown. Freight rates and charter rates have plunged with vessels being laid off and order books being canceled. Although the recent decade has witnessed a steady increase in the size of container ships deployed along the world's busiest maritime lanes seeking for the benefit of economies of scale (Imai et al., 2006), these ships cannot fully enjoy this advantage in the current market as there is a clear surplus of fleet capacity and loading factors are low. They often start their voyages with half-empty slots - if start at all. These mega ships may present sunk cost for ship-owners. As the consequence, an extensive formation and recombination of new liner shipping alliances might be resulted and a new framework of the shipping industry might emerge soon. There have been some convincing cases. With freight rates continuing to soften, some ocean carriers start to announce new joint services on some trade lanes. The world's three largest container lines: Maersk Line, MSC and CMA CGM have announced in March 2011 that they are prepared to introduce a joint new service on transpacific route utilizing five 6000 TEU ships by the second half of this year. A number of other carriers have similar expansion plans, with market report counting at least six new loops in total that are either confirmed or being discussed.

In terms of the economic stability of competitive markets developed in the last century, game theory has been regarded as one of the most effective tools for analyzing market behavior. In particular, core theory makes predictions of the relation between costs and feasibility of cooperation by modeling the self-interested interactions of economic decision-maker. Liner shipping industry has been a main field for core application due to its natural

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characteristic of demand and cost curve. As for other transportation modes such as air, railway and road, the unit capacities are insignificant in comparison to the demand of the entire market. However the capacity of a single container ship, especially the mega container ship during one week in one lane is too large to be ignored. Hence, the marginal cost can be regarded as continuous in land and air transport but discontinuous with several sub-functions in shipping market. The liner shipping industry is also characterized by unit or box transportation where commodities are identical in shape and volume which makes the demand divisible to each carrier in the market. In addition with the variability of demand, empty core always exists in liner shipping market and shipping alliances.

Considering the increase of ship size and new strategy of alliance, this paper aims to sequentially expand the application of core theory to explore more inner mechanism of liner shipping market and alliance. The rest of the paper is organized as follows: in Section 2, a literature review of liner shipping alliance, deployment of mega container ships and the application of core theory into liner shipping industry is put forward. After a brief introduction of core theory in Section 3, Section 4 discusses market characteristics and the cost functions of both competitive and cooperative market. Section 5 discusses the stability of the alliance employing joint mega container ship by looking into market profitability (cost saving). In Section 6, an analysis on demand structure inside alliance corresponding to different joint-ship sizes is represented from members' perspective. An illustrative case is introduced in both Section 5 and Section 6 aiming to explicitly demonstrate the theoretical analysis. Conclusion is drawn in Section 7.

2. Literature review

Shipping conference as well as strategic alliance has a long history among liner companies because of fierce competition. Poulsen (2007) addresses liner shipping strategic alliance from a historical aspect. It is pointed out that historians and shipping analysts have argued that it is the technological innovation of container that has driven shipping companies toward deeper cooperation because the investment in such a new technology required access to a very large group of customers and large quantities of cargo. By means of cooperating, liner companies are able to handle a critical mass of cargo and capital for such a major investment. Haralambides, Benacchio, and Cariou (2002) denotes more details on cooperative motivations, which include wider geographical coverage, operational efficiency, risk and investment sharing, economies of scale and so on. Brooks (2000) identifies the types of technical cooperation agreements such as slot-chartering agreements, coordinated services, equipment sharing agreements and vessel-pooling consortium or joint venture. Cariou (2002) provides an "empirical estimation of horizontal effect" in alliance operational synergies and its result shows that collective action works better in achieving economies of scale.

As for deployment of mega container ships, Cariou (2002) explains that economies of scale does not restrict to the vessels only, but requires an upgrade of the whole string with large vessels. Imai, Nishimura, Papadimitriou, and Liu (2006) analyzes viability of mega container ships considering competitive circumstances by using game theory. This paper concludes that mega container ships are competitive in all scenarios for Asia–Europe lane but viable for Asia–North America lane only when the freight rates and costs of feeder services are low. Furthermore, it is also addressed that as world trade increases, the ship size will increase in a corresponding manner in order to better enjoy economies of scale. Veldman (2009) assesses the elasticity of shipping costs versus ship size for Post-Panamax ships ranging from 4000 TEU to 20000 TEU and predicts that it is time to introduce bigger ships up to 20000 TEU.

Liner shipping market is regarded as a very special study objective among all the transportation market because of its nature characteristic. By taking core theoretic approach, economists argue that under free market condition, liner shipping market will not achieve equilibrium and therefore spontaneous collusion and alliances must exist. Sjostrom (1989, 1993) indicates that the reason for collusion in the liner market is to impose equilibrium where non-empty core exists. He proves that empty core is more likely to appear in liner shipping market where carriers' minimum average costs demonstrate limited variability, demand is less elastic and the excess capacity exists. He also recognizes that inefficient entry is the main cause for an empty core to occur in liner shipping market. Pirrong (1992) further summarizes that the instability is consist with a market when costs are characterized by indivisibilities and demand is finely divisible. Whether core is empty or not is independent from market size. The existence of such discontinuities in cost data of liner market is also tested in this paper. Zhao (2009) concludes in his paper that "the non-empty core analysis not only helps to estimate cooperative costs and to explain why profitable cooperation might not be formed, but also provides an understanding of possible future breakups of completed cooperation. With regards to the shipping industry, core sheds light on both understanding the stylized fact that cooperation is likely to occur in markets plagued by excess capacities and explaining the finding that industries for lumpy goods will have an empty core when demand is low".

Song and Panayides (2002) apply core theory to liner shipping strategic alliance where they analyze not only the cost allocation but also fair profit allocation among members within the alliance. Fair allocation could be considered as one of the conditions that keeps consortia or alliance stable. A similar idea can also be seen in Ryoo and Thanopoulou (1999), which shows that core is a prominent and widely accepted notion of fair allocation of costs and stability in cooperative game theory. Agarwal and Ergun (2009) study the liner alliance from companies' perspective with a core theory approach. They designed allocation mechanism through a capacity exchange cost structure, among which one possible mechanism could be to provide side payments to companies as an additional incentive for a partially decentralized alliance to share the benefits of the collaboration. By doing so, all members are motivated to act in the best interest of the alliance.

Applications of core theory can also be found in other transport fields. Button (2003); Button and Nijkamp (1998) explains why empty core may emerge in network industries such as transportation and explores both the application of core theory in air transport and the desirability of government actions to alleviate associated players' performance. Yang and Odani (2005) as well as Krajewska and Kopfer (2006) work on similar topics of optimizing in land cooperative transport system to pursue maximal common profit and calculate reasonable side payments for each member in the system.

This paper extends the above mentioned research in two ways: Firstly, most researches applied core theory by focusing on inherent characteristic of liner market but failed to consider the impact of current strategy and technology development. This paper takes some new phenomena and trends into consideration such as joint-service by vessel sharing or pooling and mega ships in order to show their influences on the market. Secondly, previous researches either stressed the market structure and fluctuant demand from macro perspective or highlighted the cost or profit allocation methods inside alliance from micro point of view. This paper applies core theory to a miniature market where there are few liner carriers in a certain shipping lane and considers the change of operating slots as the only variable from both the market and carrier's perspective.

3. A brief introduction of core theory

Traditional game theoretic approach assumes that players act independently, not cooperatively. Comparing to non-cooperative game, core theory aims to solve problems when a group of decision-makers decide to undertake a project together with tight binding agreements for achieving their joint objectives such as to increase total revenues (profit maximization) or to reduce total costs (Song & Panayides, 2002). Simply speaking, core is a set of equilibrium outcome. If competitive equilibrium does not exist, it might be because the core of the market is empty. To use core to judge an alliance's stability is based on two rationalities: the collective rationality which means cooperation should generate profit, and a more important one, the individual rationality which postulates that the split of a cooperative profit to each member in the coalition is better off than any potential profit they could obtain by forming any other coalition. In particular, a group of unaligned players can also be regarded as a coalition. The condition of a core is demonstrated mathematically below.

Suppose R is a set of coalition structure β_i defined for a coalition $N = \{1, 2,\ldots\ldots, n\}$ as:

$$R = \{\beta_1, \beta_2, \ldots \beta_m\},$$

$$\beta_i = \{B_{i1}, B_{i2}, \ldots B_{im}\} \quad B_{i1} \cup B_{i2} \cup \ldots \cup B_{im} = S$$

Where B_{ip} is a sub-coalition which could be an individual or a combination of individuals, $p = 1, 2,\ldots.m$. If $p \neq q$, $B_{ip} \cap B_{iq} = \emptyset$.

Heuristically, a coalition structure represents the breaking up of set N into mutually disjoint sub-coalitions. Suppose such a structure is reached. It is assumed that each of the sub-coalitions B_{ip} costs $C(B_{ip})$. Then each coalition structure β_i presents an imputation, which is stable in the sense that no coalition has the power or inclination to change it. Suppose its unit cost configuration is $X=(x_1, x_2,\ldots\ldots x_n,)$. To reach this goal, an obvious requirement will be that of individual rationality

$$x_i \leq C(i) \quad \text{for all } x_i \in X$$

A further possible requirement might be that no coalition structure β will form instead of the grand coalition if one of its sub-coalitions can cost less than the cost vector x_i gives it. Thus

$$\sum_{i \in s} x_i \leq \min_{\beta_i \in R} \left\{ \sum_{\beta_{ip} \in S} C(\beta_{ip}) \right\} \quad x_i \in X$$

The following sections will discuss empty core in liner shipping alliance based on the above mentioned two conditions with the new alliance characteristic.

4. Cost function of liner companies

Strategic alliance is based on cooperative arrangements among firms. There are several main forms of these arrangements in liner shipping industry. Slots charter and slots exchange are simple arrangements in which a carrier on a lane may offer another carrier a fixed number of spaces per voyage for a fixed period of time at an agreed price or slots in some other shipping service. Vessel sharing is more advanced and is an agreement between two or more carriers in which an equal number of slots are reserved on particular vessels for each of the participants. The number of slots and thereby space of each party on different ships on the same lane can vary by ship type and direction. These kinds of arrangements are commonly found in conjunction with coordinated service, where two carriers coordinate sailing schedules so as to jointly offer regular frequency. The characteristic of this form of cooperation is that carriers retain their independent identities and market organizations. Joint venture is a more complex cooperative arrangement such as equipments sharing agreements and vessel-pooling consortium where carriers contribute ships and other resources to create a new brand offering more frequent service than each could provide alone. Joint-venture, on the other hand, is organized in such a way that it is closer to a merger in effect because of their common brand to the customer.

By March 2011, there are 29 shipping lines providing 145 services on the trade lane between Far East and North Europe (including Scandinavian and Baltic countries). A total number of 350 container ships are employed on this route with an average ship size of 7635 TEU. It is difficult to ignore that the maximum ship size is 15550 TEU, the biggest container ships so far. In total, there are 64 mega container ships serving this route and each of them can carry no less than 10000 TEU. However this picture will soon be replaced with Maersk Line announcing its order of ten Triple-E class container ships in South Korea, which will be used for Far East – Europe trade when completed. These new Triple-E class ships have an impressive capacity of 18000 TEU each and to some extent they are leading liner shipping sector into an unknown territory. These jumbo ships will on the one hand enjoy a lower unit cost and hence economies of scale, but on the other hand they have more physical limitations and are less flexible. Most importantly, the cargo volume on this lane has already decreased greatly with the current economic slowdown. How quickly would the demand starts to pick up and the market recover are still unclear. Therefore it is doubtable if these Triple-E class ships can be fully utilized when join the service in two to three years.

In order to explain the analysis explicitly, an illustrative case is designed and brought along with the following theoretic analysis based on the description above. It is important to note the following assumptions:

- A certain shipping lane from Far East to North Europe is considered as an independent market;
- Assume n liner carriers $L_1, L_2 \ldots L_i \ldots L_n$ have been identified in this shipping lane. Carriers provide similar weekly service and have a regular weekly demand of q_i for carrier L_i respectively;
- The market demand Q as well as individual demand q_i is fluctuant in certain period;
- Carriers are free to form coalitions. Vessel sharing and vessel pooling are recognized as available strategies for all possible coalitions and carriers can retain their market organization.
- Coalitions will probably deploy larger ships in order to meet the combined demands Q from alliance's member. If $\{L_1, L_2, L_3\}$ is a grand coalition, the joint-ship size of $\{L_1, L_2, L_3\}$ is s_{i+n}. For any two carrier coalition $\{L_i, L_k\}$, the joint-ship size is s_{i+k}. For any single carrier L_i, its ship size is s_i;
- There are 8 sizes of ships available for carriers to deploy in this shipping lane and the minimum increment of ship size is 2000 TEU. We define that s_1 is 6000 TEU ship, s_2 is 8000 TEU ship and s_8 is 20000 TEU ship accordingly. Any carrier i in this shipping lane must have $s_i \geq q_i$;
- The unit cost per TEU for ship s_i is $c(s_i)$.

Based on the hypotheses, two cost functions are identified as $f(q_i)$ and $g(q_i)$. $f(q_i)$ indicates unit cost of different ship size when ships are fully loaded. $g(q_i)$ denotes the unit cost for ship s_i with variable loading factors. Especially, the loading factors of one certain ship also can be looked as carry capacity.

$$f(q_i) = \begin{Bmatrix} c(s_1) & q_i \le s_1 \\ c(s_n) & s_{n-1} \le q_i \le s_n \end{Bmatrix} \quad n = 1, 2, 3\ldots$$

$$g(q_i) = c(s_i) \cdot \frac{s_i}{q_i} \quad q_i \le s_i$$

Fig. 1 presents the unit costs of different ship sizes in a certain Europe - Far East trade lane from literature. Fig. 2 shows the change of unit costs with increasing loading factors based on data from Fig. 1.

Fig. 1 indicates that $f(q_i)$ is a decreasing segment function composed by a series of sub-functions corresponding to different ship sizes. It can be noted that the marginal unit cost is decreasing with ship size increasing which means the unit cost is less elastic to ship size. In contrast, $g(q_i)$ is a continuous sloping-down concave function to a certain ship size s_i. Given the demand volume, we have:

$$f(q_i + q_j)(q_i + q_j) \le f(q_i)q_i + f(q_j)q_j$$

$$g(q_i + q_j)(q_i + q_j) \le g(q_i)q_i + g(q_j)q_j \qquad q_i, q_j, q_i + q_j \le s_i$$

This characteristic is defined as sub-additivity, which is an important concept in game theory. Any cost saving strategies must be supported by stable solutions which are non-empty core, if its characteristic function is sub-additive.

If the carriers decide to form an alliance and share their vessels, the total weekly demand Q in all probability will exceed the individual capacity in use, i.e. any s_i. This means a larger ship s_{i+n} will be needed in the joint-service that will lead to changes of both loading factors and ship sizes. As a result, the cost function of joint-service strategy, expressed by $h(q_i)$ as Fig. 3 shows, can be calculated by $f(q_i) \cdot g(q_i)$. $h(q_i)$ is the unit cost for cooperative operation and has no characteristic of sub-additivity. $h(q_i+q_j)(q_i+q_j)$ can be either greater or less than $h(q_i)q_i + h(q_j)q_j$.

As is shown in Fig. 3, different curves present unit costs of different given ship sizes. The optimal unit cost ($h(Q)$) for cooperative operation is marked with shadows, which refers to the unit cost of only one larger ship deployed in the market to meet the weekly demand of all members.

The unit cost function for individual carrier in competitive market is:

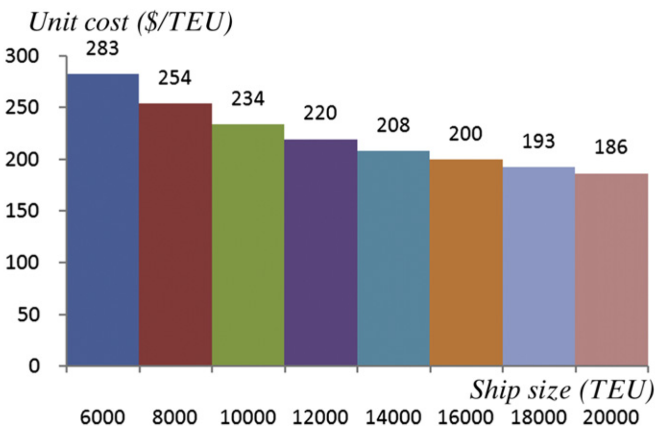

Fig. 1. Unit costs of different size of container ships when fully loaded. Source: Author's elaboration with data from Veldman 2009.

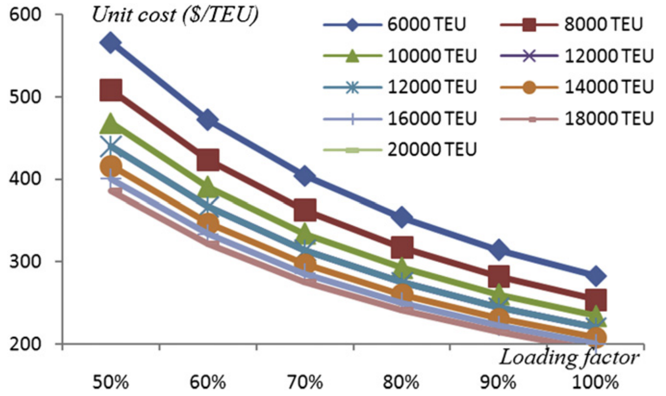

Fig. 2. Unit costs of different size of container ships with different loading factors. Source: Authors' own composition.

$$h(q_i) = \begin{cases} \dfrac{c(s_1)s_i}{q_i} & q_i \le s_1 \\ \dfrac{c(s_n)s_n}{q_i} & s_{n-1} < q_i \le s_n \end{cases}$$

The average unit cost function for the competitive market is:

$$h\left(\sum q_i\right) = \sum_{i=1\ldots n} \frac{m(s_i)c(s_i)s_i}{\sum_{i=1\ldots n} q_i} \quad q_i \le s_1$$

Here, $m(s_i)$ indicates the number of s_i size ship that is deployed in the market. We then have the collective unit cost function for the grand alliance in the market:

$$h(Q) = \begin{cases} \dfrac{c(s_1)s_i}{Q} & Q \le s_1 \\ \dfrac{c(s_n)s_n}{Q} & s_{n-1} < Q \le s_n \end{cases} \quad Q = \sum q_i$$

Generally speaking, cooperative agreement among alliance members is only valid over a specific period of time. Therefore we assume that this cost function is suitable to consider short-term market and will rarely have any impact on long-term market.

5. Empty core in liner shipping market

Imagine there are three carriers L_1, L_2 and L_3 that serve this shipping lane. In Fig. 4, the competitive cost function C_1 shows the case where L_1 is the only carrier in the market who deploys 6000 TEU ships to provide weekly service. Now suppose L_2 and L_3 then enter the market in sequence and also deploy 6000 TEU ships

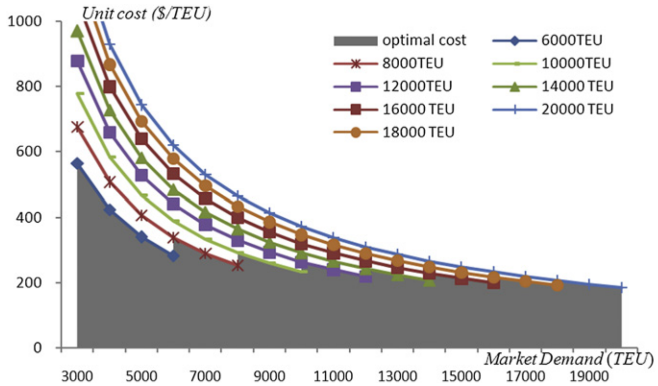

Fig. 3. Optimal unit cost of cooperative operation. Source: Authors' own composition.

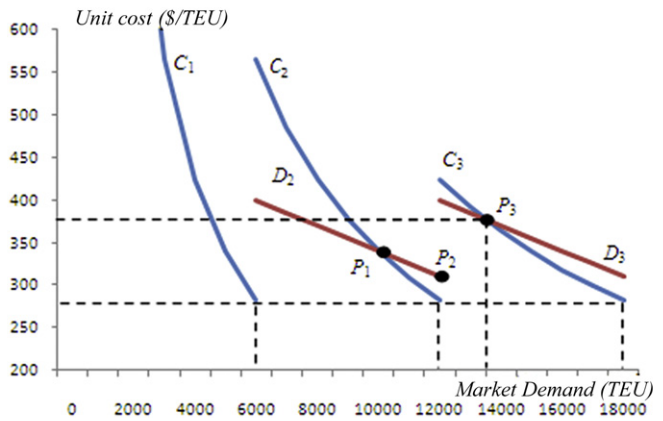

Fig. 4. Cost function of competitive liner market. Source: Adapted from Sjostrom (1989).

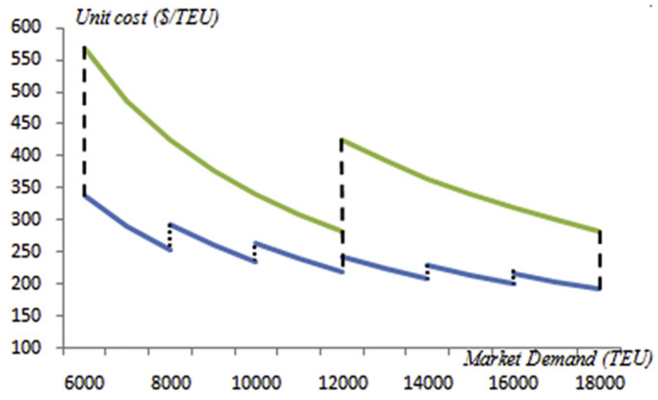

Fig. 6. Comparison of cost function of competitive and cooperative liner market. Source: Authors' own composition.

to provide weekly service separately. We use C_2 and C_3 to present competitive average cost functions of the market when there are two and three carriers in the market, respectively. Assume two demand curves D_2 and D_3 which are less elastic than the cost have been fixed, then the follows deserve discussion regarding Figs. 4 and 5.

In Fig. 4, point P_1 is the intersection of demand curve D_2 and cost function C_2. The part of C_2 to the left of P_1 indicates that the marginal cost fails to cover unit operating cost when carrier operates below capacity. In practice it implies that when there is excess capacity than the demand, then at least one carrier is not able to fill his ship to its profitable capacity. To meet the shippers' demands, carriers would have to accept the loss by running at lower loading factors or even keeping the ship idle to save avoidable cost. Mathematically, it is expressed as $h(\sum q_i) > c(s_i)$.

When there is no profit in the market, the core is empty according to core's first condition of profitability. The area to the right of point P_1 on the contrary means it is profitable of two carriers when the market demand is between P_1 and 12000 TEU. But when the market demand exceeds 12000 TEU, demand cannot be met because the two carriers in the market can only offer a total capacity of 12000 TEU (by two ships) at the cost of P_2. Since the market is free entry, a third carrier must enter the market to meet the exceeded demand. Assume the new entry also brings in a capacity of 6000 TEU, then the competition will probably drive the average unit cost to curve C_3. Suppose the demand has wide deviation from D_2 to D_3 (Demand increases but the elasticity of price and demand remain the same), the situation will repeat and there is no way out with empty core dilemma. Pirrong (1992) indicates that "the divergence between minimum acceptable and maximum feasible surplus does not systematically decline even in large markets with lumpy commodity". When there are discontinuities in marginal costs, one cannot expect the market size to mitigate the severity of empty core problems. Excess capacity occurs periodically due to variations in demand and hence the core is periodically empty. Due to this character, collusion appeared since the beginning of liner market formation. Carriers built the conference system to specify output quotas or prices to mitigate the severity of core. When freight rate is set higher than the cost at P_1 or when the market capability supply is less than the demand of P_1, core will not be empty no matter how demand changes. However these regulations have been prohibited with the collapse of conference system in some regions and instead strategic alliances have been promoted. The following issues are then derived from the above mentioned discussion: 1) what happens in the market if new forms of cooperative strategies appear, e.g., deployment joint mega container ships; 2) how new phenomena and trends affect the conditions of empty core.

Suppose a slump market where the core is empty, carrier L_1, L_2 and L_3 decide to form an alliance through sharing or pooling vessels to avoid lost. They employ a larger ship to provide weekly service to all their customers. Assume 5 ship sizes from 6000 TEU to 14000 TEU are available for sharing or pooling. Fig. 5 shows the h(Q) under the market demand condition of D_2 which is totally same D_2 in Fig. 4. It is obvious that the alliance can save costs and avoid the periodical empty core under such condition.

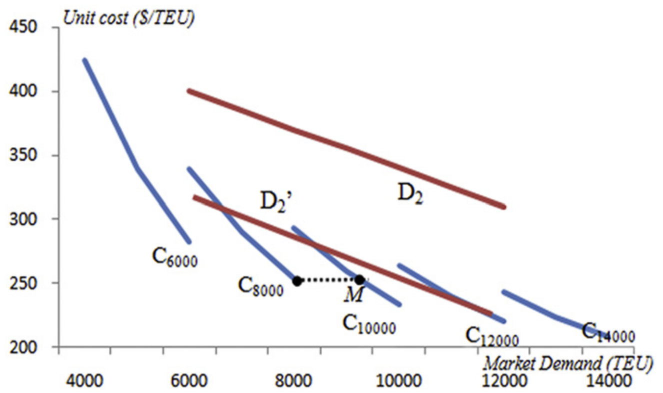

Fig. 5. .Cost function of cooperative liner market. Source: Authors' own composition.

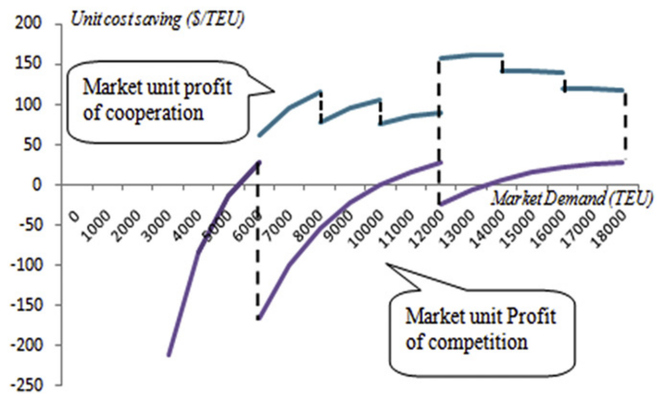

Fig. 7. Comparison of profit function of competitive and cooperative liner market. Source: Authors' own composition.

Table 1
Stable conditions of q_2 for two carriers' alliance.

s_{i+k}(TEU)	$c(s_i)$	q_1	$q_{2(1)}$*	$q_{2(i+1)}$**	$q_{2(i+2)}$	$q_{2\ (i+3)}$	$q_{2(i+4)}$	$q_{2(i+5)}$	$q_{2(i+6)}$	$q_{2(i+7)}$
6000	283	3000	(0,3000)	–	–	–	–	–	–	–
8000	254	4000	(0,4000)	**(592,5000)**	–	–	–	–	–	–
10000	234	5000	(0,5000)	**(610,6000)**	(1140,7000)	–	–	–	–	–
12000	220	6000	(0,6000)	**(631,7000)**	(1191,8000)	(1662,9000)	–	–	–	–
14000	208	7000	(0,7000)	**(627,8000)**	(1219,9000)	(1734,10000)	(2150,11000)	–	–	–
16000	200	8000	(0,8000)	**(688,9000)**	(1279,10000)	(1831,11000)	(2298,12000)	(2656,13000)	–	–
18000	193	9000	(0,9000)	**(676,10000)**	(1338,11000)	(1893,12000)	(2408,13000)	(2830,14000)	(3134,15000)	–
20000	186	10000	(0,10000)	**(673,11000)**	**(1324,12000)**	**(1961,13000)**	**(2484,14000)**	**(2962,15000)**	**(3340,16000)**	**(3592,17000)**

*$q_{2(1)}$ denotes the ship capacity constrain when $k = 0$; **$q_{2(i+1)}$ denotes the constrains when the joint ship is in size of $i+1$, for example when s_i is 8000 TEU, the $q_{2(i+1)}$ mean the constrain of q_2 when the joint-ship upgrade to 10000 TEU. The bold numbers indicate the constrains which function among all the constrains at last.

In order to reveal more characteristics of the cost function, Fig. 6 and Fig. 7 are drawn for further comparison. Fig. 6 compares two cost functions $h(\sum q_i)$ and $h(Q)$. Some interesting results can be observed. Firstly, the segments of $h(Q)$ are much shorter and more gentle than those of $h(\sum q_i)$ which means the alliance, with strategic joint-ship services, can flexibly respond to market changes. Secondly, the difference at the discontinuous point of $h(Q)$ is much shorter than $h(\sum q_i)$ and becomes even lessened with size increase which means it is less risky to increase shipping capacities than to put one more new ship in the market. This is due to the fact that liner carriers can share fix costs and variable costs by joint-service.

The comparison of profits between two market modes as Fig. 7 provides material for analysis from another point of view. If the market is symmetrical, the unit market profit equals to market unit price minus unit operating costs. The average unit profit is $P-h(\sum q_i)$ in a competitive market and P-$h(Q)$ for an alliance in cooperative market. With the P derived from demand curve D_2, Fig. 7 shows two series of unit profit curves with regards to differences between assumed price and two cost functions respectively. In a competitive market, when ship size is fixed at 6000 TEU and market is proportional for carriers, the three curves underneath show the situation where there are 1, 2 and 3 carriers in the market operating separately. It should be noted that more than the half of the bottom-left curve, which represents the unit profit function with only one carrier in the market, is less than zero. In contrast, most of the bottom-right curve, which is the unit profit function with three carriers in the market, is greater than zero. Assume demand increases proportionally with ship capacity, it then implies that the possibility of profitability increases with more carriers in the market even if the market experiences periodically empty core. Besides, the curves become less elastic when the number of ships increases which indicates that the marginal profit declines with more carriers entering the market. That is because new members share the market profit but at the same time they also share the market risk. As for the case of cooperation, more segmented curves indicate more available upgrades of ship size. All the curves carry positive values and the changes of segment intervals are shorter when market demand increases. The marginal profit changes more gently than that of the competition case. The above-mentioned analysis suggests that carriers forming alliance with joint-service strategy save cost, alliance deploying mega ship is more flexible to cope with empty core and less sensitive to the change of demand.

However as is shown in Fig. 5, if demand decreases dramatically as the demand curve shifts down from D_2 to D_2', then the empty core appears again in the market. Therefore, it is important to note that the strategic cooperation can only relax empty core condition to some degree but cannot avoid it completely.

6. Empty core in liner shipping alliance

Even though cooperation saves cost theoretically, a stable alliance relies not only on profitability but also on the fact that alliance members can get a better payoff in a rational distribution designed by the core. This section extends the previous discussion into the allocation problem. Song and Panayides (2002) developed an example to illustrate the empty core induced by unreasonable allocation of revenue in liner shipping market. Differ from Song and Panayides (2002), we do not focus on revenue in this paper but consider the source of revenue, which is the relationship between alliance's capacity supplies (joint-ship size) and their market demands. The analysis shown below is implemented from carriers' perspective.

In practice, liner carriers are not willing to lose control over their individual sales and marketing activities in joint-service. Before entering an alliance, a contract will be enacted by potential alliance members, prescribing the sharing or pooling capacities of each

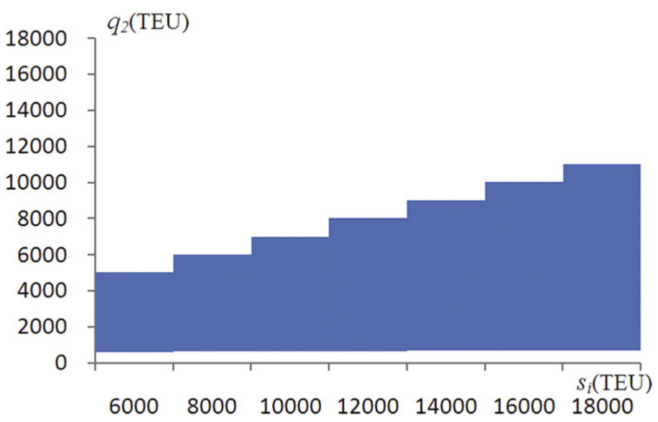

Fig. 8. Change of q_2 with growth of i. Source: Authors' own composition.

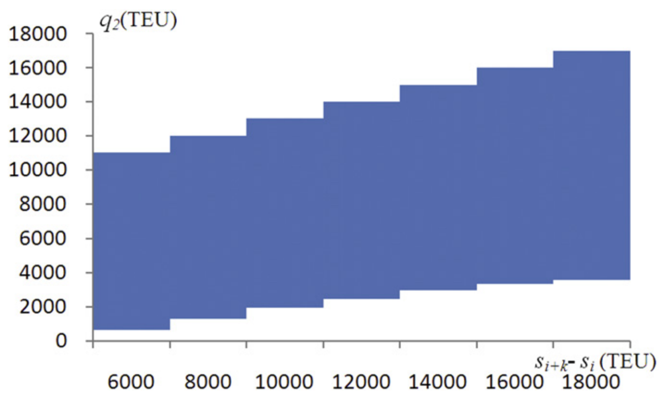

Fig. 9. Change of q_2 with growth of k. Source: Authors' own composition.

Table 2
Stable conditions of q_3 when $k = 1$, $n = 2$ and q_2 is relatively weak.

s_i(TEU)	s_{i+k}	s_{i+n}	q_1	q_2	q_3^1	q_3^2	q_3^3	q_3^4	q_3^5	q_3^6	q_3^7	q_3
6000	8000	10000	3000	592	≤6408	**≥548**	**≤885**	≤19082	**≥548**	≥331	≤9453	(**548,885**)
8000	10000	12000	4000	610	≤7390	**≥582**	**≤835**	≤31097	**≥582**	≥−3818	≤15476	(**582,835**)
10000	12000	14000	5000	631	≤8369	**≥588**	**≤1036**	≤47212	**≥588**	≥−4846	≤23091	(**588,1036**)
12000	14000	16000	6000	627	≤9373	**≥652**	**≤377**	≤60392	**≥652**	≥−5866	≤31096	(**652,377**)
14000	16000	18000	7000	688	≤10312	**≥649**	**≤1150**	≤82192	**≥649**	≥−6868	≤40233	(**649,1150**)
16000	18000	20000	8000	676	≤11324	**≥649**	**≤1037**	≤106324	**≥649**	≥−7888	≤52408	(**649,1037**)

member. Conventionally, this is decided by their current market share. Therefore their voyage costs after cooperation are also in a large degree proportional to their previous transport capability in the market. In another word, the carriers' voyage costs pre-alliance and post-alliance are in the same structure. On the other hand, as many large ships have already been ordered, we assume the capital costs of these vessels are not affected by the cooperative strategies. Therefore carriers' capital costs will not be taken into consideration. Note that in the following analysis, we consider the carriers' voyage costs are in the same proportion pre-alliance and post-alliance.

The following case illustrates the situation in which a profitable cooperation still has an empty core. Imagine $s_1 = s_2 = s_3 = 6000$ TEU, $q_1 = q_2 = 4900$ TEU, $q_3 = 2300$ TEU. If there forms a grand coalition {L_1, L_2, L_3} through deploying a 14000 TEU ship, then the unit cost $h(Q)$ is 241 based on the cost function built in Section 4. The $h(q_1)$, $h(q_2)$ and $h(q_3)$ can also be obtained as 347, 347 and 738, respectively. Because $h(Q) < h(q_i)$, the grand coalition is profitable than carriers operating individually. However, the cooperation of {L_1, L_2, L_3} is not stable since a sub-coalition {L_1, L_2} has a lower unit cost of 239 by deploying a 10000 TEU joint-ship. Therefore the core for grand coalition {L_1, L_2, L_3} in this market is empty.

Core theory can be used to identify which coalition is stable and what is the optimal number of q_i for the coalition members. According to the description in Section 3, the core's condition for grand coalition $N = \{L_1, L_2, L_3\}$ in this market is:

$$h(q_1 + q_2 + q_3) = h(Q)$$

$$h(q_1 + q_2) \le \min(h(q_1), h(q_2))$$

$$h(q_1 + q_2 + q_3) \le \min(h(q_1 + q_3), h(q_1 + q_2), h(q_2 + q_3))$$

These equations mean that the unit cost of the grand coalition should be less than any possible sub-coalition of these members. As shown in Section 5, they also indicate that marginal profit of operating slots for the alliance should be greater than the marginal cost including updating ship size.

Assume the cooperation starts from a two carriers' coalition and is then extended to a three carriers' coalition. When two carriers' alliance {L_1, L_2} forms, the following equations hold for cost function:

$$q_2 \le s_{i+k} - q_1$$

$$c(s_{i+k})s_{i+k}/(q_1 + q_2) = c(s_i)s_i/q_1(q_2), \quad k = 0, 1, 2, 3 \ldots q_i, q_2 \le s_i, q_1 + q_2 \le s_{i+n}$$

Since $c(s_i)$, $c(s_{i+k})$ and s_i, s_{i+k} are known, if q_1 is fixed, then the relationship of q_1 and q_2 is

$$q_2 \ge \left(\left(C\left(s_{(i+k)}\right) s_{(i+k)} \right) / (C(s_i)s_i) - 1 \right) q_1$$

In order to keep the core of {L_1, L_2} non-empty, ally L_2's operating slot q_2 is decided by two parts. The first part is the ratio between alliance's joint-ship cost $c(s_{i+k})s_{i+k}$ and the original ship's individual cost $c(s_i)s_i$. The second deciding factor is q_1. Assume the market is slump and q_1 is down to half of its weekly supply s_i, then the boundary conditions of q_2 with increasing sizes of joint-ship are calculated.

When $k = 0$, the maximal q_2 equals to the remaining slots of L_1's capacity supply which is $s_i/2$. If $k > 0$ ($k = 1 \ldots 7$), the row of $q_{2(i+k)}$ shows possible q_2 to keep the alliance's core non-empty when the ship is upgraded to s_{i+k} size. Because there are two variables i and k, it is interesting to investigate the changes of q_2 in two scenarios.

Firstly, fix k to 1 and increase i, this means the increment between L_1's ship s_i and joint-ship s_{i+k} for {L_1, L_2} is always 2000 TEU but s_i increases from 6000 TEU to 18000 TEU and s_{i+1} increases from 8000 TEU to 20000 TEU accordingly. Secondly, fix i to 1 and increase k, this means L_1's ship s_i is constantly 6000 TEU but the joint-ship size s_{i+k} increases from 8000 TEU to 20000 TEU. Table 1 shows the boundaries of q_2 under different constraints. The row of $q_{2(i+1)}$ gives the trend of q_2 in the first scenario and the last column for the second scenario.

Fig. 8 and Fig. 9 are drawn in order to illustrate the two scenarios in a more explicit way. As Fig. 8 shows, in scenario 1 the increase of q_2's lower boundary can almost be ignored comparing to the significantly increase of its upper boundary. As a result, q_2 is stable in a much broader area when i becomes relatively large. It implies that in order to keep core non-empty for the two carriers' alliance {L_1, L_2}, L_2 turns to have more choices with the growth of ship size s_i of L_1 and s_{i+1} of {L_1, L_2} at the same time. Fig. 9 presents that although q_2's lower boundary shows a clear growth, the increase of q_2's stable area is still apparent with increase of k. This is because the increase rate of lower boundary is slower than that of the upper boundary. It implies the range of choice for L_2 also becomes wider when the increment between joint-ship size s_{1+k} and L_1's ship size s_i increases.

In summary, the above results show that the low boundary of q_2 is only slightly change with increase of the joint ship size no matter what s_1 is. It reveals that the stability of cooperation is not affected significantly by the increasing marginal unit cost of larger ship in two carriers' coalition. On the other hand, the upper boundary equals to the joint ship's capacity in both scenarios and increases

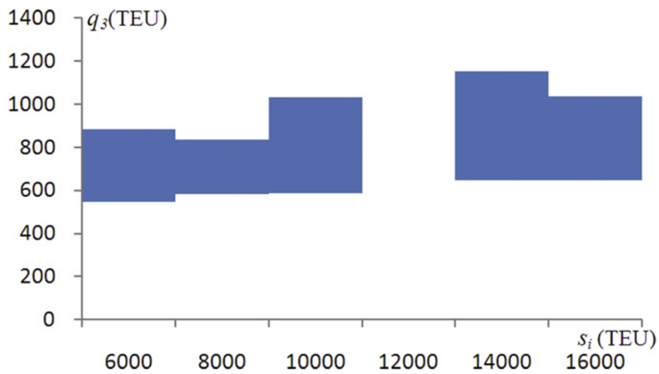

Fig. 10. Change of stable area of q_3 with growth of k (large q_2). Source: Authors' own composition.

significantly comparing to increasing marginal unit cost. Therefore, in a two carriers' coalition, L_1 has broader chances to find an ally L_2 when s_1 is relatively large.

In general, a game with more than two players shows more characteristics of core theory. Suppose a third carrier L_3 enters the market, core's condition of grand coalition { L_1, L_2, L_3 } is then:

$$q_3 = s_{i+n} - q_2 - q_1 \tag{1}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i+k)s_{i+k}/(q_1+q_2), \quad k,n = 0,1,2,3\ldots \quad q_1 = s_i, q_1+q_2 = s_i+k \quad \{L1, L2\} \tag{2}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i+k)s_{i+k}/(q_1+q_3), \quad k,n = 0,1,2,3\ldots \quad q_1 = s_i, q_1+q_2 = s_i+k \quad \{L1, L2\} \tag{3}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i+k)s_{i+k}/(q_2+q_3), \quad k,n = 0,1,2,3\ldots \quad q_1 = s_i, q_1+q_2 = s_i+k \quad \{L1, L2\} \tag{4}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i)s_i/q_1,\ k,n = 0,1,2,3\ldots \quad q_1 \le s_i, q_1+q_2 \le s_i+k, q_1+q_2+q_3 \le s_{i+n} \quad L1 \tag{5}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i)s_i/q_2,\ k,n = 0,1,2,3\ldots \quad q_1 \le s_i, q_1+q_2 \le s_i+k, q_1+q_2+q_3 \le s_{i+n} \quad L2 \tag{6}$$

$$c(s_{i+n})s_{i+n}/(q_1+q_2+q_3) \le c(s_i)s_i/q_3,\ k,n = 0,1,2,3\ldots \quad q_1 \le s_i, q_1+q_2 \le s_i+k, q_1+q_2+q_3 \le s_{i+n} \quad L3 \tag{7}$$

The relationships of q_3 and q_1, q_2 then can be expressed as:

$$q_3 = s_{i+n} - q_2 - q_1;$$

$$q_3 \ge (q_1+q_2)\left(\frac{C(s_{i+n})s_{i+n}}{C(s_{i+k})s_{i+k}} - 1\right);$$

$$q_3 \le \frac{C(s_{i+k})s_{i+k}}{C(s_{i+n})s_{i+n} - C(s_{i+k})S_{i+k}} q_2 - q_1;$$

$$q_3 \le \frac{C(s_{i+k})s_{i+k}}{C(s_{i+n})s_{i+n} - C(s_{i+k})S_{i+k}} q_1 - q_2$$

$$q_3 \ge \frac{C(s_{i+n})s_{i+n} - C(s_i)s_i}{C(s_i)s_i} q_1 - q_2;$$

$$q_3 \ge \frac{C(s_{i+n})s_{i+n} - C(s_i)s_i}{C(s_i)s_i} q_2 - q_1;$$

$$q_3 \le \left(\frac{C(s_i)s_i}{C(s_{i+n})s_{i+n} - C(s_i)s_i}\right)(q_1+q_2)$$

Set q_1 to $s_i/2$. When $i = k = n$, L_2 and L_3 will share the remaining joint-ship capacity of L_1 as $s_i/2$. If $i = k \le n$, then it becomes a two carriers' game. Therefore we only consider scenarios when $i < k < n$. Three scenarios are prepared as follows in order to look into the relationship among q_1, q_2 and q_3.

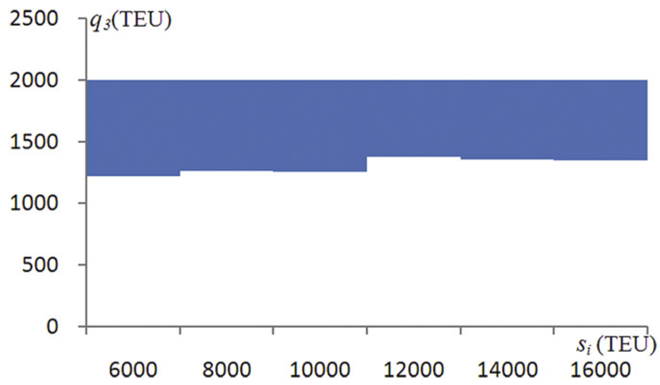

Fig. 11. Change of stable area of q_3 with growth of i (small q_2). Source: Authors' own composition.

In the first scenario, we suppose $k = 1$ and $n = 2$ constantly. Set q_2 to be the lower boundaries of two carriers' coalition as is shown in the row of $q_{2(i+1)}$ of Table 1 and we change n. Table 2 shows the boundary conditions of q_3 under these assumptions. q_3^1 to q_3^7 corresponds to the core's conditions from equation (1)–(7). These equations carry different implications. For example when $s_i = 6000$, $s_{i+k} = 8000$, $s_{i+n} = 10000$ and q_2 is fixed at 592. We can obtain 7 boundaries for q_3 from equation (1)–(7) as the first row of Table 2 shown. The final stable area of q_3 is between the smallest upper boundary in equation (6) and the largest lower boundary from equation (4) as (548,885). The lower boundary of q_3 needs to be higher than 548 because otherwise the sub-coalition {L_1, L_2} or {L_1} will overtake the grand coalition {L_1, L_2, L_3}. It means the total Q for {L_1, L_2, L_3} is not significant enough to reach the profitable loading factor for joint-ship s_{i+n} in order to achieve lower unit cost than that of {L_1, L_2} or {L_1} in practical. This value is shown by the point M as an example in Fig. 5. q_3 also needs to be less than 885 otherwise sub-coalition {L_1, L_3} will be formed instead. From the cost function in Fig. 5 we can observe that the unit cost of larger ship is less elastic to the demand than that of smaller ship. Therefore when q_3 is large enough to achieve lower unit cost for {L_1, L_3}, there is no reason for L_1 and L_3 to accept L_2 to form the grand coalition {L_1, L_2, L_3}. Fig. 10 shows the stable operating area of q_3 in this scenario, which does not change much with the increase of i. In particular, core is whatever empty when s_i, s_{i+k}, s_{i+n} are 10000, 12000 and 14000 respectively. In short, when q_2 is as small as the lower boundary for two carriers' coalition, the stable area for L_3 is very limited and hardly affected by the growth of ship size.

The following scenario exams q_3 when q_2 is large. Still assuming $k = 1$ and $n = 2$ but set q_2 to the upper boundary of two carriers' coalition. Then we have Table 3 accordingly. The lower boundary of q_3 is now only from restriction of {L_1, L_2} but the upper boundary of it is replaced by the joint-ship size limitation. Fig. 11 shows the stable area for the q_3 in this scenario, the area is a little wider than

Table 3
Stable conditions of q_3 when $k = 1$, $n = 2$ and q_2 is relatively strong.

s_i(TEU)	s_{i+k}	s_{i+n}	q_1	q_2	q_3^1	q_3^2	q_3^3	q_3^4	q_3^5	q_3^6	q_3^7	q_3
6000	8000	10000	3000	5000	**≤2000**	**≥1220**	≤29791	≤14674	≥−3860	≥−1100	≤21050	(**1220,2000)**
8000	10000	12000	4000	6000	**≤2000**	**≥1262**	≤43561	≤25707	≥−4809	≥−2213	≤33571	(**1262,2000)**
10000	12000	14000	5000	7000	**≤2000**	**≥1254**	≤61980	≤40843	≥−5781	≥−3293	≤49211	(**1254,2000)**
12000	14000	16000	6000	8000	**≤2000**	**≥1377**	≤75358	≤53019	≥−6721	≥−4295	≤65692	(**1377,2000)**
14000	16000	18000	7000	9000	**≤2000**	**≥1351**	≤99560	≤73880	≥−7662	≥−5280	≤83728	(**1351,2000)**
16000	18000	20000	8000	10000	**≤2000**	**≥1346**	≤125750	≤97000	≥−8676	≥−6345	≤10873	(**1346,2000)**

Table 4
Stable conditions of q_3 with the growth of q_2.

s_i(TEU)	s_{i+k}	s_{i+n}	q_1	q_2	q_3^1	q_3^2	q_3^3	q_3^4	q_3^5	q_3^6	q_3^7	q_3
16000	18000	20000	8000	650	≤11350	≥647	**≤694**	≤106350	≥674	≥−7892	≤52253	(**647,694**)
16000	18000	20000	8000	1000	≤11050	≥673	**≤5375**	≤106000	≥324	≥−7834	≤54367	(**673,5375**)
16000	18000	20000	8000	1391	≤11000	≥702	**≤10609**	≤105609	≥−67	≥−7770	≤56731	(**702,10609**)
16000	18000	20000	8000	1391	**≤10609**	**≥702**	≤10605	≤105609	≥−67	≥−7770	≤56729	(**702,10605**)
16000	18000	20000	8000	4000	**≤10609**	**≥897**	≤45500	≤103000	≥−2676	≥−7338	≤72490	(**897,8000**)
16000	18000	20000	8000	6000	**≤9000**	**≥1047**	≤72250	≤101000	≥−4676	≥−17007	≤84571	(**1047,6000**)

previous scenario but it is slightly declining when the ship size increases.

The third scenario naturally focuses on the change of q_3 caused by the increase of q_2 when q_1 is $s_i/2$, and s_i, s_{i+k}, s_{i+n} are fixed to 16000, 18000 and 20000 TEU, respectively. Table 4 illustrates the boundaries of q_3 in this scenario. the lower boundary is still under restriction from {L_1, L_2}, however the upper boundary is much different with the previous scenarios. it is inverted 'L'-shaped as Fig. 12 shows. the left part increases sharply and it is constrained from the condition of the sub-coalition {L_1, L_3}. the right part is under the capacity limitation of joint-ship, which is $s_{i+n}-q_1-q_2$, since $s_{i+n}-q_1$ is constant under our assumption, this limitation is liner regressive with q_2. the intersection point is the maximum value of q_3, which is $(c(s_{i+n})s_{i+n}\text{-}c(s_{i+k})s_{i+k})/c(s_{i+n})$, equals to10609 TEU. This value in meaning actually indicates that the profit with incremental demands brought by L_3 to the grand alliance {L_1, L_2, L_3} needs at least more than the cost for upgrading ship size from s_{i+k} to s_{i+n}. q_2 at this point is 1391 TEU

The three scenarios demonstrate that the stable area of q_3 is not affected significantly by the magnitude of ship size if q_1 and q_2 are fixed. If only q_1 is fixed, there is a maximum option for q_3 with the change of q_2. In another word, it implies that the third ally L_3 is much dependent on q_2. In the illustrative case, under the assumption of certain joint-ship size, the two carriers' coalition which includes one carrier with large demand (8000 TEU) and the other one with relatively small demand in number (1391 TEU) has the most potential to take in new member. The choice area declines at both side of this number. The left side decreases faster than the right side, which means the increase of ship size is less elastic to the feasible choices of q_3 than the threaten from sub-coalition {L_1, L_2}, but the threaten from sub-coalition {L_1, L_2} only functions in a very narrow area (less than 1391 TEU in the scenario). To sum up, the optimal combination of liner shipping alliance can be evaluated by the demands and capacity of joint ship size of alliance and the stable structure can be forecasted through core theory.

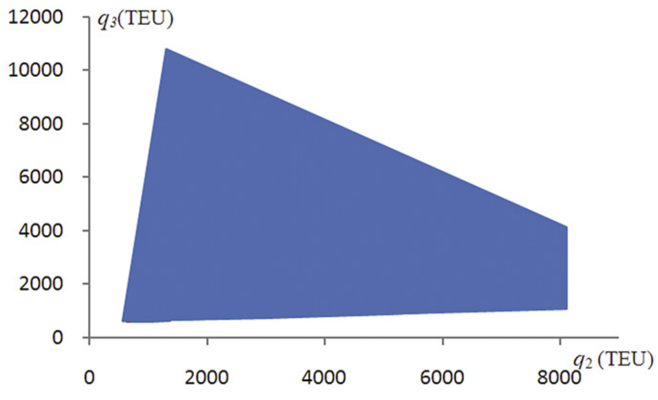

Fig. 12. Change of stable area of q_3 with growth of q_2. Source: Authors' own composition.

7. Conclusions and further research

International shipping market can be recognized as an unstable market in which more and more carriers adopted shipping alliances as their strategy to ensure operations and market shares. This is particularly true with increasing ship size where alliance has the advantage to guarantee loading factors and reduce voyage cost. However, participating alliance or employing bigger ships can only help to avoid the uncertainties to some degree but is not always the perfect solution to the ever-changing market.

To the authors' best knowledge, this paper is the first attempt to take both the mega container ships and alliance's strategy together into consideration and apply core theory to investigate the influence of increasing ship size to the stability of shipping alliance. Two conditions of core theory, i.e., profitability and inner profit allocation, are mentioned and applied in the analyses of this research. The former condition is proved by introducing a cost function for liner shipping alliance that adopts the strategy of joint-service. The periodically empty core of shipping market caused by unprofitability is explained firstly. Joint-mega ship strategy adopted by an alliance in the hope of reducing unit costs of its members. Although the strategy does not prevent empty core from appearing periodically, it is proved that they indeed improve the alliance's stability to some degree. In order to further describe how this strategy influences the stability of alliance, the latter condition–profit allocation principles are discussed in the text of alliance capacity supply and demand structure. As for two carriers' alliance, if one carrier's demand is fixed, the slow-growing slot marginal cost in a large ship will increase the lower boundary of the cooperator but is negligible when the growth of upper boundary caused by the increasing ship size is taken into consideration. This means that the advantage of employing larger vessels to overcome empty core becomes more significant with increasing ship sizes. Regarding three carriers' alliance, the situation is more complex but also manifests more interesting implications. When the demands of two liner carriers are fixed, the demand limitation to the third ally brought by the increasing ship size is not apparent. The lower boundary of the third carrier is always restricted by the possible overtaken of sub-coalition composed by the original existing two carriers because of its even lower unit cost. The upper boundary is restricted either by the possible overtaken of sub-coalition composed by the existing relatively large carrier and the new comer when the other existing carrier is relatively small in demand or by joint-ship capacity when the other existing carrier is relatively large in demand. When only one existing liner carrier's demand and joint-ship size are fixed and another's demand is set as the independent variable to the third comer's demand, a certain number of the second carrier's demand can be calculated as optimal, in which the third ally has the widest choice of its demand. If the second carrier's demand is larger than this number, whether the core is empty or not depends on the capacity limitation of the joint-ship, otherwise it depends on the possible overtaken of sub-coalition composed by the first and the second carriers. In general, the alliance's stability is significantly related to the structure of member's demands and joint-ship's capacity when they decide to use joint-service strategy.

Although the anti-trust legislation has been promoted to restrain the conference system, many new alternative strategies have appeared in the market to avoid empty core. It is the authors' hope that this study will enhance understanding and decision-making behavior in liner shipping sector.

Due to limited time and data access, the authors recognize that there is still space to further study this topic. Potential directions include, but are not limited to: 1) to consider more factors regarding strategies of deploying mega container ships such as using new shipping lanes or reducing frequencies; 2) to investigate other forms of cooperation in liner shipping industry; 3) to look into cases with more than three players and 4) to obtain precise data and more practical information on demand curve and alliance's operation in order to describe the market in a more appropriate manner.

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EDITORIAL

Design and evaluation of transportation networks: constructing transportation networks from perspectives of service integration, infrastructure investment and information system implementation

Xiaoning Shi · Thierry Vanelslander

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Many enjoy services that are provided by current transportation networks worldwide. Meanwhile, researchers are engaged in further improving the transport services by various means, e.g., service integration, infrastructure investment and information systems implementation. The main aims of such improvements would be to enhance human well-being, eliminate externalities, facilitate decision making processes, etc.

In an attempt to show readers of this journal, especially those who major in kinds of perspectives of transportation, a number of critical ideas and cases demonstrating how transport research can be of help both in daily business and policy making, this special issue on *Design and Evaluation of Transportation Networks* was set up.

Firstly, it is now clear that the transportation business features vertical and horizontal integration together with competition [1, 2]. Transportation networks are then constructed from the infrastructural perspective as well

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as from the service perspective. Since the start of the current financial crisis, the on-going integration within the transportation industry, to a great extent, seems to have come to a temporary halt. However, if we have a look at what the research & development departments of nearly all transport service providers are now focusing on, the cumulated power of the next round of integration and competition can be felt and a reboot of infrastructure investment is to materialize as soon as the economy situation turns brighter again. In the meantime, many transportation providers may not survive the economic downturn. This short-run perspective is not the core focus of this special issue. However, some of its papers put attention to short-run issues, like the elastic demand of facility factors, the analysis of what is extremely valuable in view of the current over-capacity situation and similar factors.

Secondly, from the perspective of information systems implementation, many actors involved in the transportation networks are eager to construct or implement more effective and efficient decision support systems and appropriate portals. This kind of decision support tools seems indispensable to reach the aforementioned service integration in a smooth way. However, there are some practical issues that need attention. For instance, a conflict on data sharing might occur between those business-related agents. Imagine that a liner shipping company, as one of the papers in this special issue mentions, would make her operational and consequent financial analysis based on the fleet schedule, but that port operators would not like to share their operational details with the liner shipping carrier during the negotiation procedures. Hence, it would be hard for the liner to choose ports of call and consequently to optimize its schedule. Another instance of such conflict of data sharing could be the reluctance to co-operate with adjacent local authorities, especially when they are governing almost the same hinterland. Regional or local authorities could be of help to implement for instance a common information platform. If such co-operation is not possible, it might be hard to reach optimal planning from the perspective of many of the chain players involved, which is detrimental to the entire supply chain in the end. Equally, such tool could be of great help to governments in optimally planning their ports and hinterland connections.

Thirdly, specific interest goes to the perspective of passenger transportation. The environment needs to be protected in different ways, and releasing less green house gas (GHG) might be one of the most popular ways. One contribution in this special issue, directly or indirectly, provides food for thought on how better public mass transit networks could be designed, without ignoring passengers' well-being, so that more and more passengers are self-motivated to taking public mass transit instead of using less-environmental-friendly transport modes.

In this context, this special issue of *Design and Evaluation of Transportation Networks* includes a collection of outstanding papers, made after a thorough selection and refereeing process. This special issue covers topics at the cutting edge of transportation research: evaluating transport mode decision making by taking into account user's happiness; designing liner shipping services by taking into account cooperative stability; setting pricing policy of a short sea shipping service; using information systems to support ocean–sea shipping services; and comparing different strategies of port operators along adjacent geographic ranges.

The first paper, on *a New Approach in Transportation Planning: Happiness and Transport Economics*, by André Duarte, Camila Garcia, Grigoris Giannarakis, Susanna Limão, Amalia Polydoropoulou and Nikolaos Litinas, analyses the relationships between happiness and transport economics in terms of incorporating well-being measurement when choosing between a private and a public transport mode, e.g., between owned car and metro. This paper proposes a novel idea in applying behavioural analysis together with psychology in transport economics analysis. The approach seems very promising and interesting, though this respect has not yet been heavily stressed by previous research. This paper can be regarded as a good example of how human behaviour affects transport economics as well as the other way around.

The second paper, on *an Integrated Approach for Port Selection Ship Scheduling and Financial Analysis*, by Jasmine Siu Lee Lam, researches the popular topic on the ship routing and scheduling problem at both planning level and operational level, taking into account the financial analysis and market dynamics simultaneously. An integrated intelligent system is designed and demonstrated to support the decision making process. Therefore, the demonstration of this Decision Support System (DSS) is of great interest to the liner shipping carrier.

The third paper, on *Short Sea Shipping Intermodality and Parameters Influencing Pricing Policies: The Mediterranean Case*, by Monica Grosso, Ana-Rita Lynce, Anne Silla and Georgios K. Vaggelas, begins with the identification of factors and/or parameters influencing the pricing policy and the cost structure of intermodal transport. An overview of current policy is also made. Later on, a questionnaire is applied as a means to collect data and observe different elements that are influencing price and cost. The way that the authors implement interviews as well as the results of this paper can be very useful for the peers who are to examine the pricing scheme and the cost structure of intermodal transportation.

These papers mentioned above were presented at the first TRANSPORT-NET Seminar (Dec 2007) in Chios, Greece, the International Association of Maritime Economists annual conference (Apr 2008) in Dalian, China, the Italian Congress of Transport Economists (Jun 2008) in Sassano, Italy, and the Swiss Transport Conference (Oct 2007) in Switzerland. The various papers benefited from the many constructive comments and suggestions made during those conferences.

We would also like to stress that the successful implementation of this special issue owes to a whole range of individuals, including not only the enthusiastic authors but also the patient and knowledgeable referees who have spent lots of time and effort to provide valuable suggestions and comments. We would like to thank again the referees who have contributed in this special issue.

Last but not least, we would like to express our gratitude to the TRANSPORTNET Marie Curie Program under the 6th Framework of the European Union, which provided most of the authors with enormous opportunities to advance their research in terms of attending conferences and organizing research related activities, of which the contributions in this issue are a valuable proof.

Xiaoning Shi
Thierry Vanelslander
Guest editors
February 2010

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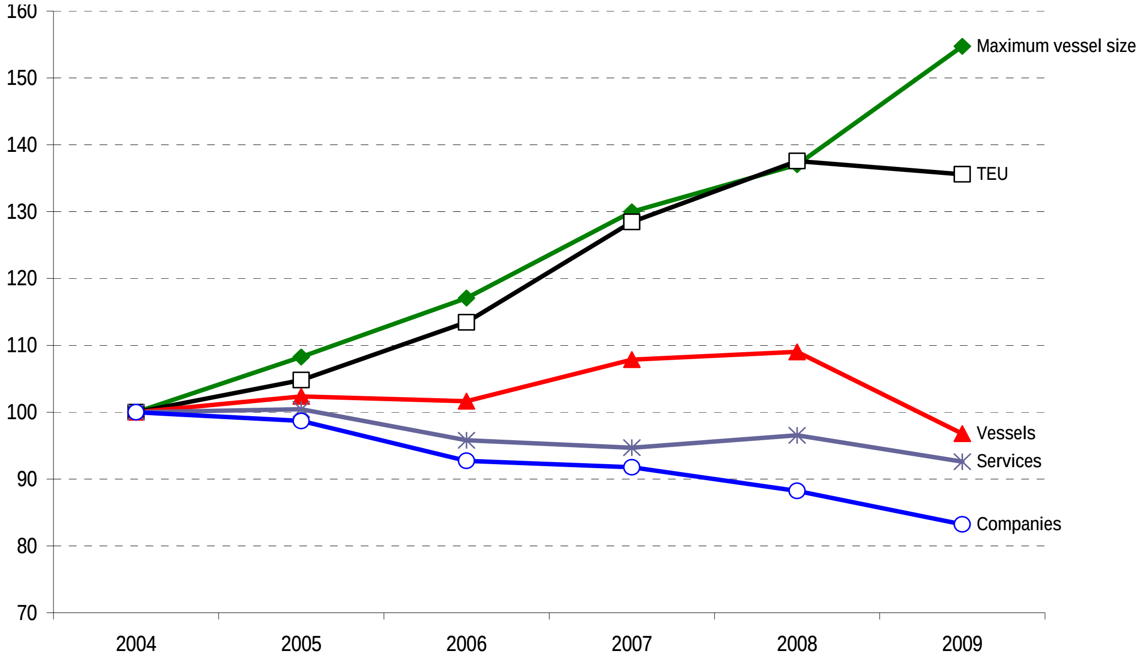
Liner Shipping Connectivity in 2009

Generated in its sixth year, UNCTAD's Liner Shipping Connectivity Index (LSCI) aims at capturing how well countries are connected to global shipping networks.[6] In 2009, China continues to be the country with the highest LSCI, followed by Hong Kong (China), Singapore, Netherlands and Republic of Korea (table 1). Developing countries which have significantly improved their LSCI ranking since 2004 include Republic of Korea (regaining important transhipment business for East Asian traffic in 2008), Morocco (moving up in the ranking since 2007 thanks to a new international transhipment facility in Tangier), Lebanon (benefiting from port reforms since 2006), and Djibouti (after investment from Dubai-based port operator DPW).

Figure 1: Trends in connectivity indicators. Index of country averages 2004 = 100



Source: UNCTAD, based on data from Containerization International Online

As regards global developments of the individual LSCI components, the 2009 data also reflects the impacts of the economic crisis. Between July 2008 and July 2009, the number of ships, their total TEU carrying capacity, the number of services and the number of companies have all decreased. Only the maximum vessel size has continued to increase: In spite of the economic crisis, new and larger vessels are being delivered by the world's ship yards. Many of these larger ships then replace smaller vessels, leading to a significant reduction in the average number of vessels per country. For the first time since UNCTAD records the data, the average container carrying capacity TEU assigned per country has discontinued its rise. Following the continued trend of mergers and acquisitions, the average number of companies offering services per country has decreased by 17 per cent since 2004 (figure 1).

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[6] The first version of the 2004 LSCI was introduced in *Transport Newsletter* No. 27, first Quarter 2005. The current version of the LSCI is generated from the five components: (a) number of ships; (b) the container carrying capacity of those ships; (c) the maximum vessel size; (d) the number of services; and (e) the number of companies that deploy containerships on services from and to a country's ports. The data is derived from *Containerisation International Online*. The index is generated as follows: For each of the five components a country's value is divided by the maximum value of that component in 2004, and for each country, the average of the five components is calculated. This average is then divided by the maximum average for 2004 and multiplied by 100. This way, the index generates the value 100 for the country with the highest average index of the five components in 2004.

Table 1: LSCI, 2004 - 2009

Country	2004	2005	2006	2007	2008	2009	Rank 2009	Change 2009/2008	Change 2009/2004
China	100.00	108.29	113.10	127.85	137.38	132.47	1	-4.91	32.47
Hong Kong (China)	94.42	96.78	99.31	106.20	108.78	104.47	2	-4.30	10.05
Singapore	81.87	83.87	86.11	87.53	94.47	99.47	3	5.01	17.60
Netherlands	78.81	79.95	80.97	84.79	87.57	88.66	4	1.09	9.85
Korea, Republic of	68.68	73.03	71.92	77.19	76.40	86.67	5	10.28	18.00
United Kingdom	81.69	79.58	81.53	76.77	77.99	84.82	6	6.83	3.14
Germany	76.59	78.41	80.66	88.95	89.26	84.30	7	-4.96	7.71
Belgium	73.16	74.17	76.15	73.93	77.98	82.80	8	4.82	9.64
United States	83.30	87.62	85.80	83.68	82.45	82.43	9	-0.02	-0.87
Malaysia	62.83	64.97	69.20	81.58	77.60	81.21	10	3.61	18.38
Spain	54.44	58.16	62.29	71.26	67.67	70.22	11	2.56	15.78
Italy	58.13	62.20	58.11	58.84	55.87	69.97	12	14.10	11.84
France	67.34	70.00	67.78	64.84	66.24	67.01	13	0.77	-0.33
Japan	69.15	66.73	64.54	62.73	66.63	66.33	14	-0.30	-2.82
Taiwan Province of China	59.56	63.74	65.64	62.43	62.58	60.90	15	-1.67	1.34
United Arab Emirates	38.06	39.22	46.70	48.21	48.80	60.45	16	11.65	22.40
Egypt.	42.86	49.23	50.01	45.37	52.53	51.99	17	-0.55	9.12
Saudi Arabia	35.83	36.24	40.66	45.04	47.44	47.30	18	-0.14	11.47
Oman	23.33	23.64	20.28	28.96	30.42	45.32	19	14.90	21.98
Greece	30.22	29.07	31.29	30.70	27.14	41.91	20	14.77	11.68
Canada	39.67	39.81	36.32	34.40	34.28	41.34	21	7.06	1.68
India	34.14	36.88	42.90	40.47	42.18	40.97	22	-1.21	6.83
Morocco	9.39	8.68	8.54	9.02	29.79	38.40	23	8.61	29.02
Malta	27.53	25.70	30.32	29.53	29.92	37.71	24	7.78	10.17
Thailand	31.01	31.92	33.89	35.31	36.48	36.78	25	0.30	5.77
Sri Lanka	34.68	33.36	37.31	42.43	46.08	34.74	26	-11.34	0.06
Portugal	17.54	16.84	23.55	25.42	34.97	32.97	27	-2.00	15.43
Panama	32.05	29.12	27.61	30.53	30.45	32.66	28	2.21	0.60
South Africa	23.13	25.83	26.21	27.52	28.49	32.07	29	3.58	8.94
Turkey	25.60	27.09	27.09	32.60	35.64	31.98	30	-3.66	6.38
Mexico	25.29	25.49	29.78	30.98	31.17	31.89	31	0.73	6.60
Sweden	14.76	26.61	28.17	25.82	30.27	31.34	32	1.07	16.59
Brazil	25.83	31.49	31.61	31.64	30.87	31.08	33	0.21	5.25
Lebanon	10.57	12.53	25.57	30.01	28.92	29.55	34	0.63	18.98
Iran, Islamic Rep. of	13.69	14.23	17.37	23.59	22.91	28.90	35	5.99	15.21
Australia	26.58	28.02	26.96	26.77	38.21	28.80	36	-9.40	2.22
Denmark	11.56	24.25	25.39	22.10	26.49	27.68	37	1.19	16.12
Pakistan	20.18	21.49	21.82	24.77	24.61	26.58	38	1.98	6.41
Vietnam	12.86	14.30	15.14	17.59	18.73	26.39	39	7.65	13.53
Argentina	20.09	24.95	25.58	25.63	25.70	25.99	40	0.29	5.90
Indonesia	25.88	28.84	25.84	26.27	24.85	25.68	41	0.83	-0.20
Jordan	11.00	13.42	12.98	16.46	16.37	23.71	42	7.34	12.71
Romania	12.02	15.37	17.61	22.47	26.35	23.34	43	-3.02	11.32
Colombia	18.61	19.20	20.49	29.13	21.64	23.18	44	1.54	4.56
Ukraine	11.18	10.81	14.88	16.73	23.62	22.81	45	-0.81	11.63
Uruguay	16.44	16.58	16.81	21.28	22.88	22.28	46	-0.60	5.84
Dominican Republic	12.45	13.95	15.19	19.87	20.09	21.61	47	1.53	9.16
Russian Federation	11.90	12.72	12.81	14.06	15.31	20.64	48	5.32	8.73
Venezuela, RB	18.22	19.90	18.62	20.26	20.46	20.43	49	-0.03	2.21
Nigeria	12.83	12.79	13.02	13.69	18.30	19.89	50	1.59	7.05
Slovenia	13.91	13.91	11.03	12.87	15.66	19.81	51	4.15	5.91
Jamaica	21.32	21.99	23.02	25.50	18.23	19.56	52	1.33	-1.76
Côte d'Ivoire	14.39	14.52	12.98	14.98	16.93	19.39	53	2.46	5.00

Country	2004	2005	2006	2007	2008	2009	Rank 2009	Change 2009/2008	Change 2009/2004
Ghana	12.48	12.64	13.80	14.99	18.13	19.33	54	1.21	6.86
Bahamas, The	17.49	15.70	16.19	16.45	16.35	19.26	55	2.91	1.77
Chile	15.48	15.53	16.10	17.49	17.42	18.84	56	1.42	3.36
Israel	20.37	20.06	20.44	21.42	19.83	18.65	57	-1.17	-1.71
Djibouti	6.76	7.59	7.36	10.45	10.43	17.98	58	7.56	11.22
Ecuador	11.84	12.92	14.17	14.30	13.16	17.09	59	3.93	5.25
Peru	14.79	14.95	16.33	16.90	17.38	16.96	60	-0.42	2.17
Philippines	15.45	15.87	16.48	18.42	30.26	15.90	61	-14.36	0.45
Trinidad and Tobago	13.18	10.61	11.18	13.72	12.88	15.88	62	3.01	2.70
Senegal	10.15	10.09	11.24	17.08	17.64	14.96	63	-2.67	4.81
Mauritius	13.13	12.26	11.53	17.17	17.43	14.76	64	-2.67	1.63
Guatemala	12.28	13.85	18.13	15.40	15.44	14.73	65	-0.71	2.45
Yemen, Rep.	19.21	10.18	9.39	14.28	14.44	14.61	66	0.17	-4.60
Costa Rica	12.59	11.12	15.08	15.34	12.78	14.61	67	1.83	2.02
Togo	10.19	10.62	11.09	10.63	12.56	14.42	68	1.86	4.23
Namibia	6.28	6.61	8.52	8.37	11.12	13.61	69	2.49	7.33
Benin	10.13	10.23	10.99	11.16	12.02	13.52	70	1.50	3.39
Cyprus	14.39	18.53	17.39	18.01	11.81	13.31	71	1.50	-1.08
Kenya	8.59	8.98	9.30	10.85	10.95	12.83	72	1.88	4.24
Cameroon	10.46	10.62	11.41	11.65	11.05	11.60	73	0.55	1.14
Congo, Republic of	8.29	9.10	9.12	9.61	11.80	11.37	74	-0.43	3.08
Angola	9.67	10.46	9.46	9.90	10.22	11.31	75	1.09	1.64
Syrian Arab Republic	8.54	11.84	11.29	14.20	12.72	11.03	76	-1.70	2.49
Puerto Rico	14.82	15.23	14.68	15.96	15.62	10.92	77	-4.70	-3.90
Honduras	9.11	8.64	8.29	8.76	9.26	10.68	78	1.42	1.57
New Zealand	20.88	20.58	20.71	20.60	20.48	10.59	79	-9.89	-10.29
Nicaragua	4.75	5.25	8.05	7.89	8.91	10.58	80	1.68	5.83
El Salvador	6.30	7.32	8.07	7.90	8.67	10.34	81	1.67	4.04
Finland	9.45	10.16	8.58	10.70	9.72	10.15	82	0.43	0.70
Tanzania, UR of	8.10	8.59	8.71	10.58	10.46	9.54	83	-0.92	1.44
Libyan Arab Jamahiriya	5.25	5.17	4.71	6.59	5.36	9.43	84	4.07	4.18
Mozambique	6.64	6.71	6.66	7.14	8.81	9.38	85	0.57	2.74
Sudan	6.95	6.19	5.67	5.66	5.38	9.28	86	3.89	2.33
Poland	7.28	7.53	7.50	7.86	9.32	9.21	87	-0.12	1.93
Gabon	8.78	8.76	8.72	8.57	8.93	9.16	88	0.23	0.38
Fiji	8.26	8.32	7.24	7.35	10.31	8.74	89	-1.57	0.48
New Caledonia	9.83	10.34	9.00	8.81	9.23	8.74	90	-0.49	-1.09
Madagascar	6.90	6.83	8.31	7.97	7.82	8.64	91	0.82	1.74
Netherlands Antilles	8.16	8.23	7.82	9.22	8.56	8.57	92	0.01	0.41
Guam	10.50	10.52	9.56	8.73	8.56	8.57	93	0.00	-1.93
Croatia	8.58	12.19	10.47	12.33	15.36	8.48	94	-6.88	-0.10
French Polynesia	10.46	11.14	8.91	8.60	9.01	8.39	95	-0.62	-2.07
Algeria	10.00	9.72	8.70	7.86	7.75	8.37	96	0.62	-1.63
Guinea	6.13	6.89	8.71	8.47	6.41	8.32	97	1.91	2.19
Lithuania	5.22	5.88	5.66	6.83	7.76	8.11	98	0.35	2.88
Bahrain	5.39	4.34	4.44	5.99	5.75	8.04	99	2.29	2.65
Norway	9.23	8.31	7.34	7.80	7.91	7.93	100	0.03	-1.30
Bangladesh	5.20	5.07	5.29	6.36	6.40	7.91	101	1.51	2.71
Ireland	8.78	9.66	8.18	8.85	7.64	7.60	102	-0.04	-1.18
Gambia, The	4.91	6.13	4.80	4.74	4.97	7.53	103	2.56	2.62
Mauritania	5.36	5.99	6.25	7.90	7.93	7.50	104	-0.44	2.14
Papua New Guinea	6.97	6.40	4.67	6.86	6.92	6.58	105	-0.34	-0.39
Kuwait	5.87	6.77	4.14	6.22	6.14	6.54	106	0.40	0.66
Tunisia	8.76	7.62	7.04	7.23	6.95	6.52	107	-0.43	-2.24
Cuba	6.78	6.51	6.43	6.71	6.12	5.92	108	-0.20	-0.86
Bulgaria	6.17	5.61	4.47	4.83	5.09	5.78	109	0.70	-0.38

Country	2004	2005	2006	2007	2008	2009	Rank 2009	Change 2009/2008	Change 2009/2004
Estonia	7.05	6.52	5.76	5.78	5.48	5.71	110	0.24	-1.34
Sierra Leone	5.84	6.50	5.12	5.08	4.74	5.56	111	0.83	-0.28
Liberia	5.29	5.95	4.55	4.50	4.25	5.49	112	1.23	0.20
Maldives	4.15	4.08	3.90	4.75	5.45	5.43	113	-0.02	1.28
Latvia	6.37	5.82	5.10	5.87	5.52	5.18	114	-0.34	-1.19
Cape Verde	1.90	2.28	2.76	2.45	3.63	5.13	115	1.50	3.23
Iraq	1.40	1.63	4.06	2.61	1.20	5.11	116	3.90	3.71
Comoros	6.07	5.84	5.39	5.51	5.15	5.00	117	-0.16	-1.08
Seychelles	4.88	4.93	5.27	5.29	4.49	4.90	118	0.40	0.01
Barbados	5.47	5.77	5.34	5.79	5.36	4.75	119	-0.61	-0.72
Iceland	4.72	4.88	4.75	4.72	4.72	4.73	120	0.01	0.01
Cambodia	3.89	3.25	2.93	3.25	3.47	4.67	121	1.20	0.78
Samoa	5.44	5.33	5.09	6.50	6.66	4.62	122	-2.04	-0.82
American Samoa	5.17	5.30	4.86	6.28	6.44	4.60	123	-1.84	-0.57
Haiti	4.91	3.43	2.91	2.87	3.44	4.40	124	0.95	-0.51
Guyana	4.54	4.37	4.60	4.51	4.36	4.34	125	-0.02	-0.20
St. Lucia	3.70	3.72	3.43	4.21	4.25	4.25	126	0.00	0.55
Vanuatu	3.92	4.48	4.41	4.34	4.36	4.22	127	-0.15	0.30
Faeroe Islands	4.22	4.40	4.43	4.45	4.20	4.20	128	0.00	-0.01
Suriname	4.77	4.16	3.90	4.29	4.26	4.16	129	-0.10	-0.60
Grenada	2.30	2.52	3.37	4.09	4.20	4.13	130	-0.07	1.83
St. Vincent & the Grenadines	3.56	3.58	3.40	4.34	4.52	4.13	131	-0.40	0.57
Tonga	3.81	4.75	4.45	4.07	4.23	3.99	132	-0.24	0.18
Solomon Islands	3.62	4.29	3.97	4.13	4.16	3.96	133	-0.20	0.34
Brunei	3.91	3.46	3.26	3.70	3.68	3.94	134	0.26	0.03
Micronesia, Fed. Sts.	2.80	2.87	1.94	3.13	3.85	3.85	135	0.00	1.05
Georgia	3.46	3.81	2.94	3.22	4.03	3.83	136	-0.20	0.37
Congo, Dem. Rep.	3.05	3.03	2.66	2.68	3.36	3.80	137	0.45	0.76
Palau	1.04	1.04	1.87	3.07	3.79	3.79	138	0.00	2.75
Myanmar	3.12	2.47	2.54	3.12	3.63	3.79	139	0.16	0.67
Northern Mariana I.	2.17	2.20	1.85	2.86	3.76	3.76	140	0.00	1.59
Equatorial Guinea	4.04	3.87	3.76	3.36	3.86	3.73	141	-0.12	-0.31
Virgin Islands (U.S.)	1.77	3.00	3.22	3.76	3.81	3.70	142	-0.11	1.94
Guinea-Bissau	2.12	5.19	5.03	5.22	5.34	3.54	143	-1.80	1.42
Aruba	7.37	7.52	7.53	5.09	5.09	3.52	144	-1.57	-3.85
Eritrea	3.36	1.58	2.23	-	3.26	3.26	145	0.00	-0.10
St. Kitts and Nevis	5.49	5.32	5.59	6.16	6.19	3.08	146	-3.11	-2.41
Kiribati	3.06	3.28	3.05	3.06	3.06	2.85	147	-0.20	-0.21
Marshall Islands	3.49	3.68	3.26	3.06	3.06	2.85	148	-0.20	-0.63
Somalia	3.09	1.28	2.43	3.05	3.24	2.82	149	-0.42	-0.27
Switzerland	3.53	3.40	3.20	3.27	3.01	2.74	150	-0.27	-0.79
Dominica	2.33	2.51	2.33	2.40	2.31	2.73	151	0.41	0.40
Antigua and Barbuda	2.33	2.56	2.43	3.76	3.82	2.66	152	-1.16	0.33
Sao Tome and Principe	0.91	1.28	1.57	1.64	2.54	2.38	153	-0.16	1.47
Albania	0.40	0.40	0.40	2.28	1.98	2.30	154	0.31	1.89
Belize	2.19	2.59	2.62	2.61	2.32	2.30	155	-0.02	0.10
Greenland	2.32	2.32	2.27	2.27	2.36	2.27	156	-0.09	-0.04
Qatar	2.64	4.23	3.90	3.59	3.21	2.10	157	-1.12	-0.54
Cayman Islands	1.90	2.23	1.79	1.78	1.78	1.76	158	-0.02	-0.14
Bermuda	1.54	1.57	1.57	1.57	1.57	1.57	159	0.00	0.03
Czech Republic	0.44	0.44	0.44	0.44	3.20	0.44	160	-2.76	-0.00
Montenegro	2.92	2.92	2.96	2.96	3.20	0.02	161	-3.18	-2.90
Paraguay	0.53	0.53	6.32	6.30	0.65	0.00	162	-0.65	-0.53

Source: UNCTAD, based on data from Containerisation International Online

Paper

From transocean routes to global networks: a framework for liner companies to build service networks

Xiaoning Shi and Stefan Voß

Abstract—During the previous two decades liner carriers within maritime shipping have broken the barriers from being pure transportation providers towards being logistics service providers. Most of the top 20 liner carriers worldwide have set up spin-offs providing services from local booking up to 3rd party logistics services, combining the business advantages of tight linkages with liners together with the negotiation freedom with demanding customers by providing an extension of service coverage. Economical evaluations of transocean routes and global networks are of interest for decision makers responsible for business strategies as well as for operations. It is crucial to achieve appropriate judgements about which liner routes are profitable and how to build better service networks so that the companies' brand could be attractive to, e.g., shippers, including exporters, importers and forwarding agents. In this paper we discuss the corresponding trade-offs as well as related decision support systems of relevant service providers and companies.

Keywords*— *liner, port, logistics, networks, decision support system.

1. Introduction

Stemming from the inherent characteristics of world trade, the international shipping industry faces general issues of globalization, volatility, capital-intensity and periodicity. These issues, among others, provide the maritime shipping and logistics industry with a wealth of opportunities, however, with considerable uncertainties. The fact that liner carriers have already broken the barriers from being transportation providers towards being logistics service providers during the last two decades lets researchers consider related improvements and optimization after those extensions of business processes. Most of the top 20 liner carriers set up spin-offs providing different services, from local booking services up to 3rd party logistics services, combining the business advantages of tight linkages with the liners together with the negotiation freedom with demanding customers. A trade-off results from the relatively ambitious goals of the liner carriers and the marketing pressure of their spin-offs focusing on 3rd party logistics services, namely, the economical comparison between transocean routes and global networks. On one hand, as top liners deploy mega ships, economies of scale and single voyage efficiency are needed in order to accomplish the aim of unit cost saving. Thus, there is a need to focus on (long haul) transocean routes. On the other hand, for a 3rd party logistics provider (3PL), a global network with reliability and agility is crucial, too. Decision makers handling business strategies as well as operations, who are willing to resolve this trade-off, must be aware of which routes are productive and how to build up better service networks so that the brand and the reputation of affiliated companies is attractive to shippers, including exporters, importers and forwarding agents.

In this paper, besides presenting a literature review on a variety of papers relevant to the topic, we also attempt to discuss the evaluation and analysis of route choice and the optimization of networks. We start with the ingredients of related networks – ports and routes – and later extend by addressing different functions of the liners and the 3PL, as well as illustrating several criteria suitable for the selection of a transhipment hub as well as inland feeders. Regarding the dynamic competition and cooperation within the liner market, we finally sketch a theoretical framework, which may be of use regarding the development of decision support systems (DSS) of the liner companies, on how to build efficient service networks.

2. Ingredients of the networks – routes and ports

Logistics services could be identified as appropriate extensions of existing networks. Therefore, cf. [3], we interpret the connections among routes and ports of call as subnetworks. As the definition of logistics can be quite broad we need to focus. That is, in this paper we are mainly concerned with door-door service derived from long-distance shipping services. Short-distance inland distribution logistics without any shipping is not covered in this paper. In order to gain better understanding about the networks of shipping and logistics, the routes and the ports could be defined as the links and the nodes, respectively, as basic ingredients forming the networks.

2.1. Routes – links/ports – nodes

There are three main transocean lanes, namely transatlantic, transpacific and far-east to Europe [5], playing significant roles as the cheapest transportation mode serving commodity flows. Besides these main lanes, each liner carrier would arrange its services based on given freight requirements, thus, the required routings from the shippers motivate the liner carriers to construct complete world-wide networks. The lanes and routes connecting the ports can be viewed as the links in a graph with the seaborne transportation demands of the links denoted as weights.

Various researchers have addressed the definition of a "port". For instance, Carbone and De Martino [4] define: "*Ports have been natural sites for transhipment in order to transfer goods from one mode of transport to another. They have historically provided the link between maritime and inland transport, and the interface between the sea, rivers, roads and railways*". This definition is not fully comprehensive, as ports often also function as nodes without any mode diversity, e.g., from ship to ship. At least this statement indicates that ports are nodes with cargo in-flow and out-flow. (See, e.g., [31, 32] for a container terminal oriented survey.)

Considering the ports as nodes, we note that the liner carriers and their logistics spin-offs discussed in this paper are also of other characteristics – direct service networks together with indirect physical networks. For instance, a shipper as customer may book a door-to-door service in terms of local booking service[1] provided by a 3PL spin-off of the liner carriers. That is, the shipper and the service provider have direct service connections. However, it does not mean that this cargo freight is transported by the 3PL related liner carrier[2] only, not even within multi-modal transportation including inland-haul and short-sea distribution, if any, according to the service contract between the shipper and the 3PL. Therefore, indirect physical networks exist, which urges smooth and seamless connection.

2.2. Similarities among networks

Not only maritime shipping (transportation) networks have the features discussed in Subsection 2.1. Also some other (service) industries share the features which can be investigated by applying similar methods. It deserves to be noted that shipping and the logistics industry, as well as the telecommunications industry, share common characteristics of networks such as facility indivisibilities, technology interconnectedness and utility externalities, etc. A simplified comparison between the telecommunications and the port operations as well as freight shipping can be shown as follows. Similarities mainly exist regarding four aspects: generation and infrastructure development, distribution, mode choice and assignment. A brief comparison is that telecommunication service carries packages which contain data and messages; port operation moves containers either vertically up/off to/from ship or horizontally connected with trucks or trains; and also freight transport carries commodities from origins to destinations. Moreover, we can state that in all these "systems" we are concerned with consolidation and transhipment points.

Regarding the basic features of those industries and their similarities, theoretically, the literatures and research outcomes from each area could be applied to each other if done in an appropriate manner. For a review on the service network design for freight transportation see, e.g., Wieberneit [36] who specifically investigates tactical planning problems in freight transportation. Regarding the classification of the planning of a transport system, we refer to, e.g., [6]. In Section 3, we focus on the freight shipping industry.

3. Selection and preference of ports and networks

From a historical point of view, the main routes that contain lots of cargo desires are those routes firstly developed by ancient traders, and those nowadays need to be deployed with mega ships. However, taking basic logistics requirements into account, a superficial contradiction seems to arise from the liner companies and their 3PL spin-offs.

3.1. A superficial contradiction

On one hand, the target market niche of liner services is to provide transportation by visiting fixed ports according to pre-announced fixed schedules, meanwhile at a relatively stable freight of all kinds (FAK) price. More specifically, even the names of liners' vessels are settled and announced in advance once the liners are willing to provide liner services, and those container vessels are supposed to visit selected ports one by one in a timely fashion, also based on pre-announced fixed schedules. Cargo fitting into containers are shipped at settled prices (in this paper we ignore the issue of setting booking prices and the strategic contractual wholesale prices) disregarding what the cargoes really are. As a result, we refer to any TEU (twenty-foot equivalent unit; measurement of containers) as a profitable "unit". A fundamentally common aim of the liner companies is to achieve economies of scale together with significant cost savings per unit, achieved by deploying bigger ships along profitable routes consisting of productive ports with deep drafts.

On the other hand, attractive service offerings provided by the logistics companies could be increased frequency, less quantity per shipment and higher agility based on customers' specialized requirements. Logistics companies providing 3rd party services with local booking authorities, especially those spin-offs of the liner companies considered here, are actually blooming since the last decline of the liner industry under the hope of attracting more customers from competitors providing similar liner services. Those 3PL spin-offs are endowed with the advantages of getting allocated capacities at lower contractual prices with their head companies or sister companies. Nevertheless,

[1]For reason of domestic maritime regulation and territory security, most countries do not authorise the foreign liners full authority of direct-booking. This is one of the reasons that foreign liners set up 3PL spin-offs as interfaces providing local-booking services to the shippers.

[2]It refers to a liner carrier who sets up a 3PL spin-off. Later, those two companies might become sister companies belonging to the same group.

they are trying every effort to accomplish and fulfil door-to-door and even value-added services as well as to expand networks by means of visiting feeder ports and setting up inland distribution centres.

Then a superficial contradiction occurs between the selection of transhipment hubs and the expansion of networks under the capital constraint and management constraint of the head-corporation of the liner company and the involved 3PL. In this paper, we consider the network design problem as a strategic issue.

Note that we regard a spin-off of the liner carriers providing logistics service as 3PL. However, other researchers might rate liner carriers themselves as 3PL considering buyer and seller of the respective trade contract ([28], p. 252). Here we somewhat ignore the debate of who can actually be regarded as 3PL or even "4PL". Instead, we focus on the performance and value of the service networks. For a framework for evaluating 3PL see, e.g., [33].

3.2. Possible solutions to solve the contradiction

In this section, we investigate liner carriers and their 3PL spin-offs from a network theory perspective, which might shed some light on resolving the above mentioned contradiction. Applying network theory allows the liner carriers to optimize their current networks as well as aggregate potential partners' network [3]. Consequently, a multi-criteria optimization system should be set so that a rational selection on transhipment hubs and feeder ports could be accomplished. For a comprehensive literature review up to 2000 on freight transportation structuring from the viewpoint of choice processes we refer to [18]. Here we further discuss some other criteria in terms of networks, information as well as the 3PL spin-offs.

In practice, the selection of ports of call, including transhipment hubs and feeder ports, could be viewed as selection processes for business partners, no matter whether it relates to vertical or horizontal partnerships. However, before they become business partners, port operators, to great extent, might be competitors within the same industry. That is, players belonging to the same region, neighbouring each other and sharing overlapping hinterland, form a competitive relationship (e.g., the so-called North-Range in Europe). As some literatures address, financial health, adequate physical facilities, intangible assets [1, 10] are crucial as contributing factors during preliminarily screening the potential ports of call. Further references regarding port selection can be found in, e.g., [17, 24].

3.2.1. Criteria of hubs/transhipment hubs

Distribution network. One difference between hubs and transhipment hubs is whether there exists an advanced distribution network to connect to the hinterland. If there is an advanced distribution network, the hub may not only act as a media to move cargoes from one ship to another (cf. the term crossdocking in slightly different context), but also between different transport modes, e.g., from ships either to trains or to trucks. However, for many transhipment hubs, like Hong Kong or Singapore, a high percentage of the whole throughput refers to ship-to-ship movements. Thus, in such a case the hinterland distribution network is not of utmost importance (compared to, e.g., Hamburg). Most important are the free-port regulation and a sophisticated handling system that make the B/L transaction and water-water transhipment convenient.

Information system. Congestion, either on the seaside or on the landside could enlarge the total time of a vessel in the port, which would actually imply increased operational costs for the liner carriers. However, congestion free access to a port or congestion within the port is usually not one of the (main) criteria for choosing the hubs. As a matter of fact, several hubs suffer congestion quite often. It seems most important whether there is an efficient and effective information system to support the daily operations within the port so that even if congestion happens, a constructive solution would be suggested by the information system quickly. Recent discussion in this respect refers to so-called port community systems (see, e.g., www.dakosy.de for some example).

The 3PL spin-offs. In the hubs that the liner carrier or its corporation chooses, usually a related 3PL spin-off is set up, too, to ensure the convenience of the service that they could provide to the customers as a package. Comparing the local forwarder agent located in other feeder ports, the 3PL spin-off has stronger linkage with the liner carrier and, in return, might get more allocated capacities as support.

3.2.2. Criteria of feeder ports

Local forwarder agent. In practice, the selection of feeder ports is usually combined with the selection of the local forwarder agents. In most cases, if one forwarder agent distinguishes himself by his performance in one port, then other ports covered by this forwarder agent's business are probably also selected by the liner carrier as feeder ports. One superficial reason could be that the forwarder agent has a long cooperation with the liner carrier and gets used to follow all the managerial habits of the liner carrier which satisfies the liner carrier's requirements and further brings the liner carrier more freight. Another reason is that this forwarder agent could to great extent support the freight and fill capacities of the liner carrier by utilising his own network and attract shippers located in the hinterland. Considering the transocean routes initially constructed by the liner company, we define the extended inland or short-sea network of the local forwarder agent as the sub-network.

This phenomenon indicates that potential feeder ports would be selected due to their contribution to the original networks in fashion of better sub-network connection and accessibility. It should also be noted that such expected contribution might not happen as soon as the alternative feeder ports are added into the network, they might play their roles step by step. Unfortunately, as time goes by, the freight flow may amplify itself and then the profit-driven liner carriers may set up their own spin-off or stock-holding companies there instead of cooperating with the former forwarder agents. Consequently, this feeder port may even have the chance to be upgraded as hub within the ports of call of this liner.

Besides the practical criteria mentioned above, Lirn *et al.* [15] apply the analytic hierarchy process (AHP) as a method for evaluation and selection of transhipment ports from a global perspective. In addition, other researchers propose multi-criteria optimization for partner selection issues, which could be regarded as the amendment and development of an AHP application, see [9, 10].

4. Network optimization for a dynamic liner market

In this section we discuss aspects of optimizing service networks regarding the dynamic liner shipping market by taking into account the capacity of other sub-networks with a whole networks perspective. General concerns of cost efficiency in container shipping can be found, e.g., in [30].

4.1. Dynamics as a characteristic of the liner shipping industry

In spite of the cooperation among the liner carriers and other players involved in the liner shipping industry, many observations disclose the fact that the liner shipping industry is full of dynamics, including membership diversity, partnership reshuffling, network restructuring, etc. Rimmer [27] provides a historical description on the membership diversity among the liner shipping alliances up to the mid nineties. A more recent exposition of cooperation, mergers and acquisitions within the liner shipping industry is given by Notteboom [25]. Furthermore, for an up-to-date review on the dynamics existing in this industry see [29].

In short, the membership of the shipping alliances can switch from partnership towards being competitors and vice versa. This not only results in fleet capacity changes but also leads to diversity between the services that the alliances can provide. In this case, the related liner carriers' behavior of changing membership can be interpreted as attempting to combine new sub-networks with other players, no matter whether the other players are carriers or local in-land haul service providers.

4.2. Flexibility as response

Due to the dynamic environments of the transportation industry, flexibility plays a vital role if relevant companies are willing to survive. Reasons for the importance of flexibility include network externalities, as pointed out by David [7]; benefits of users/producers of the services are depending on the presence of other users/producers. Robinson ([28], p. 248) states that "*shipping lines are in the business of delivering value to buyers and sellers – and of capturing value to ensure they remain in business*". Considering the dynamics of the liner market, we address the flexibility of the network as one of the competitive advantages to ensure that shipping lines remain competitive and survive in business.

Once liner carriers have to compete in context of flexibility, the selection and integration of sub-networks becomes vital. Min and Guo [22] investigate the location of hub-seaports in the global supply chain network from the point of view of cooperative game theory. They develop a cooperative strategy in order to support the liner carriers and the shippers to determine optimal locations for the hub-seaports. However, our approach is slightly different as we do not assume the liner carriers and the local sub-network providers having binding agreements among each other. To some extent, we deepen our research based on the non-cooperative assumption, which is more realistic in the real business. As discussed in Subsection 2.1, routes and ports would be regarded as the basic features of the service networks of the liner carriers. The following four aspects need to be taken into account: generation of seaborne transportation, distribution of the shipping requirements, modal split and assignment of the shipping volume.

4.2.1. Zoning

While discussing ports serving the container flows, related regions are actually divided within the overall transportation networks by means of zoning. Zoning is a process that combines similar nodes into different zones and separates them from each other. Such zoning process depends a lot on the objectives of the networks, the available data, budget and time constraints as well as the zones homogeneity. Furthermore, due to the limited knowledge of all the details of every node almost all information (or expectation) of the nodes could be integrated into the "zone" and lateron each zone is reduced to a point. Then, spatial dimensions of a zone diminish. For instance, once ports A and B are integrated into one zone, the spatial distance between A and B is not important any more. In contrast, whether A or B would act as the hub of this zone would be an important decision. Once A acts as the hub and B acts as the feeder port, the assignment of the inbound and outbound links to and from this zone is related to the network design, while the volume between A and B within this zone is related to the sub-network design. In other words, one of the ports, say A, is selected as the central port because of advantageous transportation conditions while utilizing other ports, say B, as subsidiary within the zone. We note in passing, that a comprehensive survey of operations research approaches for the design of hub and spoke systems is provided in [34]. A simple adoption of hub and spoke systems to ship assignment is provided by Mourao and Pato [23].

4.2.2. Coding

The whole network is simplified by means of zoning and coding. Coding is a process that captures network links and centroids to represent the characteristics of the zone, respectively, instead of the former random links and nodes. That is, the network links and centroid are more relevant for the networks rather than the sub-network.

Now we are prepared to explain the behavior of the liner carriers: sometimes they set up 3PL spin-offs located in different areas and sometimes they simply select some local agents to act as the forwarder service and logistics service provider. However, the in-depth ideas are similar. The liner carriers set up their own 3PL spin-offs after zoning their current and potential traffic network and let the 3PL spin-off represent (the features of) this zone so that it could serve in the best possible way. As a different option, they select the local agents acting as a representative of a sub-network, whoever could contribute best to the whole network. Thus, the competition of the liner carriers, to some extent, is a competition of network integration. Furthermore, the turbulence of the liner market requires the flexibility of the network to ensure the just-in-time change. Once the circumstances or factors change as, e.g., observed with respect to the Panama Canal expansion, the sub-network and the whole network of the liner carriers should change accordingly to match customer demands and the circumstances.

In general, all the cargoes currently are served by the networks and the containerized shipments are transported from door to door, and during this procedure, at least two hubs are chosen (maybe more than two if the transhipment is included regarding the long distance). One hub locates in the zone of the origin, and the other hub locates in the zone of destination. Thus, the whole logistics procedure could be decomposed into the liner carrier's network and its 3PL spin-off/local service's sub-network. Furthermore, the sub-network selection and their connectivity are of great importance. We note that this is closely related to intermodal transportation problems, airline transportation networks as well as problems in telecommunications network design. For the latter see, e.g., the formal modeling approaches in [13, 20]. Route design in a specific liner shipping problem is considered in, e.g., [12].

In the following, we describe the problem from two aspects: sub-network selection and shipment distribution. Let $G = (N,A)$ be a graph consisting of a set of nodes N and a set of arcs A. G represents a physical network provided by the liner carriers and the logistics providers. Let K define a set of cargo shipments. A specific sea cargo shipment $k \in K$ is defined by an origin-destination or O−D pair, with $o(k)$ as origin and $d(k)$ as destination. The set of all paths from $o(k)$ to $d(k)$ for k is defined as P^k and the set of all O−D-pairs throughout the network is defined as P. The demand of a network or sub-network related to shipment k is denoted as d^k, which has to be transported from $o(k)$ to $d(k)$. In this paper important constraints such as time window constraints are not considered as key constraints as we ignore operational details. The main constraints refer to arc-capacity so that they could fulfil the demands d^k. Considering the integration of some networks, the total capacity of the involved links should be enough to cover the total demands. One might include binary decision variables indicating whether a sub-network is to be added to the whole network, or not. Another variable x_p^k is a nonnegative shipment flow variable, which indicates the flow of shipment $k \in K$ transported via the path $p \in P$, i.e., the amount of cargo to be shipped. F_p^k denotes the freight rate of the shipment $k \in K$ via the path $p \in P$. F_P^s denotes the freight rate of the additional shipment $s \in S$, which is attracted by the newly-added sub-network defined as S.

By adding appropriate arc inclusion indicator variables as well as flow variables we can model a multicommodity flow problem similar to those in telecommunications network design, see, e.g., [13, 20]. Here we concentrate on the objective function.

Let C_p^k be the shipment flow cost or variable cost of handling the goods per unit flow of k along path $p \in P^k$. The fixed costs of the network are not considered, because they are sunk costs in this problem. When the liner carrier decides to integrate with some potential sub-networks, the fixed cost of the carriers' network had already been invested before, and the amount of it would not be taken into account for the next stage. In contrast, the fixed costs of the potential sub-networks should be considered because they are among the main factors of the decision making process.

The objective function can then be formulated as follows:

$$\max \sum_{k\in K} \sum_{p\in P^k} F_p^k x_p^k + \sum_{s\in S} \sum_{p\in P^k} F_p^s x_p^s - \sum_{k\in K} \sum_{p\in P^k} C_p^k x_p^k ,$$

where:

$$x_p^k \geq 0, \quad \forall k \in K, \quad p \in P^k .$$

The objective is to maximize the total profit of the integrated network by taking into account not only the original shipping demand but also the additional shipping demand attracted by the improved network.

The nodes can be denoted as n_i and the zones can be denoted as z_i after zoning. Suppose that the liner carrier attempts to construct the global network or just to improve some part of the whole network. Figure 1 demonstrates the nodes, zones and the links of the sub-network and the whole network, respectively. We could not clearly separate the procedures of selection (set up 3PL spin-offs or select local agents) and zoning because they actually happen almost at the same time. However, slight differences still exist. As for setting up a 3PL spin-off of the liner carrier, it might happen after zoning because at the moment of location selection the liner carrier has already build up a global service network and most probably the headquarter of the 3PL spin-off will be located just in the centroid of the zone. In contrast, the selection of the local agents may influence the zoning of the liner carrier because some of the local agents are so strong that the shipping volume of the related zone changes too much. However, the common idea of the setting up and selection is whether such decision would contribute to the payoff of the whole network as well as the sub-network itself. Suppose that one liner carrier attempts to cover the two main lands. The zoning process follows the criteria of covering as many freight nodes and simplifying the whole area as much as possible. The coding process lets the z_i represent instead of n_i, which tremendously decrease the links and the voyage time of the vessels. However, once comparing the potential options of the local agents of z_6 and z_7, an overlap of these two zones is found. This infers that if the first local agent of z_6 is not strong, the initial zoning result can be obtained, but if another alternative local agent is to be integrated, then the zoning of z_6 and z_7 shall be reorganized.

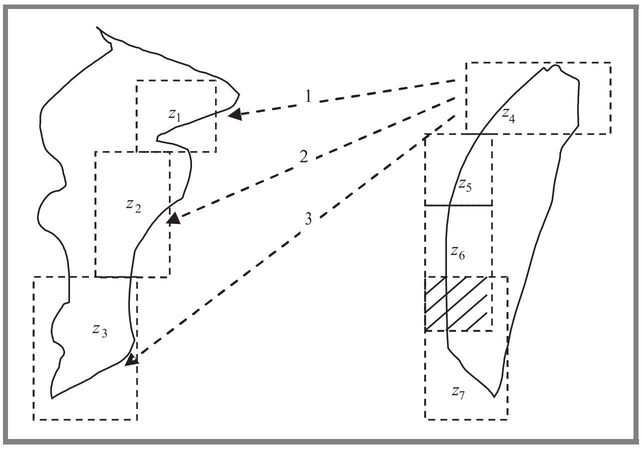

Fig. 1. The zoning of the origin and the destination of long distance transportation.

In Fig. 1, without loss of generality, we take z_4 as the origin area and the left side as the options of destination, including z_1, z_2 and z_3. The optimal route from the right hand side to the left hand side of this figure depends on the sub-networks inside the zones z_1, z_2 and z_3 and their connectivity.

Regarding the integration of any sub-network into the whole network, both the payoff of the sub-network provider, in this case, a 3PL or local agent, and the payoff of the whole network must be positive and bigger than the former stages. Otherwise, such integration usually makes no sense to the liner carriers.

For possible heuristics to solve and validate some concept proposed in this paper, we refer to [35]. Regarding a mathematical proof of a similar port-of-call scheduling problem we refer to [19]. In addition, an interesting case study including six European ports in the context of port selection in the hinterland of Europe is [8].

5. Decision support systems in transportation companies

As indicated in Section 3, competition among the liner carriers currently relies on the implementation of the service networks by means of selecting sub-network providers and cooperating with them. Furthermore, in order to have a smooth coordination and integration of different sub-networks some sophisticated information systems are necessary.

5.1. Liner carriers and port operators integration for efficient supply chain management

Stepping back in history and the development of trade, transportation and logistics, liner carriers or shipping carriers in general were pure traders centuries ago. However, nowadays they tend to have the ambition of being more comprehensive players. The shipping carriers attempt to touch inland-haul service, short-sea connections and certainly logistics service mainly related to door-door transportation (here we do not refer to the so-called value-added activities inside manufacturing factories which are always included as logistics, too).

Shippers and consignees are exporting and importing the cargoes and pay the freight rates, accordingly. However, as they only have direct service contracts with the liner carriers or the 3PL rather than with the port operators [29], the detailed operations between logistics providers and port operators are of less interest for them. Consequently, the efficient and effective integrated services including transportation services and port operations would be most welcomed by the customers, i.e., the shippers and the consignees.

In order to obtain better performance of service integration, DSS are of great importance for the liner carriers. Regarding the difference between DSS and decision making systems we distinguish whether the systems recommend several potential actions or automatically implement actions [16]. For the current solution methodologies, optimization-based solutions of information systems focus more on the average demands and requirements under static conditions, and simulation-based solutions accommodate the system dynamics which could be more suitable for the real-world business [16]. Furthermore, heuristic-based models contain the capability taking into account almost all network configurations providing optimized solutions accordingly.

5.2. Decision support system applications in liner and logistics companies

Since the last decade internet-based business (or e-business) activities have become a new technological challenge for the shipping industry. However, beyond the introduction of electronic data interchange (EDI) little systematic and theoretical research on e-business has been undertaken within this area so far. Therefore, we attempt to investigate the application of information systems in the shipping industry (the container shipping industry is focused in this paper) and their impacts of e-business on the container shipping industry in order to provide the liner carriers with the managerial recommendations accordingly. For a literature review on general business dynamics and the technology strategies of six different e-business models in the container shipping industry see [2]. Moreover, we should note that various areas lack the practical application of DSS, largely due to the lack of unified generally applicable systems, cf. [11].

While business activities could be divided into operational, tactical and strategic activities, the respective sub-information systems perform various functions. End users of a container shipping company could be basically distinguished regarding activities along those time horizons from strategy promoters up to in-putters of daily operational data. These include vessel positions, container status, service requirements, payment transactions and so on.

As an example we consider Maersk Sealand which is regarded as a benchmark from almost every aspect in the shipping industry. We focus on a "handwaving" description of its information systems applications as well as implementations. The whole information system could be called MGM, consisting of three subsystems, namely MARS, GCSS and FACT, aiming at handling contracts, booking accomplishment and finance accounting, respectively.

Once we start our observation from the most basic activities – slot booking and bill of lading (B/L) issuing – of a container shipping company, it would shed light on the whole applied information system. As shown in Fig. 2, the exporter books capacity based on his planned cargo transportation[3], which is going to be transported to the importer. To simplify the process, we regard the exporter as the shipper and the importer as the consignee regardless the pure medium trader who actually does not produce or own cargo. The pure medium trader gains profits by buying and selling cargo at different price, or maybe only transacting the B/L rather than cargo itself.

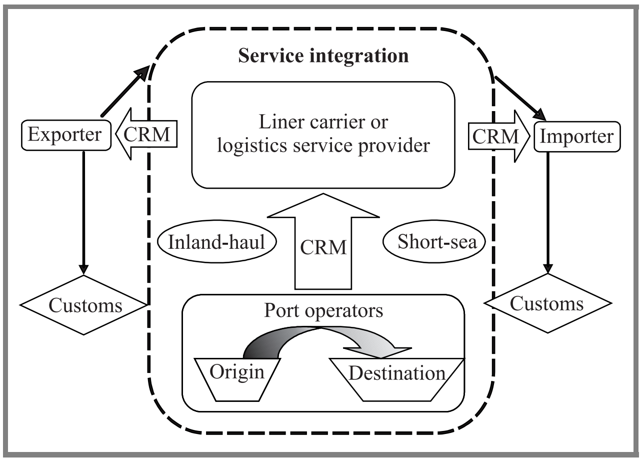

Fig. 2. The service integration and its cash/cargo/information flows (CRM – customer relationship management).

There are older and mature information systems applied within Maersk Sealand, namely MARS and RKDS, which help sales representatives and customer service staff to advise transportation services, arrange routes, input and output data. The interfaces of those systems were long-time criticized as not being user-friendly enough. They are still simultaneously applied together with a new system called global customer service system (GCSS) designed and developed by IBM. The GCSS is currently used mainly by the customer service group globally providing functions like routing, tracking, on-line publishing, etc. A "rater" – providing customer service – is supposed to use GCSS to figure out the service contract of a shipper and fix the service price according to this shipper's booking. Beyond expectation, more "raters" are now hired in Maersk Sealand than during the period of applying the old systems, as it turns out to be even harder to exchange data using the new information system. Moreover, the interface of GCSS with other subsystems is not as smooth as expected. Manual work is arranged to supplement system problems.

Regarding tactic and strategic level business management, profit judgement and risk evaluation would be two main aspects for which information systems perform decision support functionality.

Process standardization. From a customers' perspective, requirements would be well satisfied if they are met timely and specifically. In the past, once the requests of VIP customers change, the workflow of the carriers may change as well. However, implementing a new information system results in a situation where most customers are regarded exactly the same no matter what amount of cargo they transport, while those customized requirements would be noted in the specific entries inside the systems. Due to standardized workflows within the system even exception handling is assumed to be more streamlined especially when faced by employees who are new to specific situations.

Profit pre-analysis. Continuous deficits push decision makers to consider whether persisting transportation operations along the involved routes and ports are profitable or not. Various aspects are vital since any change of the liner routes and logistics networks would lead amounts of investment not only in marketing surveys but also in acquisition of infrastructures including vessels and cranes, etc. That is, it is a capital-condensed and cost-sensitive industry.

Similar to the operational systems of other liner carriers and logistics companies, MARS in Maersk Sealand provides distinctive options for cost per unit and expected benefit calculation for various types of containers regarding, e.g., volumes they occupy on deck and in haul (such as 20DC/40DC, i.e., a single 20- or 40-foot container containing dry cargo; HC, i.e. a 45-foot high cube container; etc.). Currently, an SAP R/3 package is implemented, namely financial accounting for container transport (FACT), and it is planned to be released by the end of 2008.

Risk evaluation. Risk evaluation based on historical data, service simulation, and expert judgement is of importance to demonstrate whether to accept specific transportation requirements. For risk management considerations regarding other types of cargo, such as crude and product oil see, e.g., [21].

[3]Here we assume trade contracts in terms of CIF (cost, insurance and freight). In applying other INCOTERMS, the analysis is similar. For basic knowledge on INCOTERMS, we refer to, e.g., [14].

Different types of containers as well as cargo need to be handled differently, especially reefer and hazmat containers. On December 18, 2006, the REACH (registration, evaluation, authorisation and restriction of chemicals) regulation was formally adopted by the European Union and is enforced since June 1, 2007. In order to save the testing cost on chemicals and to get an overview about which studies are available, a system which could serve as data sharing platform is currently under construction. A supplementary but vital requirement of this system is to ensure that not only manufacturers and importers but also their customers and distributors have the information they need to use and transport chemicals safely. Information relating to health, safety and environment properties, and risk measurement is required to be shared along the supply chain. Commercially sensitive information is not required to be exchanged [26]. Although REACH has just been put into force recently, its effect on information flow management within supply chains is regarded as huge.
However, it should be noted that, due to fast EDI processes, the information centre of the liner carrier need not be the centroid of any zone defined in Section 4. Actually, some of the information centres of the liner carriers are even located far from hubs, following various criteria such as human resources availability and cost. The geographic location of an information centre is not a key issue in this paper and it may be viewed as a fictitious node that contributes to the whole service network.

6. Conclusions and further research

In this paper, we have discussed the network structure of the maritime liner shipping companies and their spin-offs providing 3rd party logistics services. Commonalities with intermodal transportation in general as well as with telecommunications network design may serve as a means for advancing the subject. Moreover, game theoretical approaches may help to support strategic as well as tactical decision making in liner shipping. This may involve the assumption of cooperative as well as non-cooperative behaviors of involved players on different levels.

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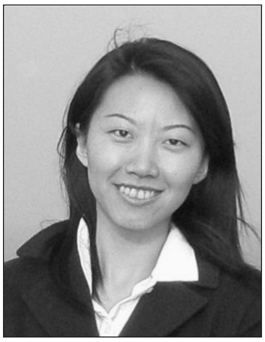

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Iterated Cooperation and Possible Deviations Between Liner Shipping Carriers Based on Noncooperative Game Theory

Xiaoning Shi and Stefan Voss

The top liner shipping carriers have already established alliances in the shipping industry and are investigating new business connections with customers, suppliers, competitors, consultants, and other companies. Several studies have attempted to explain this phenomenon using a variety of conceptual and theoretical frameworks. This paper focuses on liner shipping strategic alliances and their establishment and transformation within the framework of noncooperative game theory, which is considered an effective tool to analyze motivations, competitive structures, strategies, and potential payoffs in a number of industries, including the turbulent liner shipping industry. Not only can a liner shipping company be seen as a player in a shipping alliance, but a liner shipping strategic alliance itself can be viewed as a player when it competes with other alliances. In this paper, more attention is paid to the former situation by assuming that those liner companies are unable to make enforceable contracts through outside parties. This paper aims to (*a*) indicate the motivations for short-term cooperation among several liner carriers, (*b*) analyze the pros and cons of being a member of a liner shipping strategic alliance, (*c*) explain a player's deviation or departure behavior when it faces turbulence and unpredictable shipping circumstances, and (*d*) recommend ways to enhance long-term alliance stability by increasing benefits while decreasing drawbacks. Of those four main points, the differences between short-term cooperation and long-term alliance are the number of subgames and the potential future payoff. Specific models based on the assumption of noncooperative behavior are set up as iterated games to give those differences clear explanations. The outcome of this paper will be helpful for liner shipping carriers attempting to succeed in the shipping industry with greater efficiency, better customer service, and lower cost.

Expanding global transportation requires paying more attention to the strategic and operational analyses as well as planning issues for transport companies. Transportation desires include containerized cargo transportation, tramp shipping, and oil and liquefied chemical transportation, among others. In this paper, the focus is on suppliers such as liner shipping carriers who meet one specific aspect of transportation—containerized cargo. Liner shipping carriers provide types of services as linkages connecting nodes including port, container yard, container freight station, and door to meet customers' different demands.

In regard to business practice, the discussion and conclusion of this paper is useful not only for researchers but also for practitioners. First, this paper helps managers engaged in liner services. A better understanding of the structure and formation of the liner shipping strategic alliances sheds light on more effective cooperation among them. Second, this paper helps managers engaged in port operations. As many sources state (*1–5*), the capacity and utilization of container ports are determined, to a great extent, by those liners and the alliances who select these ports as service providers. Thus, port operators could provide more advanced service to meet the requirements of the liner carriers by means of understanding how these liner alliances transform (*6–9*).

From the aspect of theoretical methodology, game theory is considered as a suitable tool to analyze competitive structures and competitive advantages in various industries. Because of common imbalances between supply and demand in the liner shipping market (*10*), competition in the liner shipping industry is fierce. There is a need to create a theoretical framework for understanding shipping's competitive structures and the competitive advantages of being members of liner shipping alliances, especially those of fast-developing liner shipping carriers. To create this framework, it is necessary to identify and understand different elements in the games of liner markets. The aim of this paper is to analyze liner shipping strategic alliances and their establishment as well as possible transformations under market uncertainties within the framework of game theory.

The paper is organized as follows. The next section presents a brief sketch of the liner industry, including the turbulence in it. That is followed by a review of the literature on the applications of game theory to liner shipping alliances and other industries. Motivations of short-term cooperation among liner carriers are discussed next, followed by a discussion of a conceptual framework of long-term strategies for shipping companies. Finally, after a scenario demonstration, some conclusions are reported together with suggestions for further research.

REVIEW OF LINER SHIPPING ALLIANCES

Fundamentals of Alliances

An alliance is a close, collaborative relationship between two or more firms with the intent of accomplishing mutually compatible goals that would be difficult for each to accomplish alone (*11*). Liner shipping alliances are collaborative relationships among different companies, with each member being financially independent. If the expected benefits are not gained, however, a liner company would no longer

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choose collaboration as a strategy, which leads to the transformation of alliances.

The motivations leading independent liner companies into alliances are sketched as follows:

- Globalization. In the liner shipping industry, globalization of trade markets has been the driving force behind alliance formation. The shippers' demand for better routing networks (*12–14*) and connections (*15, 16*) can be met by means of alliances.
- Knowledge transfer. Alliances expand the scope of knowledge and practices available to the partners and ease access to the related knowledge (*17*).
- Competition. Cooperation with another liner carrier can extend supply to meet increasing demand without having to wait for newly built megacontainer ships, which makes liner companies more agile in the face of the increasing market demand raised by shippers (*18–22*) and decreases the development time (*23*) accordingly.
- Development. Given that many mergers and acquisitions fail to achieve their stated objectives, alliances are a less costly alternative to achieve development (*24*).
- Financial reasons. The liner shipping industry faces high fixed costs that are mainly the result of construction costs of megavessels (*25*). When firms cooperate intensively in a number of fields, the high fixed costs would decrease dramatically (*26*) offering better value and better connections to customers at a competitive price (*27*).

Motivated by these considerations, alliances pass through a series of stages, such as strategy formulation, partner selection, negotiation, implementation, and evaluation. Each stage is built on a changing alliance landscape as the vision for the alliance becomes a reality and then grows into a mature business (*11*).

Development of the Liner Shipping Industry

In an attempt to protect carriers in the conferences from the new steamships serving trade to India and the Far East, the traditional liner shipping companies established cartels in 1875 to control the important trade between these regions. Under the liner conference system, which has long been an established feature of the shipping industry, a group of shipowners of one or several nationalities serves a group of ports on a given route (*28*). Research on the liner conferences and liner shipping strategic alliances has paid much attention for decades either from the perspective of globalization (*20, 22, 29*) or from the perspective of the impact on port operations (*30*) and supply chain partners' cooperation (*31, 32*). Among liner carriers, the so-called top 20 (*33*) are of interest in most references and surveys together with their evaluation and the formation of strategic alliances (*34, 35*).

Before the 1990s the liner carriers cooperated with others by means of conferences (*36*). Since the mid-1990s, the development of the liner shipping industry could be divided into three phases as shown in Figure 1. On the basis of the information shown in this figure (*37*), some business issues can be derived from such transformation.

First, overcapacity is blamed for the poor financial performance and economic inefficiency over the long-term history of the liner shipping industry (*38–41*).

Second, some liner carriers differentiate themselves in regard to services offered, low freight rates, such as China Shipping Container Line and Mediterranean Shipping Company, or high-quality service, such as Maersk & Sealand Corporation. Integrating these different kinds of liners too tightly into an alliance with the corresponding requirement for "seamlessness" might pose more problems as a result of different opinions on service values.

Third, in alliances there is much uncertainty and ambiguity. The relationships between partners are hard to predict. In other words, today's partners may be tomorrow's rivals (*42*). Figure 1 clearly indicates that members of alliances are not fixed forever and may switch between alliances. For example, Nedlloyd originally belonged to the Global Alliance and then switched to the Grand Alliance in about 1998 and was later acquired by Maersk & Sealand in 2005 (*43*). Furthermore, members as well as even the name of the Global Alliance changed to the New World Alliance (*44*).

The fourth issue concerns exclusivity. That is, membership turbulence implies that firms group themselves into blocks more or less irreversibly linked (alliances versus mergers or acquisitions) to each other. Membership in one strategic block does preclude a firm from

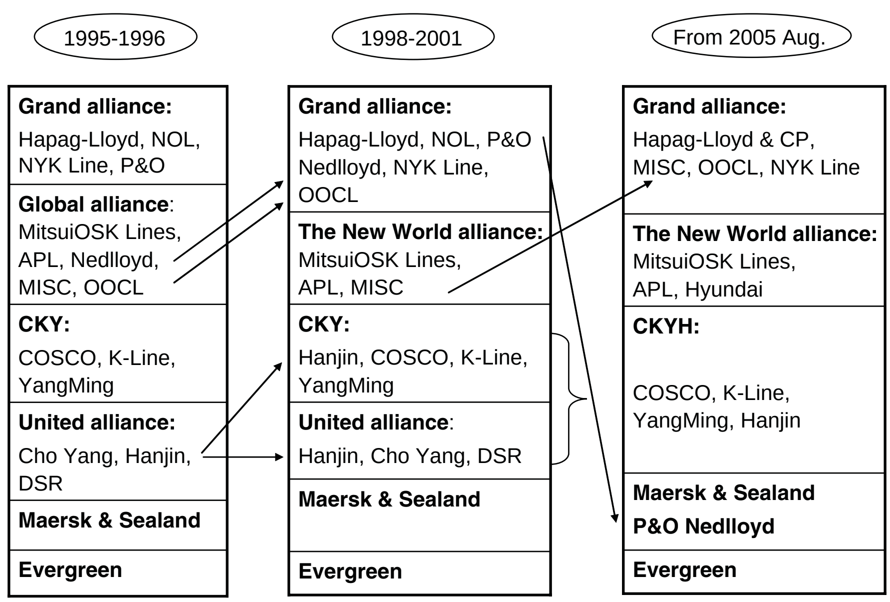

FIGURE 1 Development and transformation of liner shipping alliances.

membership in a different strategic block. However, to some extent there seems to be some tolerance. As long as the linkage that is established with a third firm does not conflict with the objectives of the block, a firm might be linked with firms outside the block. That is, in the long run, alliance relationship management is more important than the initial formal design.

The fifth issue is related to the market cycle. Forming alliances and other types of firm linkages can be considered to be the result of strategic decision making caused by a turbulent business environment. The speed of change to which today's markets are subjected creates a great deal of uncertainty in regard to which are the best strategic activities for competing in the present markets. Firms cannot internally adapt to these strategic options at the required speed and have to possess the strategic capabilities needed to pursue those market opportunities (*45*). Thus, the formation of alliance networks is a response to an uncertain market for strategic capabilities. Firms have to keep reshaping their strategic capabilities to match the needs of the ever-changing business. Every firm has to incorporate or gain access to the complementary capabilities of other firms to be able to respond to the demands of a continuously changing marketplace.

Last but not least in importance, the (de-)regulations of the liner shipping industry make sense (*39*). Antitrust policy pushed the liner carriers, to some extent, to form strategic alliances (*46, 47*) instead of keeping liner conferences as in the past. In addition, some contributions (*48, 49*) explain the advantages and disadvantages, from the point of view of the liners, of entering into alliances and explore the impact of the U.S. regulatory regime of cooperative agreements.

Besides the general issues discussed above, some researchers also observed specific routes. For instance, Rimmer (*50–53*) as well as Bendall and Stent (*54*) did a series of surveys in the 1990s focusing on the liner shipping strategic alliances in the Pacific Economic Zone.

The essence of strategy formulation of a liner carrier is coping with fierce competition in the liner shipping industry. Concerning the status of the liner shipping market, some research has been done from the perspective of an oligopoly model (*55*) and the problem of free riders when there is entry deterrence (*56*). However, taking into account the relationships between the liner carriers, to be able to play the alliance game, managers have to identify the rules that govern the formation of an alliance. Moreover, in the fight for market share, competition is not manifested only with other players. It is clear that liner carriers cannot accomplish their cooperative strategy in isolation. They are embedded in a network of corporate relationships that influence the available options for each other. Once an alliance is formed, the relatively competitive positions in an industry change as a result of the bargaining power of suppliers and customers. And the newly formed alliances build up barriers that defend against other entrants and substitutes, accordingly.

Thus, to explain and solve the key issues of strategic alliances, the tool of choice is game theory, which plays vital roles in shaping competition and cooperation in the liner shipping industry. This industry has an underlying structure and a set of fundamental economic and technical characteristics implying the turbulence mentioned above. Other liner carriers, customers, suppliers, potential entrants, and substitute products are all players that may be more or less prominent or active depending on this industry. Also, the strategies of rational players obviously depend on the strategies of other players (*57*) surviving in the same market. The strategists have to learn which motivations and factors make the environment change. Then they can position the company to cope best with the shipping industry environment and to influence that environment in the company's favor. Game theory thus makes an appropriate tool to analyze strategies of companies in the liner shipping industry.

APPLICATION OF GAME THEORY TO LINER SHIPPING ALLIANCES

Game theory applications in various industries seem to be a dime a dozen. Here a very short selection is provided as they may be related to liner shipping alliances.

One motivation of cooperation is that rational players realize that if they arrange the business from a collective rationality perspective, more payoffs can be achieved (*58*). However, those players do not have the confidence that other rivals, their potential business partners, would like to cooperate in a fair way. Concerning the criteria of selecting partners, multicriteria decision-making models (*59, 60*) are referred to here as well as other methodologies (*61*) based on the motivations and former performance of the potential partners (*62*). Some bargaining or even several rounds of negotiation thus may occur before real cooperation takes place. The bargaining and negotiations are aiming at balancing risks and benefits (*63, 64*) to improve mutual capabilities of the partners to survive in the turbulent market. In liner service cooperation, the main negotiation and compromise lie in vessel capacity allocation.

Tijs and Driessen (*65*) applied the concept of Shapley's core (*66, 67*)—an important concept of fairness in cooperative games—to analyze varieties of allocation problems, including marginal cost in entering coalitions, minimizing maximum unhappiness or maximum regret and separable and nonseparable costs. Moreover, this research was advanced toward the cost gap allocation method by using a value concept introduced in 1981. Skorin-Kapov formulates cost allocation problems in industries as a cost cooperative game (*68*). The main idea is to find a fair share of the total cost for those who attempt to use the networks independent from the network's purposes and utilities (*69*). Since the late 1980s and the 1990s, the application of core theory in the shipping industry arose to analyze the monopoly market status (*70*), market equilibrium (*71*), and noncooperative entry deterrence (*72*), among other factors. Some of the optimized output, or a good output computed by a core heuristic, could be applied to any related industry once it incorporates competition and cooperation. The research mentioned above is based mainly on the cooperative behaviors of the involved players. As for the general survey on the cooperative strategies of international business, refer to partner cooperation (*73*) as well as the solution of the partner asymmetries problem (*74*). In 2002, Song and Panayides (*26*), who focus their research specifically on maritime transportation, applied cooperative game theory to liner shipping strategic alliances. They not only analyzed the cost allocation but also mentioned fair profit allocation among members of liner shipping alliances based on the assumption of cooperative behaviors. This could be one of the factors that keep consortia or alliances stable. Similar ideas are also mentioned by Ryoo and Thanopoulou (*75*).

However, the essence of formulating a strategy is relating a company to its environment. Although the previous paragraph mentioned methods to allocate costs and benefits with acceptable fairness and satisfactory solutions, the fact that the environment of a company changes every now and then should not be ignored (*76*). When the market and rivals are beyond what a company or an alliance forecast before, turbulence inevitably occurs (*77*). It may then be the right time to apply noncooperative game theory to restructure the status and situation in such an industry because, unlike cooperative game theory, noncooperative game theory does not assume that all players have incentives to cooperate with each other with tight binding agreements, which provides more possibilities to better simulate real-world scenarios. The common assumption of cooperative and noncooperative game theory is that the players are rational. This is a suitable assumption for members and competitors of liner shipping alliances. Top liner carriers can be regarded as rational players in games (subgames and iterated games) because they all have long-time experience and have survived successfully as carriers providing liner shipping services.

The Cournot model is by far the most widely used framework for performing an assessment of the profit potential in various industries (*78*). It is also suitable for the liner shipping industry based on its oligarchic characteristic as discussed previously.

APPLICATION FOR SHORT-TERM STRATEGY FOR LINERS IN THE LINER INDUSTRY

Incentives of Liner Carriers as Players

First, some notation is defined:

l_i = liner *i,* acting as one of the players in the game discussed,
q_i = slot (ship) supply of liner *i* in a certain lane,
u_i = payoff of liner *i* in a certain lane,
Q = entire slot (ship) supply in a certain lane,
U = entire payoff of all liners in a certain lane,
R = entire demand in a certain lane,
n = number of liners,
d_i = number of liner *i*'s ships in a certain lane,
p = slot selling price that could sell out all the slots,
a, b = two positive parameters in the price function,
c_i = unit variable cost of liner *i,*
q^*_{icnt} = best slots (ship) supply of liner *i* based on the Cournot model in static games,
u_{icnt} = maximum payoff of liner *i* based on the Cournot model in static games,
c_{avg} = average unit variable cost of those liner carriers in a certain lane,
Q^* = best slots (ship) supply from integral point of view,
U^* = maximum payoff from integral point of view,
q^*_{icop} = from integral point of view the best ship supply of liner *i* based on cooperation,
u^*_{icop} = from integral point of view the maximum payoff of liner *i* based on cooperation,
q^*_{idym} = best slot (ship) supply of liner *i* in dynamic games,
u^*_{idym} = maximum payoff of liner *i* in dynamic games,
Q_{cnt} = entire slot (ship) supply based on the Cournot model in static games,
Q_{dym} = entire slot (ship) supply in dynamic games,
P_{cnt} = freight rate based on Cournot model in static games,
P_{dym} = freight rate in dynamic games,
λ_i = percentage that liner *i* shares the additional payoff caused by cooperation,
γ = discount factor,
δ = present value rate,
q^*_{idev} = best slot (ship) supply of liner *i* when it deviates from cooperation in iterated games,
u^*_{idev} = maximum payoff of liner *i* when it deviates from cooperation in iterated games,
t = stages of iterated games, and
x_i = penalty ship supply of liner *i* based on iterated games.

But the customer's transportation desire sometimes exceeds the ship supply in the liner shipping market. Meanwhile, liner companies are aware that an increased ship supply would increase freight income by transporting more goods. However, the average period of building a new vessel (18 months) is relatively longer than the lead times that could respond to the market well. In other words, the market supply–demand situation might change a great deal while new vessels are being built and after those vessels are launched. Thus, in most cases, cooperation with other liner companies could be a better choice than investing too much capital in new vessels. Besides cost saving, providing an agile response to the liner shipping market leads to this kind of cooperation.

On the other hand, the ship supply sometimes exceeds customer desire in the liner shipping industry, resulting in overcapacity (*78, 79*). Under this situation, the motivation for cooperation is to improve transportation services by approaches such as extending hinterland, reducing voyage time, increasing feeder ports, and strengthening transport networks. There are two main modes of cooperation, common vessel scheduling and slot agreement, which include slot-exchanging and slot-chartering business.

When transportation desire exceeds ship supply, the liners need to improve their services to meet customer demands and provide a quick response to the liner market as well. Therefore, cooperation among the liners is built based on the liners' common benefits. However, when overcapacity occurs in the liner industry, it is not that easy to understand why the liners still cooperate with others. Therefore, in this paper, more effort is put into discussing how short-run and long-run cooperation are set up when overcapacity occurs.

Ship Supply Exceeding Transportation Desire

A static game is first constructed and later further developed into a dynamic game. A static game in this case means that all the competitive liner carriers make their decisions on slot supply at the same time or perhaps not at exactly the same time, but without knowing the others' decisions in advance. The following assumptions and formulations are made:

When liners $l_1, l_2, \ldots, l_n$ service ship supply $q_1, q_2, \ldots, q_n$, then the entire ship supply in the liner market should be

$$Q = \sum_{i=1}^{n} q_i$$

The freight rate price is *p,* which varies according to the following function:

$$p = p(Q) = a - b\sum_{i=1}^{n} q_i$$

Fixed costs of vessels do not change according to different use of slots. That is, those fixed costs are not related to the subsequent strategies and can be viewed as sunk costs.

The marginal cost c_i of liner l_i ($i = 1, 2, \ldots, n$) is equal to the average variable cost, because fixed costs are regarded as sunk costs as discussed above. The payoff of liner l_i (player l_i) could be defined as follows:

$$u_i = q_i p(Q) - c_i q_i = q_i\left[a - b\left(q_i + \sum_{j=1}^{n} q_j\right)\right] - c_i q_i \qquad i = 1, 2, \ldots, n; \text{ and } j \neq i$$

$$\max u_i = -bq_i^2 + \left(a - b\sum_{j=1}^{n} q_j - c_i\right)q_i \qquad i = 1, 2, \ldots, n; \text{ and } j \neq i \quad (1)$$

From this objective function, it can be deduced that the best response of l_i depends on the strategies of other players l_j, $i \neq j$.

Let

$$\frac{\partial u_i}{\partial q_i} = 0 \qquad i = 1, 2, \ldots, n$$

then

$$-2bq_i + \left(a - b\sum_{j=1}^{n} q_j - c_i\right) = 0 \qquad i \neq j$$

According to the definition of Nash equilibrium (*57*), to obtain as much payoff as possible, the best response of l_i is

$$q_{icnt}^{*} = \frac{\left(a - b\sum_{j=1}^{n} q_j - c_i\right)}{2b} \qquad i \neq j \tag{2}$$

Then

$$u_{icnt}^{*} = \frac{\left(a - b\sum_{j=1}^{n} q_i - c_i\right)^2}{4b} \qquad i \neq j \tag{3}$$

With different i one obtains different q_{icnt}^{*}, u_{icnt}^{*}. However, each player makes the decision based on individual rationalities.

Another scenario is now considered, one in which the same problem is discussed from an integration point of view, in other words, from the aspect of collective rationality rather than individual rationalities.

$$U = Q \cdot p(Q) - c_{avg} \cdot Q = Q(a - bQ) - c_{avg} \cdot Q$$
$$= -bQ^2 + (a - c_{avg})Q$$

Let

$$\frac{dU}{dQ} = 0$$

then

$$Q^* = \frac{(a - c_{avg})}{2b} \tag{4}$$

$$U^* = \frac{(a - c_{avg})^2}{4b} \tag{5}$$

Compared with the results obtained based on individual rationalities of the players, if

$$\sum_{i=1}^{n} q_i \geq Q^*$$

and

$$\sum_{i=1}^{n} u_i \leq U^*$$

the formulations above denote that the efficiency of collective rationality (i.e., alliances or consortia) is higher than that of individual rationalities (i.e., individually operate in the market). In the liner shipping industry, this means that a relative lower slot supply could imply an even higher payoff and make the market reach status with higher efficiency, namely Pareto-optimality movement. That is, once liner carriers break the barriers of individual rationalities, better payoffs can be achieved compared with operating the businesses individually. However, the Nash equilibrium (*57*), which is based on individual rationalities, is stable if neither outside factors nor other players change. If there are changes, the conflict of individual rationalities and collective rationality occurs. Even if there is a former stable equilibrium, attention will be paid to those motivations that induce the cooperation and the stability as well as the turbulence of it.

Negotiation on Capacity Allocation Before Cooperation

Here a dynamic game is constructed that is started by l_1. Because l_1 is the first mover of this game, when l_2 moves, l_2 already knows how l_1 acts. The optimal response of l_1 is to make every effort to obtain maximized payoff. Therefore, l_2 should be analyzed first, although l_2 is not the first mover in this game.

$$q_{2dym}^{*} = \frac{(a - b \cdot q_1 - c_2)}{2b} \tag{6}$$

$$u_1 = -b \cdot q_1^2 + (a - b \cdot q_2 - c_1)q_1$$

Let

$$\frac{\partial u_i}{\partial q_i} = 0$$

Then

$$q_{1dym}^{*} = \frac{(a - c_1 + c_2)}{2b} \tag{7}$$

$$u_{1dym}^{*} = \frac{(a - c_1 + c_2)^2}{8b} \tag{8}$$

$$q_{2dym}^{*} = \frac{(a + c_1 - 3c_2)}{4b} \tag{9}$$

$$u_{2dym}^{*} = \frac{(a + c_1 - 3c_2)^2}{16b} \tag{10}$$

$$Q_{dym} = q_{1dym}^{*} + q_{2dym}^{*} = \frac{(3a - c_1 - c_2)}{4b} \tag{11}$$

$$p_{dym} = a - b \cdot Q_{dym} = \frac{(a + c_1 + c_2)}{4} \tag{12}$$

Compared with results obtained from the Cournot model based on the static game:

$$q_{1cnt}^{*} = \frac{(a - c_1 - b \cdot q_2)}{2b} = \frac{(a + c_2 - 2c_1)}{3b} \tag{13}$$

$$q_{2cnt}^{*} = \frac{(a - c_2 - b \cdot q_1)}{2b} = \frac{(a + c_1 - 2c_2)}{3b} \tag{14}$$

$$u_{1cnt}^{*} = \frac{(a - 2c_1 + c_2)^2}{9b} \tag{15}$$

$$u^*_{2\text{cnt}} = \frac{\left(a - 2c_2 + c_1\right)^2}{9b} \tag{16}$$

Add Equations 13 and 14,

$$Q_{\text{cnt}} = q^*_{1\text{cnt}} + q^*_{2\text{cnt}} = \frac{\left(2a - c_1 - c_2\right)}{3b} \tag{17}$$

$$p_{\text{cnt}} = a - b \cdot Q_{\text{cnt}} = \frac{\left(a + c_1 + c_2\right)}{3} \tag{18}$$

Some important conclusions can now be made. First,

$q^*_{1\text{dym}} > q^*_{1\text{cnt}}$

Second, from Equations 7 and 13, $c_2 > 0$, $q_2 > 0$, so $q^*_{1\text{dym}} > q^*_{1\text{cnt}}$:

$u^*_{1\text{dym}} > u^*_{1\text{cnt}}$

From Equations 8 and 14, $c_1 > 0$, $a - c_1 + c_2 > a - 2c_1 + c_2$, and $8b < 9b$, so

$u^*_{1\text{dym}} > u^*_{1\text{cnt}}$

Third,

$Q_{\text{dym}} > Q_{\text{cnt}}$

From Equations 11 and 17, while $a > 0 > -(c_1 + c_2)$, then

$9a - 3(c_1 + c_2) > 8a - 4(c_1 + c_2)$

so $Q_{\text{dym}} > Q_{\text{cnt}}$.

Fourth,

$p_{\text{dym}} < p_{\text{cnt}}$.

From Equations 12 and 18 together with the third conclusion, $p_{\text{dym}} < p_{\text{cnt}}$ is derived.

On the basis of the conclusions above, it is clear that static games and dynamic games are quite different and lead to different payoffs, accordingly. Furthermore, dynamic games consider the steps of the player and the strength differences between players, too. This provides a possible foundation to observe the leader and the followers in the game. It is proposed that the power ratio of players is $\lambda_1 : \lambda_2 = q_{1\text{dym}} : q_{2\text{dym}}$. This means that an intuitive strength difference between players is indicated by their supplies in dynamic games if consequences of the games are taken into account. This original proposal is an assumption used in the further discussion of modeling approaches.

CONCEPTUAL FRAMEWORK OF LONG-RUN STRATEGIES FOR LINER SHIPPING CARRIERS

"Tit-for-Tat" as a Strategy to Survive in Iterated Subgames

To make the games "play" in a long run requires players to repeat and iterate the subgames several times, no matter whether the following games are exactly the same as before or not. This fits the liner market well if the continuous competition year after year is considered. Then the decisions about prices and supplies could be regarded as subgames. When the subgames repeat infinitely, how can cooperation continue and succeed?

At the first stage, two players choose ($q^*_{1\text{cop}}$, $q^*_{2\text{cop}}$) together with respective payoffs and keep it until stage $t - 1$. If at stage $t - 1$, both players' supplies meet ($q^*_{1\text{cop}}$, $q^*_{2\text{cop}}$), the cooperation continues. Otherwise, the supplies change to ($q^*_{1\text{cnt}}$, $q^*_{2\text{cnt}}$).

The main idea of this tit-for-tat strategy is to attempt cooperation at the first stage. If other players deviate from the former cooperation, a penalty from the cooperation partner is waiting for them.

Suppose that l_1 has already taken the tit-for-tat strategy, then l_2 would take it also. The payoff for every year could be defined as ($u^*_{1\text{cop}}$, $u^*_{2\text{cop}}$). The present value of payoff after iterated games could be presented as

$$u^*_{i\text{cop}}\left(1 + \delta + \delta^2 + \cdots + \delta^n\right) = \frac{u^*_{i\text{cop}}}{\left(1 - \delta\right)} \qquad n \to \infty, \qquad 0 < \delta < 1 \tag{19}$$

When l_2 deviates from the former cooperation, the first stage supply decision must lead l_2's payoff as much as possible so that it is attractive enough to let him deviate (and if it happens at a certain stage *t*, the analysis is the same because the former $t - 1$ stages could rationally be deleted). In other words, l_2's decision $q^*_{2\text{dev}}$ depends on his former partner's decision $q^*_{1\text{cop}}$.

$$\begin{aligned} \max u_{2\text{dev}} &= \max\left[\left(a - b \cdot Q\right)q_{2\text{dev}} - c_2 q_{2\text{dev}}\right] \\ &= \max\left[-bq^2_{2\text{dev}} + \left(a - bq_{1\text{cop}} - c_2\right)q_{2\text{dev}}\right] \end{aligned} \tag{20}$$

The following can be obtained:

$$q^*_{2\text{dev}} = \frac{\left(a - bq_{1\text{cop}} - c_2\right)}{2b} \tag{21}$$

$$u^*_{2\text{dev}} = \frac{\left(a - bq_{1\text{cop}} - c_2\right)^2}{4b} \tag{22}$$

This payoff result is higher than what he can get at the first stage $u^*_{2\text{cop}}$. However, from the second stage, l_1 would take strategy $q^*_{1\text{cnt}}$, accordingly. Then l_2 will compulsively take strategy $q^*_{2\text{cnt}}$ as a countermeasure; meanwhile the payoff would be $u^*_{2\text{cnt}}$, accordingly.

Therefore, when there are infinitely many iterated subgames, the present value of l_2's payoff would be as follows:

$$u^*_{2\text{dev}} + u^*_{2\text{cnt}}\left(\delta + \delta^2 + \cdots + \delta^n\right) = u^*_{2\text{dev}} + u^*_{2\text{cnt}}\left(\frac{\delta}{1 - \delta}\right) \qquad n \to \infty; \quad 0 < \delta < 1 \tag{23}$$

If Equation 19 and Equation 23 are compared, the infinite iterated subgames based on the Cournot model have actually changed to be the player's decision selection between $q^*_{i\text{cop}}$ and $q^*_{i\text{dev}}$. As for l_2, tit-for-tat is the optimal strategy only when l_2 obtains more payoff when taking the tit-for-tat than when not taking it. Otherwise, l_2 would like to deviate from the cooperation, that is, give up being a member of the long-term strategic alliance.

That is,

$$\frac{u^*_{2\text{cop}}}{\left(1 - \delta\right)} \geq u^*_{2\text{dev}} + u^*_{2\text{cnt}}\left(\frac{\delta}{1 - \delta}\right)$$

The following is obtained:

$$\delta \geq \frac{\left(u^*_{2\text{dev}} - u^*_{2\text{cop}}\right)}{\left(u^*_{2\text{dev}} - u^*_{2\text{cnt}}\right)} \tag{24}$$

Inequality 24 indicates that a player's optimal decision depends on the present value rate δ.

If δ is too small to fit Inequality 24, the payoff in the future is not important and attractive enough to affect the player's decision. Players concentrate more on the present value instead of long-term payoffs. Furthermore, the players are not afraid of the penalty from other alliance members, which means that deviation from the alliance is the best response for l_2 against the tit-for-tat from l_1. In short, the tit-for-tat would not help the alliance's stability if δ is too small.

On the contrary, if δ is significant enough to fit Condition 24, the payoff in the future is attractive enough for the liner carrier. Obviously, it is not an optimal decision to inflame his partner and to give up the long-run cooperation while obtaining only the present short-run payoff. The closer δ approaches to 1, the more vital the future payoff is. As a result, two liner carriers would like to take cooperation as strategies for both as equilibrium. The subgame of the infinitely iterated game is still an infinitely iterated game, and then it is easy to understand that both players take the tit-for-tat as an equilibrium strategy to set up a perfect subgame Nash equilibrium route of every stage of the subgames. Consequently, a more efficient long-term alliance is established under this circumstance.

Penalty If Deviation Occurs

Concerning the former discussion of infinitely iterated games, when δ fits Condition 24, the tit-for-tat presented in the last stage would be helpful to set up a relatively long-term stable alliance. However, the real-world competition keeps changing constantly. When δ becomes smaller and does not fit Condition 24 any longer, what strategy could liner l_1 deploy so that the long-term cooperation with l_2 would continue? Then a much looser additional condition together with δ is needed to ensure a subgame equilibrium with higher efficiency.

At the first stage, two players l_1 and l_2 provide $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$; at stage t, if the transport service provided at stage $t-1$ is $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$, then continue the decision $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$ at the next stage. If the vessel supply at stage $t-1$ is (x_1, x_2), then provide $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$ at the next stage, also. Otherwise, this means that the slot supply at stage $t-1$ is different from the two possibilities mentioned above, and then those two players provide (x_1, x_2) at the coming stage.

The variable x_i is called "penalty supply" here, and this strategy is named the "penalty of deviation." The penalty supply x_i would never be the supply decision $q^*_{i\text{cnt}}$ based on the Cournot model. The penalty should be regarded as a way to prohibit other players from the deviation rather than as a permanent strategic equilibrium. If the penalty supply itself is set as the static $q^*_{i\text{cnt}}$ from the Cournot model, then it performs more like a static equilibrium than what players originally expected.

In other words, a certain player makes this decision at the next stage when the other partner acts differently from the way the player acts. If the partner acts the same as the player, there should be no penalty. Therefore, this kind of penalty of deviation could be viewed as a "carrot-and-stick" strategy. The "carrot" is the positive attitude and cooperative action, and the "stick" is the penalty once deviation occurs.

If both players take the above-mentioned strategies, then they supply capacity $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$ at every stage and obtain payoff $(u^*_{1\text{cop}}, u^*_{2\text{cop}})$ at the same time. After repeating the subgame infinitely, the present value of payoff for l_i is

$$\frac{u^*_{1\text{cop}}}{(1-\delta)}$$

Next, the processes are explained in detail. If l_1 has already chosen this strategy, then the present value of payoffs for l_2 is

$$\frac{u^*_{2\text{cop}}}{(1-\delta)}$$

when l_2 chooses this strategy, too. However, if l_2 deviates at the first stage with supply vessel $q^*_{2\text{dev}}$, then certainly he wants to enlarge his payoff $u_{2\text{dev}}$ as much as possible.

As supply,

$$q^*_{2\text{dev}} = \frac{(a - b \cdot q_{1\text{cop}} - c_2)}{2b}$$

is obtained, and as payoff,

$$u^*_{2\text{dev}} = \frac{(a - b \cdot q_{1\text{cop}} - c_2)^2}{4b}$$

is obtained. At the second stage l_1 will supply capacity x_1 as a penalty, then l_2 has to supply capacity x_2 as a countermeasure. The reason this happens is not that (x_1, x_2) is a static Nash equilibrium (actually, it is not the Nash equilibrium); the reason is that l_2 could make this decision only to avoid the next penalty from his partner l_1. Then one can obtain:

$$u_2 = [a - b(x_1 + x_2)]x_2 - c_2 \cdot x_2 \tag{25}$$

To make u_2 maximum, one gets

$$x_2 = \frac{(a - bx_1 - c_2)}{2b} \tag{26}$$

$$u^*_{2\text{dev}} = \frac{(a - bx_1 - c_2)^2}{4b} \tag{27}$$

From now on, the cooperation restarts and continues even if deviation occurs at some stage. Two liner companies supply vessel $(q^*_{1\text{cop}}, q^*_{2\text{cop}})$ at every following stage. On the basis of that, whether l_2 chooses to deviate at the first stage or not depends on whether the profit of deviating could cover the present value of the penalty he faces at the second stage. That is, l_2 will not deviate if

$$\delta \cdot u_{2\text{dev}} \le u^*_{2\text{cop}}$$

Together with Equation 27, one could get

$$\frac{\delta(a - bx_1 - c_2)^2}{4b} \le u^*_{2\text{cop}} \tag{28}$$

And Inequality 28 points to the fact that whether the long-run alliance is to continue or not depends not only on δ, but also on the amount of penalty x_1.

When δ is fixed, the smaller x_1 is, the easier it is for player l_2 to deviate. That means that the penalty is not strong enough to force l_2 to always stay with the cooperation approach. When δ is fixed, the more x_1 is, the more loyal player l_2 is. This means that the penalty is effective enough to keep l_2 in cooperation, and an alliance is then established.

This paper has discussed only l_2's decision at the first stage until the establishment of the long-term alliance. Actually, even if l_2 deviates at any stage except the first one, the situation that the other player faces is exactly the same as in the discussion above. Because it is an infinitely iterated game, the former stages could be ignored without affecting the final result, and the stage in which deviation occurs could be regarded as the "first-stage" rationality. Furthermore, the discussion for l_2 is suitable for l_1, as well. An explanation has been given for why and how a long-term alliance is established and survives. To make the whole process more comprehensive, the flowchart shown in Figure 2 could be helpful in providing an understanding of the main idea and the process of this research. It is assumed that supply exceeds demand; meanwhile the demand is kept relatively static in the research period.

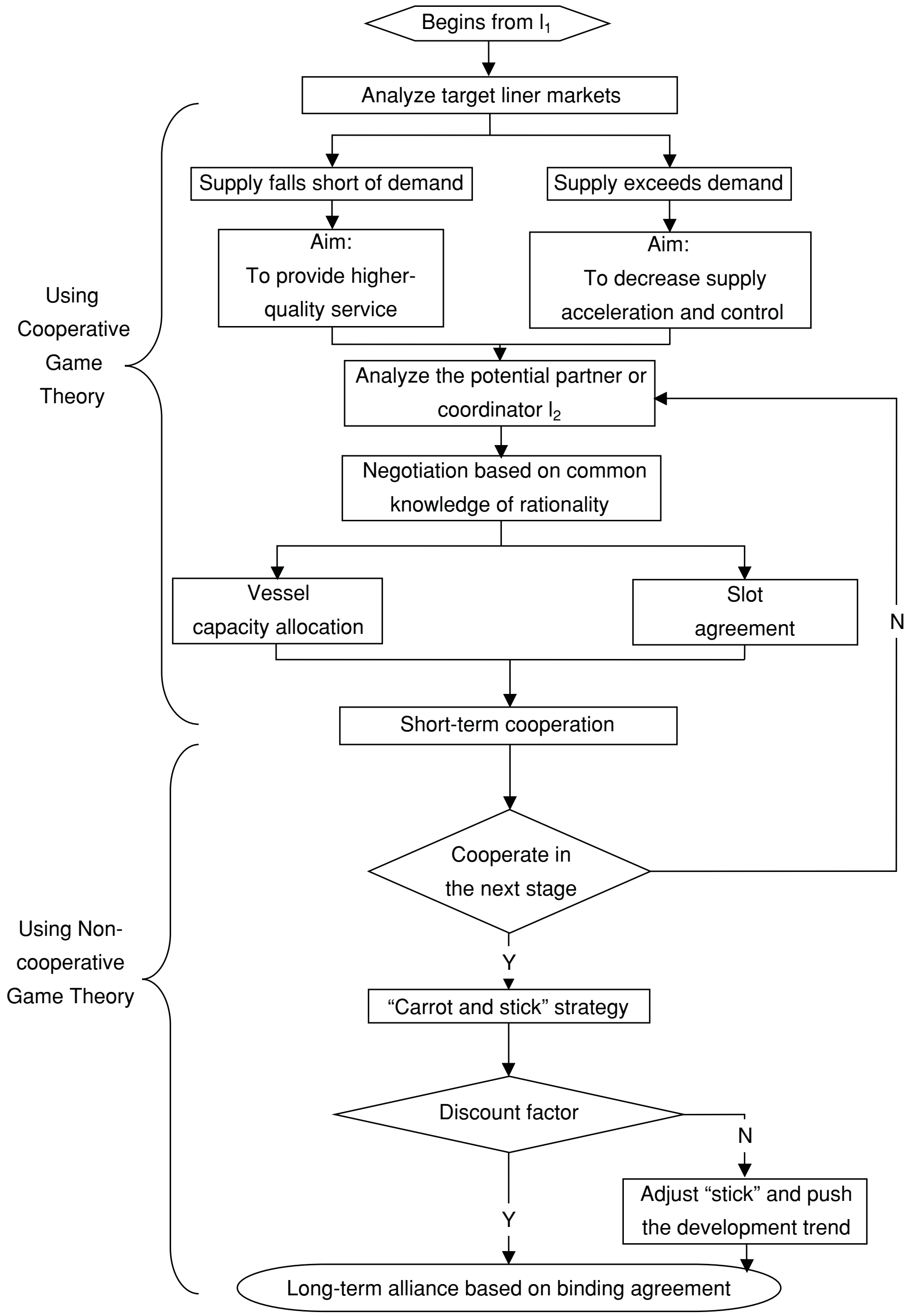

FIGURE 2 Flowchart of short-term and long-term cooperation between liner carriers.

Objective function:

$$\max\ u_1 = u^*_{1\text{cnt}} + \lambda\left(U^*_{\text{cop}} - U^*_{\text{cnt}}\right)$$

Variables q_1, q_2 (the objective function is a recessive function of these variables)

subject to

$$q_1, q_2 \le 0 \tag{29}$$

$$q_1 + q_2 \le Q^*_{\text{cnt}} \tag{30}$$

$$q_1 + q_2 \ge R \tag{31}$$

$$U^*_{\text{cop}} \ge U^*_{\text{cnt}} \tag{32}$$

$$U^*_{2\text{cop}} \ge U^*_{2\text{cnt}} \tag{24}$$

$$\delta \ge \frac{\left(u^*_{2\text{dev}} - u^*_{2\text{cop}}\right)}{\left(u^*_{2\text{dev}} - u^*_{2\text{cnt}}\right)} \tag{28}$$

$$\delta \frac{\left(a - bx_1 - c_2\right)^2}{4b} \le u^*_{2\text{cop}} \tag{33}$$

Constraint 30 indicates that the total supply of the liners who cooperate in alliances should not be more than the total supply if they operate individually in the market. Otherwise, the cooperation makes no sense in regard to investment control and price increase.

Constraint 31 (where R = shipping demand or requirements) means that the total supply of liner carriers should satisfy the liner market demand. Constraint 32 points out that the profit of the cooperation should at least be more attractive than that of the Cournot model. Constraint 33 indicates that the profits of l_2 should be greater than or equal to those of the Cournot model, so that l_2 is going to cooperate.

Constraint 24 ensures that in iterated games l_1 and l_2 would take tit-for-tat, also. If all players choose to cooperate again and again, then long-term cooperation is expected to be accomplished. If δ does not meet Constraint 24, then use Constraint 28 to get x_1.

Scenario Demonstration

For this scenario, the following assumptions are made:

$$p = 1537.5 - 0.125Q$$

$$a = 1537.5$$

$$b = 0.125$$

$$c_1 = 341 \frac{\text{USD}}{\text{TEU}}$$

$$c_2 = 390 \frac{\text{USD}}{\text{TEU}}$$

$$R = 4{,}200 \text{ TEU}$$

$$\gamma = 3\%$$

First, one must calculate the supply $q^*_{1\text{cnt}}$ and $q^*_{2\text{cnt}}$ and the payoff $u^*_{1\text{cnt}}$ and $u^*_{2\text{cnt}}$ (shown in the upper part of the Volume A column of Table 1) based on the static Cournot model. Then one refers to supply Q^*_{cop} and payoff U^*_{cop} (shown in the lower part of Volume A column of Table 1) based on the short-run cooperation.

The Volume B column takes the dynamic point of view to measure the different power of l_1 and l_2 in the same market, which indicates who the leader is, with the other being the follower.

The power measurement ratio should be acceptable to both when $\lambda_1 : \lambda_2 = 6{,}346 : 1{,}417$, which followed the assumption mentioned previously and related to $q^*_{1\text{dym}}$ and $q^*_{2\text{dym}}$. On the basis of this measurement, the allocation of the additional profit ($u^*_{\text{cop}} - u^*_{\text{cnt}}$) is reasonable and acceptable in their eyes. Consequently, the players obtain extra utilities $\Delta u_{1\text{cop}}$ and $\Delta u_{2\text{cop}}$, respectively.

TABLE 1 Individual and Collective Rationalities in Static and Dynamic Games

Volume A (static)		Volume B (dynamic)	
$q^*_{1\text{cnt}}$	3,321 TEU	$q^*_{1\text{dym}}$	6,346 TEU
$q^*_{2\text{cnt}}$	2,929 TEU	$q^*_{2\text{dym}}$	1,417 TEU
Q^*_{cnt}	6,250 TEU	$\Delta u_{1\text{cop}}$[a]	247,071.4 USD
p^*_{cnt}	756.25 USD/TEU	$\Delta u_{2\text{cop}}$	55,341.6 USD
$u^*_{1\text{cnt}}$	1,379,045.25 USD	$u^*_{1\text{cop}}$	1,626,116.7 USD
$u^*_{2\text{cnt}}$	1,072,746.25 USD	$u^*_{2\text{cop}}$	1,128,087.9 USD
U^*_{cnt}	2,451,791.5 USD	$q^*_{1\text{cop}}$	2,053 TEU
c_{avg}	364 USD/TEU	$q^*_{2\text{cop}}$	2,641 TEU
Q^*_{cop}	4,694 TEU	$q^*_{2\text{dev}}$	3,563.5 TEU
U^*_{cop}	2,754,204.5 USD	$u^*_{2\text{dev}}$	1,587,316.53 USD
p^*_{cop}	950 USD/TEU	δ	0.97

[a] Δ = utility gotten by associated player.

As for l_1,

$$\Delta u_{1\text{cop}} = 302{,}413 \times \frac{6{,}346}{(6{,}346 + 1{,}417)} \approx 247{,}071.4$$

As for l_2,

$$\Delta u_{2\text{cop}} = 302{,}413 \times \frac{1{,}417}{(6{,}346 + 1{,}417)} \approx 55{,}341.6$$

Results fit Constraints 29 through 33, the short-run cooperation setup.

Player l_1 tries to set a tit-for-tat, then an analysis is done on whether or not l_2 will set up another tit-for-tat.

While

$$\delta = \frac{1}{(1+\gamma)} \approx 0.97 > 0.89$$

The result fits Constraint 24, which means that once l_1 sets the tit-for-tat, the rational player l_2 would like to keep it without any deviation in the market. The long-run alliance is built up. Without loss of generality, the discussion continues on the γ in Conclusion 3 after Conclusions 1 and 2 in the context of market uncertainty.

Once the market circumstance changes as if $\gamma = 15\%$, then $\delta = 1/(1+\gamma) \approx 0.87$, which does not fit Constraint 24 any longer, player l_1 should set his penalty supply in the cooperation agreement to keep l_2 in the alliance.

$$\frac{\delta(a - bx_1 - c_2)^2}{4b} \le u^*_{2\text{cop}}$$

$$-805 \le 1{,}537.5 - 0.125x_1 - 390 \le 805$$

Then, the amount of penalty supply is obtained: $x_1 \ge 2{,}740$(TEU).

Finally, the turbulence of the liner market should be taken into account. The freight rate stability and the modeling performance (*80, 81*) should be related to the market environment, also. Thus, a sensitivity analysis is given in Table 2. The table shows that when δ fits Constraint 24, players will keep tit-for-tat as strategies and follow the perfect Nash equilibrium for subgames. Once δ does not fit Constraint 24, the smaller δ is, the smaller is the range of x_1. In other words, as the effect of future profit decreases, the power of the penalty decreases accordingly.

CONCLUSIONS AND FURTHER RESEARCH INTERESTS

In this paper, the motivations of taking part in liner alliances were discussed. In addition the transformation of alliances was observed.

TABLE 2 Sensitivity Analysis of γ, x_1, and δ

Variable	Incremental Change on γ, δ and Its According Value on x_1 as Decision Output				
γ	<0.12	0.15	0.18	0.20	0.22
δ	>0.89	0.87	0.847	0.833	0.82
x_1	Not necessary	>2,740	>2,651	>2,597	>2,545

Actually, it is a tit-for-tat strategy that controls the direction of liner alliances. Once a leading player wants his partners to follow his advice and signal, what the leading player should do is adjust the additional benefit that the other players would gain from the cooperation or adjust the penalty once deviation from other partners occurs. Thus, the way that these liners make cooperation contracts could be regarded as the mechanism design among the liner shipping industry. Once practitioners in the liner shipping industry take the advice from this research, better payoff and cooperation are expected to be achieved.

Future research interests are as follows: (*a*) The rates and number of slots based on the slot chartering agreements by applying the Leontief model might be possible once the negotiations between two cooperating partners are regarded as sequential games. (*b*) Although the market uncertainties are discussed in this paper by means of sensitivity analysis, further observation of market uncertainties can also be advanced by taking into account the imperfect information and fake signals that players occasionally issue. (*c*) Comparison of the similarity between airline alliances and liner shipping alliances would be helpful in advancing this research on the liner shipping industry. The development that had already appeared in the airline industry (*82, 83*) and what was going to happen in it would be food for thought for researchers and decision makers engaged in the liner shipping companies. In addition, the logistics services integration and the liners' affiliated third-party logistics service providers have been developing since the 1990s (*84, 85*). The networks integration of affiliated third-party logistics service providers and their performance need to be closely observed as well.

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THE WIN-WIN GAME IN SLOT-CHARTERING AGREEMENT AMONG THE LINER COMPETITORS AND COLLABORATORS

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ABSTRACT

Besides the liner alliances as one of the means to cooperate in the liner industry, vessel-sharing and slot-chartering agreements are also very common among the liner collaborators even if they are competitors at the same time. In this paper, we focus on slot-chartering agreements. The co-existing competition and collaboration make the negotiation of slot-chartering agreements quite tough. The liner carriers who are involved in the slot-chartering agreements are regarded as the players in this paper and the pay-off of the games should be win-win games rather than zero-sum games. Otherwise, such slot-chartering agreements may not be attractive enough to keep their either short-term or long-term cooperation.

Thus, the main idea of this research is to explain the negotiation stages as well as to design an efficient mechanism to balance the slot requirements and the equilibrium prices under different circumstances. Furthermore, the negotiation and pricing model is to be applied and demonstrated. The output of this paper is of interest to decision makers working in the liner shipping companies as well as in some other business domains.

Keywords: liner shipping, game, price, slot-chartering, negotiation

THE WIN-WIN GAME IN SLOT-CHARTERING AGREEMENT AMONG THE LINER COMPETITORS AND COLLABORATORS

1. INTRODUCTION

Since the decline of the liner conferences there were three reshuffles of the liner shipping strategic alliances re-integrations, which had been observed by many researchers (Brooks 1993 2000; Clark 1997; Fusillo 2003 2004; Heaver et al. 2000 2001; Hoffmann 2005; Shi and Voß 2007a; Slack et al. 2002). However, recently even the 'outsiders' of the liner shipping strategic alliances announced their vessel-sharing or slot-chartering agreement in order to develop more reliable service networks to their customers. For instance, the Maersk Line rebuilt the Asia-Europe route by cooperating with Evergreen Marine Corp.; meanwhile, NYK phased out its vessels from associated services.

The aforementioned turbulences within the liner shipping industry reflect the following facts: the liner shipping service could reach economies of scale (Lim 1998; Lorange 2001) by means of deploying mega container ships (Cullinane et al. 1999) as well as reach economies of scope by means of integrating sophisticated networks (Baird and Lindsay 1996; Akio et al. 2006). In addition, it could also reach economies of fitness, as the main task of this paper, by means of vessel-sharing, slot-exchanging and slot-chartering agreements.

Thus vessel-sharing, slot-exchanging and slot-chartering problems are of great importance to the liner carriers as well as of great interest to the researchers. The main difference between vessel-sharing, slot-exchanging and slot-chartering is that vessel-sharing focuses more on network integration (Evangelista and Morvillo 2000; Shi and Voß 2007b) and fleet deployment, and slot-exchanging focuses more on routes implementation, and slot-chartering more on price-and-quantity decisions. The price of the vessel-sharing and/or slot-exchanging business is represented by exchanging slots in partners' vessels or other service routes. In other words, either the price of the slots or the cost of bunker are not paid in monetary means. And the slots allocation of each liner carrier on the associated vessels is simply assigned according to the ratio of their deployed vessels for the associated services, as shown in Table 1.

	Party	Allocation on liner A operated vessels	Allocation on liner B operated vessels
1	Liner A who operates a capacities	Associated vessel's capacity x a/(a+b)	Associated vessel's capacity x a/(a+b)
2	Liner B who operates b capacities	Associated vessel's capacity x b/(a+b)	Associated vessel's capacity x b/(a+b)

Table 1: The slot allocation mechanism in vessel-sharing agreements

For reefer containers the allocations follow the same rule. Considering the fact that the top layer of a container ship usually consists of empty containers without jeopardizing stability and compatibility of the vessel, the approximated total weight limitation of all these mentioned slots stands at approximate 10 times the quantities of them even if the full load TEU might be loaded at 14 tons.

However, in most cases of the slot-chartering business, the charterer could not take the advantage of ‘exchanging’ without monetary payment due to the fact that the charterer does not deploy any vessel for the associated service. Within the framework of operational exchanges, vessel-sharing agreements skip negotiation of either price or quantity. However, things are different for the slot-chartering agreements. The charterer and the owner of the vessels need to negotiate on both price and quantity. Furthermore, at different levels of the prices, the charterer decides to accept different quantities that he would like to charter, on the other hand, the owner also decides to offer different quantities, respectively. Thus, there exist tough price-and-quantity negotiations with respect to iterated non-cooperative games, which is the main topic of this paper.

2. PROBLEM DESCRIPTION

2.1 Definitions

From the perspective of the shipping business there are slightly different definitions applied in vessel-sharing, vessel-exchanging or slot-chartering agreements. We discuss them and then define what we apply in the rest part of this paper.

Vessel Provider: The party providing the vessels and/or space, who may be the registered owner or a disposing owner. Vessel provider is usually applied in the vessel sharing business.

Slot owner: The operating liner which provides and maintains vessels (which contain the slots to be chartered) within the terms of the agreement; regardless of whether the vessels are owned or chartered for other parties regarding other contracts.

Slot charterer: The liner which purchases and utilizes the agreed number of slots as specified in the agreement. Slot owner and slot charterer are usually applied in the agreements related to slots, i.e., slot-exchanging agreement and slot-chartering agreements.

Slot: The space on board a ship occupied by one 20’x8’x8’6 ISO container or the equipment weight of 10 GWT/TEU (Gross Weight Tonnage including tare weight/Twenty Feet Equivalent Unit), whichever is reached first, transported on the routes as defined in the associated agreements. Usually, according the real world business, a slot is prefixed with the direction that it is supposed to be shipped, e.g., prefix EB denotes east bound and prefix WB denotes west bound. However, it should be noted that different liners might apply prefix and abbreviations differently.

Comparing the definitions of vessel provider and slot owner, in the remainder of this paper we assume the slot owner to denote the party of an agreement who provides slots, and assume the slot charterer to denote the party of an agreement who charters slots. In a simple way, owner and charterer in this paper mean the slot owner and the slot charterer, respectively.

In case that the slot owner fails to provide slots as agreed, e.g., clashing of sailing and force majeure, slot spaces compensation in later voyages or other means of compensation shall be discussed and agreed in good faith. However, in this paper we ignore such risk management problems to avoid redundancy.

From the perspective of methodology there is a variety of academic papers discussing business negotiations and behaviors in terms of game theory by applying slightly different definitions. In order to make our paper authentic and uniform, we briefly discuss some similar definitions as follows.

In most of the classical references which introduce fundamental game theory or advanced proofs (Gibbons 1992; Nash 1949; Phlips 1995; Shapley 1953 1971; Von Neumann and Morgenstern 1944), a player is applied to represent the individual person or group who is involved in the decision making process, especially the individual rationality conflicts with collective rationality. As time goes by, both theory itself and applications develop some other concepts to be used, e.g., agent, party, decision making unit (DMU), etc. For instance, in Gomes and Lins (2007) DMU is applied. They assume that each DMU would search at the same time for the sake of maximizing its efficiency either by means of competition or by means of cooperation. In addition, it deserves special consideration when an agent is applied to represent players involved in games, together with principal-agent mechanism and multi-agent based calculation that the appropriate comprehension of the definition is really necessary. In the remainder of this paper, agents are applied to denote the liners who are involved in the slot-chartering agreements.

2.2 Main Issues arising from the Liner Market

2.2.1 Evolution of Liners Cooperations

To avoid redundancy, here we only demonstrate the comparison of the top 20 liners listed in January 2007 in terms of operating capacities; see Table 2. For the historic ranking of the liners and the alliances, interested readers might refer to (Brooks 2000; Meersman et al. 1999; Shi and Voß 2007a) as well as most updated rankings via www.alphaliner.com.

Liner	Jan 2000		Jan 2007		Capacity Growth	
	Rank	Share	Rank	Share	Total	Per year
A.P. Möller-Maersk	1	12.0 %	1	16.8 %	184 %	16.1 %
MSC	5	4.4 %	2	9.8 %	357 %	24.2 %
CMA CGM Group	12	2.4 %	3	6.5 %	458 %	27.8 %
Evergreen Group	2	6.2 %	4	5.2 %	73 %	8.1 %
Hapag-Lloyd	14	2.0 %	5	4.4 %	346 %	23.8 %
CSCL	18	1.7 %	6	3.8 %	363 %	24.5 %
COSCO Container L.	7	3.9 %	7	3.7 %	95 %	10.0 %
Hanjin/ Senator	4	4.8 %	8	3.3 %	42 %	5.2 %
APL	6	4.0 %	9	3.2 %	63 %	7.2 %
NYK	8	3.2 %	10	3.1 %	98 %	10.3 %
MOL	10	2.6 %	11	2.7 %	107 %	11.0 %
OOCL	16	2.0 %	12	2.7 %	178 %	15.7 %
K Line	13	2.2 %	13	2.6 %	144 %	13.6 %
CSAV Group	20	1.4 %	14	2.4 %	259 %	20.0 %
Zim	11	2.6 %	15	2.3 %	82 %	9.0 %
Yang Ming Line	17	1.8 %	16	2.3 %	157 %	14.5 %

Hamburg-Süd Group	21	1.3 %	17	2.0 %	201 %	17.0 %
Hyundai Merchant Marine	15	2.0 %	18	1.6 %	61 %	7.0 %
PIL (Pacific Int'l Line)	24	1.2 %	19	1.4 %	140 %	13.4 %
Wan Hai Lines	22	1.2 %	20	1.1 %	81 %	8.8 %

Table 2: The capacity competition among the top-20 liner carriers

Source: AXS-Alphaliner: Liner Shipping Report

Based on those data, among all kinds of vessels in fleets, the VLCS (Very Large Container Ship) is the key market that represents the corporations' ship financing capabilities. The three leading liners, i.e., Maersk Line, MSC and CMA CGM, control 40% of all the VLCS (both existing and on order). However, the competition in the VLCS market also results into overcapacity problems as well as the problem of unreasonable pricing, which might either reduce the level of collective rationality of the supply side or let the demand side bear too much unreasonable cost.

2.2.2 Overcapacity

It is well known, as reported by Alphaliner (www.alphaliner.com), that some carriers prefer to luring competition observers in terms of under valuating the capacity of ships deployed, which might be because this liner does not want to terrify the competitors especially when the ships are to be launched for a new service. A good example is EMMA Maersk with 11,000 TEU as announced capacity. However, once the fully designed capacity of it is to be utilized, the capacity might reach 15,000 TEU with four-tier on deck containers. To make things even worse, there are eight EMMA class vessels booked and to be delivered in 2008 for the Asia-Europe route. Falling under this case, the overcapacity of some trade routes might, to great extent, be expected. Furthermore, the order book has since risen rapidly to reach 60% of current capacity. The pace of ordering continues and is causing some concern over the possibility of future overcapacity in the East/West trades (Drewry 2007). Liu (2007) demonstrates the selection of feasible container services under the circumstance of employing mega containerships. For a summary on vessels size evolution and its impact, i.e., deploying Post-Panamax, Super-Panamax and Supra-Panamax, we refer to Shi and Voß (2007c).

2.2.3 Asymmetric Information

Concerning the information sharing among the slot-chartering agreement parties, it is not surprising that the information is asymmetric. That is, the owner of the slots gets better access to the information of the costs of slots while the charterer gets less relevant information about it. The effective transparency of the information sharing among owners and charterers might improve the efficiency of the whole agreements. However, with regard to the published vessel-sharing, slot-exchanging and slot-chartering agreements, e.g., published on the FMC (Federal Maritime Commission) website, the amount and price of the slots are by no means transparent since they are regarded and protected as business.

2.2.4 Pricing

Taking into account three main routes, i.e., Far East to Europe, transatlantic and transpacific, lots of changes have happened considering the trade flows, cargo/value structure under influence of globalization. For instance, the supply-demand balance will weaken in the long-term with a large number of 10,000 and 12,000 TEU due to being deployed in the East-West trades in 2010-2012, demand growth will be unable to keep pace. Then a question derives from the aforementioned fact 'big is beautiful but at what cost?' The ship operation costs continue to rise and are of major concern. Once the liner carriers decide to start their cooperation by applying slot-chartering agreements as the first step, the pricing mechanism on chartered slots is vital, which is the main task of this paper.

2.3 Advantages and Disadvantages

2.3.1 Advantages

The liners desire to cooperate with each other in containerized trade to obtain optimum efficiency of fleet operation and to maximize slot utilization through slot allocation; so as to offer improved services to the shipping public. Such business optimizes capacity utilization in terms of balancing the freight flows if cooperate with partners who could occupy the inbound empty containers.

The involved liners of the slot-chartering agreement, i.e., the owner and the charterer, still retains its separate identity and shall have separate sales, pricing, and marketing functions. And each liner issues its own B/L (Bill of Lading).

From the viewpoint of cost savings, either the owner or the charterer could take advantage of the slot-chartering agreement.

Being the owner, he shall pay all wages, insurance premiums, charges, dues, taxes, agencies, commissions, fees and all other expenses whatsoever incurred in connection with the operation of the running vessels.

Being the charterer, things seem to be much simpler. The charterer only needs to pay the price that the owner requires and regards that as the unit cost of the charterer. Theoretically, such unit cost might be higher than if the charterer operates the vessels by himself. However, by means of slot-chartering, it is much easier for the charterer to focus on his marketing issues as well as customer relationship management without paying too much detailed efforts on operating the vessels by himself, not even to say the transferred risks to the owner in case of bad weather, force majeure and/or market decline, etc.

Furthermore, the slot-chartering business could also function as the trials of long-term cooperations among these involved liners, especially when some liner is attempting to amplify some sub-network. For instance, CMA CGM consolidated its 3rd rank with a fleet grew by 5.7%. Besides taking many unwanted ships by others, it also developed a relatively stable slot-chartering business step by step with CSCL and Zim, as summarized in Table 2.

2.3.2 Disadvantages

For the owner slot-chartering agreements lose, to some extent, the chance to get higher freight rates per TEU facing the flexible liner market environment (Haralambides 2004). Moreover, the performance of cooperation compared to individual operations has been tested by Haralambides and Veenstra (2000).

In addition, the asymmetric information sharing situation (Harrigan 1988) between slot-chartering parties might result in problems on the operation control and trust development within the further agreements (Das and Teng 1998).

Furthermore, the slots as resources of the liner carriers (Tsang 1998), once chartered by other competitors according the charter agreements, might negatively affect the ship scheduling (Ting and Tzeng 2003) and schedule reliabilities (Vernimmen et al. 2007) due to the uncertainties from the charterers' sides. In case of delays, the supposed total turnaround time (Notteboom 2006) together with the seamless linkages with ports would not be sustained.

2.4 Different Levels of Cooperation

In our research, we divide different kinds of cooperation among the liners on three levels. The first level is slot-chartering in some routes, the second level is slot-exchanging in different routes, and the third level is common vessel deployment or, in other words, vessel-sharing. For the first level of cooperation, the charterer needs to pay the monetary instruments to the owners, as mentioned before. For the latter two levels of cooperation, the involved liners might either exchange the slots or deploy vessels instead of paying in terms of monetary instruments, which seems to be more convenient together with higher risk of mistrust. Usually, the first level of cooperation could be rated as the temptation of the latter two levels of cooperation, say, the long-term strategic alliances. Whether one liner starts with first level or skips it directly to the latter two levels, is depending on his willingness together with his investment capability. Table 3 provides a summary of current service cooperation among the liners, where we allocate them into three different levels and focus more on the first level, i.e., slot-chartering, in this paper.

Trade Flows	**Levels of Cooperation**		
	1. Slot-chartering	2. Slot-exchanging	3. Vessel-sharing
Transpacific	ANL from CMA CGM on PRX (as USW1) ANL on CSCL/CMA CGM AAC2/Yang Tse (as USW2) Safmarine on Maersk Line loops Zim on CSCL AAC2 and ANW HMM on Evergreen NUE UASC on Hanjin AWH (as AWH) and K Line AWK (as AWS) CSCL on CMA CGM PEX3 (as AAE4) Emirates on Zim/Evergreen AUX Maersk on Evergreen NUE Evergreen on Maersk TP8 Evergreen from the New World Alliance on ESX and SZX loops	CSCL and Zim (AAS/ZCS)	See Shi and Voß (2007a 2007b) for a detailed categorization of common vessel sharing and strategic alliances evolutions.
Europe-Far East	ANL from CMA CGM on FAL1, FAL2 and FAL3 Zim on CSCL AEX1 UASC on COSCO SCX APL on CMA CGM FAL1 (as CFX) and FAL3 (as NCE) CMA CGM from APL on the New World Alliance JEX, SCX and AEX (as KEX) Yangming on TNWA AEX (as KEX) Grand Alliance lines on New World Alliance AEX, CEX and SCX APL on Grand Alliance EU2 and EU3 HMM on Grand Alliance EU3/EU4 (as LP3/LP4) and CMA CGM FAL3 (as FA3) MOL on Grand Alliance EU4 (as LP4) and CMA CGM FAL3 (as NCE)	CSCL and CMA CGM (AEX1/FAL1, FAL3) CMA CGM and Evergreen (FAL1, FAL3)	

	Safmarine on Maersk Line loops Zim on CSAV Norasia AME (as Asia North Europe Express) IRISL on CSCL AEX1		
Far East-Mediterranean	ANL from CMA CGM on MEX, FAL1 and FAL3 Evergreen on CMA CGM FAL1 and FAL3 APL on CMA CGM MEX HMM and MOL on Yangming AME (as AMS/MED) K Line from Hanjin on EMA/MEX APL on CMA CGM/MOL FAL1 (as NCE) and CMA CGM FAL3 (as CFX) APL and MOL on Grand Alliance EUM HMM on Grand Alliance EUM and EU2 (as LPM and LP2) Safmarine on Maersk Line Loops Zim on Cosco/CMA CGM AMX/MEX2 UASC on Hanjin MAP Senator on Hanjin MAP and Yangming AME (as NMX) HMM on CMA CGM/MOL FAL3 (as FA3) APL on Grand Alliance EU2 Yangming on Hanjin AMP (as CMX) HMM on Evergreen UAM	CSCL and CMA CGM (AEX1/FAL1, FAL3) CMA CGM and Evergreen (MEX/UAM)	
Transatlantic	Cosco, K Line, Yangming on MSC South Atlantic/ Gulf loop (as TAS5/EGS) Zim on Cosco/Hanjin/K Line/Yangmign (as AUE) Hapag-Lloyd on CMA CGM/ Marfret Panama pendulum ANL from CMA CGM on Liberty Bridge (as EUS2) Victory Bridge (as EUS1) and Panama pendulum	ACL and Hapag-Lloyd (ACL on Grand Alliance PAX, ATX and GAX) Maersk Line and New World Alliance	
Mediterranean-North America	APL on Maersk Line Gulf/Med services (as MGS) CSCL from Zim on ZCS (as MAX) Zim on CMA CGM/Evergreen/Gold Star Amerigo Express (as Med USA service) Cosco from Zim on ZCS (as TAS5, Haifa/USEC/Haifa only) Zim on Hapag-Lloyd Med Gulf service (as Med Gulf Express) Hapag-Lloyd on Maersk West Med (as MNX) Hapag-Lloyd on Zim ZCS (as ZCX) CSCL on CMA CGM/Evergreen/Gold Star Amerigo Express (as MAX4) Cosco, K Line and Yangming on MSC N.Atlantic loop (as TAS6)		
North America/Mid East/South Asia	Safmarine on Maersk Line services MacAndrews and MOL on Indamex		

Table 3: Three levels of cooperation among the liner carriers

Source: Own composition based on Drewry (4th quarter report 2007) and BRS online information

Other recent significant moves within the liner shipping market are outlined as follows. As of 12 February 2006, Maersk Sealand and P&O Nedlloyd started to trade as Maersk line. As of 1 May 2007, the Evergreen Group unified its three brands Evergreen Marine Corp Ltd (EMC), Italia Marittima SpA (ITS) and Hatsu Marine Ltd (HML) under the unified common trade name 'Evergreen Line'. Kawasaki Kisen Kaisha Ltd (K Line) (Japan) and Hanjin Shipping Co Ltd have swapped shares in a proportion of around 3%. Geveran Trading, a Cyprus-based firm which is part of Greenwich Holding Ltd, a company indirectly controlled by Norwegian shipowner John Fredriksen, raised its share in Hyundai Merchant Marine , triggering a reaction by HMM main shareholders to counter-act what was interpreted as a possible attempt by Geveran to take control of the company.

The Hamburg Süd group has replaced its brand Ybarra Cia. Sudamerica S.A. (Ybarra Sud) with the brand Hamburg Süd Iberia S.A., effective 1st Janurary 2007 (Ybarra Sud came under full control of Hamburg Süd on 31 December 2005). The organizational consolidation of Hapag-Lloyd AG and Hapag-Lloyd Container Linie GmbH (HLCL) already realized in 2005 has been formalized in 2006 in the context of the integration of CP Ships. Besides, all the CP Ships services were integrated into Hapag-Lloyd's network by September 2006.

All the liners mentioned in this paper are either operating individually or are consolidated with their subsidiaries, detailed information refer to appendix-2.

The behaviors of liner players and aforementioned real world business turbulence provide us more motivation to analyze and evaluate them in terms of game theoretical application.

3. RESEARCH METHODOLOGY

3.1 Problem Formulation

Concerning the competition and cooperation among the liner carriers, a lot of research had been done based on a variety of analysis including shippers' choice (Brooks 1983 1993), oligopoly market status (Fox 1994), overcapacity issues (Fusillo 2004) and additional profit allocation approaches as well as fairness based on Shapley value derived from cooperative game theory (Wang et al. 2001; Song and Panayides 2002; Liu and Akio 2005). When the slot-chartering problem is to be discussed in terms of non-cooperative games, there are several perspectives which might lead to even more different models.

From the perspective of capacity limitation, the slot-chartering problem could be viewed as zero-sum game played by two agents because the reduced slots allocation of one agent after bargaining is the added slots that the other agent would get based on the negotiation. In this case the decision variables are related to the quantities of slots allocated to each agent.

From the perspective of bargaining processes, the slot-chartering problem may also differ depending on whether or not there is an effective long-term replenishment mechanism. The mechanism design on slot-chartering price together with the respective quantity of the slots is valuable to be observed. Regarding the replenishment existing in other areas, e.g. in military management, see Lennon et al. (2007). In order to design an appropriate mechanism, the following two situations should be considered, respectively: the slot owner has superior bargaining power over the related charterer, and the other for the reverse situation. Furthermore, during the iterated negotiation processes, the higher the position of any given agent the more he intends to push down the position of others. Concerning the long-term replenishment contract based on game theoretic analysis, we also refer to Kim and Kwak (2007).

From the perspective of profit sharing which results from a slot-chartering cooperation, it could be viewed as non-zero-sum game since additional profits might occur when liners provide more options to shippers. To the best of our knowledge, so far no such research has been done in the ocean sea shipping industry. However, similar research considering the hinterland trucks picking-up and delivering tasks had recently been developed by Krajewska and Kopfer (2006) as well as Krajewska et al. (2007).

From the perspective of the evolution of the negotiations concerning the slot-chartering business, the iterated sub-games also make sense and effect the repeated assignment of the slots, see Shi and Voß (2008). There are some cases in military equipment assignments, see Lennon et al. (2007) as well as Erdem and Ozdemirel (2008).

From the perspective of the incomplete and imperfect information among the involved agents of the slot-chartering agreements, the true cost and individual prediction on the market share are, without any doubt the business confidentialities of each agent. Thus, the involved agents do not have full information about quantity options and consequently each possible quantity of the slots depends on the probabilities that the other agents perform different actions/behaviors.

Furthermore, some researches (Powell and Swart 2007) based on a game theoretical framework suggest that the learning processes might result a contingence of the equilibrium, thus, the iterated negotiations on price and quantity of the slot-chartering agreements deserve our further research observations.

3.2 Cost Structure and Capacity Constraint

Before starting to analyze the price-and-quantity negotiation, a neat cost structure needs to be investigated first so that a better understanding could be achieved.

3.2.1 Cost Structure

We conclude the cost structure in detail as shown in Table 4.

Item	**Remarks**	**Memo**
Lashing	Not common Cost	if included in pick rate (slot charterer to pay for its box)
Lashing(additional,extra lashers)	Common Cost	if additional then to be prorated as per throughput
Extra Labour / Special gang	Common Cost	To be prorated as per throughput unless for unusual loadings requested by a liner (breakbulk, project cargo, yachts etc.).
Overtime	Common Cost	To be prorated as per throughput unless Slot owner's responsibility is engaged
Meal Hours	Common Cost	To be prorated as per throughput

Detentions	Common Cost	To be prorated as per throughput unless Slot owner's responsibility is engaged
Standby gangs	Common Cost	To be prorated as per throughput unless Slot owner's responsibility is engaged
Unused Guarantee Time	Common Cost	To be prorated as per throughput
Shifting and restow (1)	Not Common Cost	To be for Slot owner a/c except when incurred for specific COD's
Shifting and restow (2)	Common Cost	as a result of an agreed change of rotation and /or of an agreed port omission
Opening/Closing hatch covers, pontoons	Not Common Cost	To be for Slot owner account
Load/Discharge Gear Boxes	Not Common Cost	To be for Slot owner account
Dockage	Not Common Cost	To be for Slot owner account
Tally charges	Common Cost	To be prorated as per throughput
similar charges as per local regulations	Common Cost	To be prorated as per throughput
Reefer mechanics	Common Cost	To be prorated as per reefer throughput
Standby for crane down	Common Cost	To be prorated as per pro rata throughput
Gangs switching vessels	Common Cost	To be prorated as per pro rata throughput

Table 4: The cost allocation between the involved agents based on agreement

3.2.2 Operational Costs Trends

Manning is the single largest operating cost budget element and there is going to be a shortage on experienced seafarer once the under-booking superpost-Panamax/supra-Panamax vessels are delivered in 2010-2012.

Insurance premiums are being dashed not just by a series of major claims but also through a rapid increase in the number of higher cost minor claims. This can only give further momentum to future premium increases (Drewry Quarterly Report).

Concerning repairs and maintenance, the ship repair industry has experienced rising prices tempered by higher steel and coal costs. Other than that, stores, spares and supplies, is the least significant element in the overall operating budget. Management and administration fees remain surprisingly stable.

Furthermore, the liner carriers always keep in mind how the BAF (Bunker Adjustment Factor) fluctuates as a consequence of bunker price changes. In most of the cases, the variable components in the BAF formula consist of the following:

$$\text{BAF} = \text{Bunker price change} \times \underbrace{\text{Trade specific constant}}_{\text{Bunker consumption} \times \text{Transit time} \times \text{Imbalance factor}}$$

Bunker consumption: the amount of metric tons of bunker fuel needed to transport a 20 feet container each day of the transit. For instance, the bunker consumption of Asia-US is 0.032mt/TEU/day (calculated via BAF calculator published on www.maerskline.com).

Transit time: the average number of days of a round trip voyage divided by two; equals the one way transit time. The transit time of Asia-US is approximately 28 days.

Imbalance factor: is the ratio of headhaul to backhaul. This measures the inequality between imports and exports in each trade. The US backhaul trades have performed well but rates have not upgraded enough to make a real difference due to the worry on the imbalance factor kept year by year. For instance, the US backhaul, i.e., Asia-US West Bound is regarded as with 0.6 imbalance factor comparing the US headhaul, i.e., Asia-US East Bound with 1.4 imbalance factor. This would influence dramatically the rates differences between West Bound and East Bound. As a matter of fact, the filling ratio of large vessels is one of the key issues always being under managers' considerations.

Bunker price change in bunker cost, up or down, during the measurement period. The price change is the new price less the original price because the base bunker cost has been included in the base ocean freight rate. For instance, the bunker price is 441 in the first quarter of 2008, and considering the bunker base element 322, we get a bunker price change as 119 USD.

As for the tactic of the liner, he might choose some monitoring port to consist his global bunker port basket aiming to control its bunker prices and adjusts the basket on a quarterly base. Most probably, Algeciras, Busan, Durban, Hongkong, Los Angeles, New York, Panama Canal, Rotterdam, Salalah, Savannah and Singapore are under consideration.

All the above mentioned costs including fixed costs and operational costs as well as the associated tactics of calculating and optimizing them would be directly or indirectly represented in the liner's profit curve and indifference curve, see Figure 1-5.

3.2.3 Chartered Slots Constraint

By applying the Leontief model (Gibbons 1992), the owner of the vessel and slots could be regarded as the position providers and the charterers could be regarded as the labors, respectively. Considering the liner shipping business realities, one of the capacity constraints is that the charterer might not charter the slots beyond 50 % of the vessel's capacity. As for the owner, he would not let the charterer purchase so many, otherwise, it reflects that his sales representatives do not work effectively enough to grasp the market share. And the retail price sold by his sales representatives should be higher than the wholesale price based on the slot-chartering agreements. From the view of the charterer, he would not like this situation either. Otherwise, the charterer might prefer to deploy another vessel and charter some slots out instead of purchasing over 50% capacity of his competitor's vessel. Under this situation, the charterer might think himself support too much to his competitor's revenue. Thus, there exists a realistic constraint that the ratio of chartered capacity will not exceed 50%.

3.3 Model

Price and quantity negotiation in a slot-chartering agreement is considered as below. Leontief (1946) presented a model of the relationship between an entity and a monopoly union. This model could also be applied to simulate and analyze the negotiation in a slot-chartering agreement, which could be described as follows:

- The owner and the charterer bargain over prices of the slots to be chartered

- The charterer retains exclusive control over the quantity of slots that he would like to charter

Here we would like to explain the similarity between the wage-labor game and the slot-chartering agreement game. From the demand-supply point of view, the charterer desiring slots behaves like the firm which desires labor and the owner supplying slots behaves like the union who supplies labor. Thus, the sequence of the sub-game might be of similar mechanism.

- The utility function of the owner is $U(p,q)$, where p is the price at which the owner would like to offer and sign with the charterer, and q is the quantity. Assume that $U(p,q)$ increases in both p and q.
- The charterer's profit function is $\pi(p,q) = R(q) - p.q$, where $R(q)$ is the revenue that the charterer can earn if he charters q slots and use them to transport the associated cargo optimally. Assume the $R(q)$ is increasing when q goes up, i.e., $R(q)$ is concave.

Suppose the sequence of the game is:

- Stage 1:the owner proposes a price p
- Stage 2:the charterer observes p and then further thinks about (and later may accept) the quantity q
- Stage 3:payoffs of the owner and the charterer are $U(p,q)$ and $\pi(p,q)$, respectively

Below we go forward to assume specific functional forms for $U(p,q)$ and $\pi(p,q)$ which make it possible to solve the payoffs explicitly by applying backwards-induction.

First, we can characterize the charterer's best response in stage 2, $q^*(p)$, to an arbitrary price proposed by the owner in stage 1, p. Given p, the charterer charters $q^*(p)$ slots to optimize his profit

$$\max_{q\geq 0} \pi(p,q) = \max_{q\geq 0} R(q) - p\cdot q$$

The first-order condition for the above formula is $R'(q) - p = 0$. In order to guarantee that the first-order condition has a solution, assume that $R'(0) = \infty$ and that $R'(\infty) = 0$, as suggested in Figure 1.

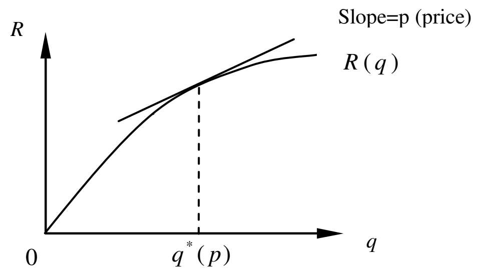

Figure 1: The revenue of charterer versus the price

Actually the $R(q)$ is the revenue that the charterer gains when he behaves as a carrier to the shippers (in most parts of this paper, the shipper is not involved). And $p \cdot q$ is the cost because the charterer himself does neither own the slots nor operate the associated vessel, but he pays $p \cdot q$ as his cost to the owners.

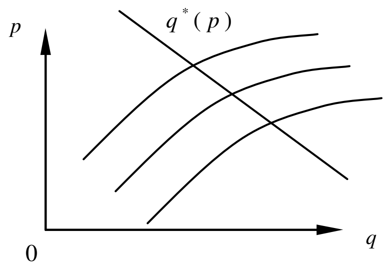

Figure 2: Slot charterer's isoprofit curves

Figure 2 depicts $q^*(p)$ as a function of p but uses axes that ease comparison with later figures and illustrates that $q^*(p)$ cuts each of the charterer's isoprofit curves at its maximum.

- Holding q fixed, the charterer does better when p is lower, in other words, the cost is lower, thus, lower isoprofit curves represent higher profit levels
- When $q^*(p)$ cuts the charterer's isoprofit curves at its maximum, it represents the fact that $q^*(p)$ maximizes $\pi(p,q)$ given p. If the charterer bargains p' other than p, for instance, then the owner's choice of q amounts to the choice of a point on the horizontal line $p = p'$
- The highest feasible profit level is attained by choosing q such that the isoprofit curve through (p', q) is tangent to the constraint $p = p'$

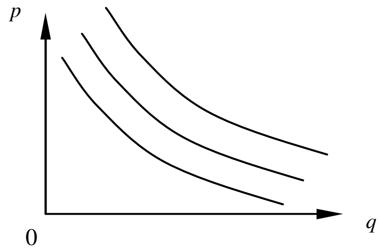

Figure 3: Slot owner's indifference curves

Figure 3 depicts the owner's indifference curves. Holding q fixed, the owner does better when p is higher, so higher indifference curves represent higher utility levels for the owner.

We turn next to the owner's problem at stage 1. Since the owner can solve the charterer's stage 2 problem as well as the charterer can solve it, the owner should anticipate that the owner's reaction to the price proposal p will be to decide the quantity level $q^*(p)$.

Thus, the owner's problem at the stage 1 amounts to

$$\max_{p \geq 0} U(p, q^*(p))$$

In terms of the indifference curves plotted in Figure 3, the owner would like to propose the price p that yields the outcome $(p, q^*(p))$ that is on the highest possible indifference curve.

The solution to the owner's problem is p^*, the price proposed such that the owner's indifference curve through the point $(p^*, q^*(p^*))$ is tangent to $q^*(p)$ at the point, see Figure 4.

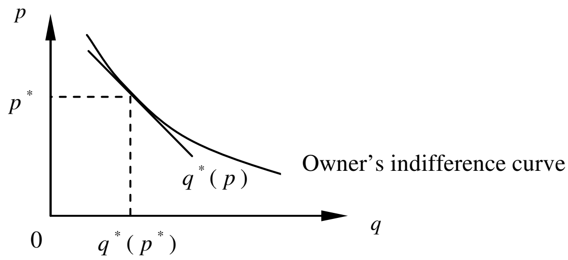

Figure 4: Equilibrium derived from backwards-induction

Thus, $(p^*, q^*(p^*))$ is the backwards-induction outcome of this price-and-quantity game.

It is straightforward to see that $(p^*, q^*(p^*))$ is inefficient: both the owner's slots capacity and the charterer's profit would be increased if p and q were in the shaded region in Figure 5.

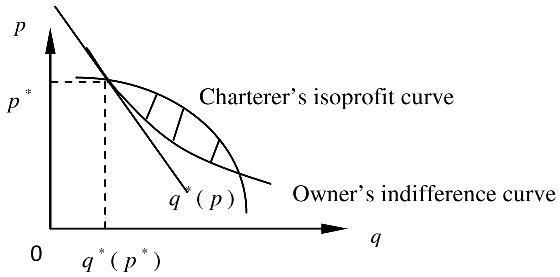

Figure 5: Shaded region of equilibrium

This inefficiency makes it puzzling that in practice the charterers seem to retain exclusive control over quantity of the slots to be chartered without exceeding 50% capacity of the associated vessle as mentioned in Section 3.2. Even allowing the charterer and the owner to bargain several times over the price but leaving the charterer with exclusive control over quantity results in a similar inefficiency.

Espinosa and Rhee (1989) propose one answer to the puzzle of inefficiency. Based on the fact that the owner and the charterer might negotiate repeatedly over time (usually every three years regarding the liner business reality) there may exist an equilibrium of such an iterated game in which the owner's choice of p and the charterer's choice of q lie in the shaded region of Figure 5, even though such values of p and q cannot arise as the backwards-induction outcome of a single round game.

In the model proposed in this paper, the backwards-induction outcome is not collective efficient. In practice, however, a charterer and an owner may discuss over the detailed terms of a three-year-agreement, then negotiate three years later over the terms of a second agreement, and so on. Thus, the relationship between the charterer and the owner may be more accurately characterized as repeated games applying dynamic strategy, Shi and Voß (2008). This problem derives conditions under which a subgame-perfect Nash equilibrium in the infinitely repeated game is Pareto-superior to the backwards-induction outcome of the one-shot game. Denote the owner's utility and the charterer's profit in the backwards-induction outcome of the one-shot game by U^* and π^*, respectively. Consider an alternative utility-profit pair (U, π) associated with an alternative price-and-quantity pair (p, q). Suppose that the parties/agents/players share the discount factor δ (per three-year period).

Derive conditions on (p, q) such that

- (U, π) Pareto-dominates (U^*, π^*)
- (U, π) is the outcome of a subgame-perfect Nash equilibrium of the infinitely repeated game, where (U^*, π^*) is played forever following a deviation.

4. MECHANISM DESIGN

4.1 Payments

In most cases, the slot-chartering agreements are to be signed every 3 years and to be amended in case the operating cost of related container ships turbulent too much, e.g., the fuel price keeps increasing.

Considering the payment method of the slots agreements, both monetary payments and other slots are possible. For instance, the partners might pay for the slots of Asia-US East coast in terms of providing slots of Asia-US West coast or Asia-Europe, which could be viewed as slot-exchanging, as mentioned in Section 2.4. Without paying monetary instruments, this provides both partners better chances to control their own cash flow as well as decreasing the risk of fuel cost.

Considering the peak season and congestion, the slot-chartering agreements are relatively more stable than the spot price of retailing slots. The agreements are supposed to be discussed and signed at least three months before put into force. So even if port congestion happens or an unexpected peak season occurs, the agreements are not easy to be broken without advance permission of the partner.

4.2 Iterations

How do the partners of the first round game likely alter their choice of contracts in subsequent games? Every curve can change. The charterer's soprofit curve is built based on the slot rate he get from the owner and the retailing price that the charterer sells to final shippers; the owner's indifference curve is built based on his own cost and the slot rate the owner sells to the charterer. Those variables of cost and revenue are actually based on the expectations of the other agent's "good guess". Perhaps the most important concern of the agents is the predictability of their partner's behavior. This might arise in an argument: if every business behavior is predictable, then there would be, in general, no agreement necessary at all. As some other literatures (Macaulay 1963) had discussed, actually a detailed contract is one mechanism for making behavior predictable, and another is trust (Gulati 1995). On one hand, the trust between partners occurs when the business development follow the originally detailed agreements. On the other hand, the trust then, in the other way around, might help stable and positive outcomes of the sequent sub-games subject to the compatible mechanism or change simultaneously based on mutual understanding. Hence iteration of sub-game may improve, no matter positively or negatively, the negotiations among the associated liners.

Besides the reason mentioned before could result iteration, there are some other factor make iteration happen as well. Recall the bunker price as one of the factors that make the operation cost different. The iterations might also happen due to sudden change of the bunker price. The liner adjusts his bunker port basket quarterly, and the iteration of slot-chartering pricing might happen accordingly.

In case axis z is to be drawn in Figure 5, it might denote the sequence of sub-game, i.e., the axis of time. The farer the node along axis z, the later the associate sub-game is to be played. And the sequential equilibrium represents best response of agents taking into account of iteration, learning and rationality.

5. SOLUTION AND SUGGESTION

The research method and provisional model proposed in Section 4 can be applied to analyze the negotiations on slot-chartering agreement. Since every bid of the negotiations is business confidentiality, it is not easy to demonstrate the data of real world business.

The simulation of the optimized price-and-quantity mechanism and sensitive analysis would be an alternative solution in our future research.

With regard to the issues mentioned in Section 2.3, some further discussion might arise. Considering Panama as one bottleneck close to the American East Coast, the extension of the Panama Canal might result not only in changes of the associated short sea shipping service but also the oversea, e.g., Far East to the American East Coast, service reshuffle. Maybe it is even better to say that the reshuffling has already started if we take into account the phasing out of NYK at the beginning of 2008 from the former agreement with Maersk Line. The suggestions for agents and regulators are briefly discussed as follows.

5.1 For Agents - Difference between Slots Provision and Slots Allocation

Any difference between slot provision and slot allocation in a cycle route, either on an occasional or long term basis, may be financially settled between the owner and the charterer. In this respect, the owner shall compensate the charterer at the level of the agreed cost times the number of slots not provided.

On the other hand, it could also be possible that the charterer loads in excess of his allocation without prior notice. If extra capacity is not available from the owner, the charterer having exceeded its agreed slot allocation will be required to reduce its TEU/DWT down to its allocation, and if necessary discharge the containers in excess at its own expense in the next port of call. If extra capacity is available from the owner, the owner might agree to carry such in excess, subject to payment only to the owner of the extra slots on an as used basis (including lost slots in case of High Cube and/or OOG).

The aforementioned difference between slot provision and slot allocation could be demonstrated as in Figure 6.

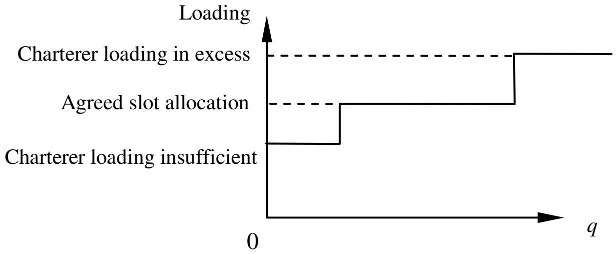

Figure 6: Difference between slot provision and slot allocation

As for the charterer who has accepted the chartering price of slots, it would be a better choice if he tries to fulfill those expensive slots by transporting high-valued cargoes, e.g., containerized chemical goods. These high-valued goods do not care whether or not the so-called FAK (Freight of All Kinds) prices posed to them turn out to be higher. Furthermore, the shift of cargoes from bulks to containerized package is another option to fulfill the capacities.

5.2 For Regulators - Difference between Fixed Agreement and Spot Market

The slot-chartering business draws attention from the market regulators as well as other players, e.g., port operators, within the liner industry (Meersman et al. 1999; Rimmer 1993 1997 1998a 1998b). In other words, the existing cooperation business pushes the regulators both in the US and in the European Union to rethink sustainable policies to support free competition (Gardner et al. 2002; Molenaar and Van de Voorde 1994).

Whether or not it is allowed to sell the unused slots to the spot market to the other active retailing requirements is one of the key issues for regulators. If it is possible for the unused slots to be sold back to the spot market by means of retailing, it might reduce the risk of the associated charterer. However, it should be noted that nowadays based on most of the slot-chartering agreements in the liner shipping business, the charterer shall not assign, delegate, sub-charter or transfer the rights and duties under the agreements, which means the charterer cannot sub-let any slots to any other third party, unless otherwise agreed, agreement not to be unreasonably withheld.

However, there might exist another way to build-up a buffer area connecting with the spot market. Upon negotiating the agreement, the charter might fight for being entitled to sell/allocate slots to his wholly owned subsidiaries as from the start of this agreement, which could to great extent amplify the charterer's chances to finally fulfill his bought slots. Certainly, in order to be fair to the owner, the charterer should advise in writing the owner at least some time, e.g., two weeks, prior the first loading to avoid any operational/booking distortions.

6. CONCLUSION AND FURTHER RESEARCH

In this paper we have investigated the detailed cost structure of the owners and charterers involved in slot-chartering agreements. The different cost allocation of the vessel provider and the charter party and other agents involved in vessel-sharing agreements and its impact on their network integration belongs to our future research interest. In addition, due to the difficulties to get the real cost structure, some segments of the total costs, e.g., bunker price, could be used as key factor when accomplishing sensitivity analysis to simulate the real business.

Taking into account the similarities between the airline industry and the liner shipping industry, the slot-chartering problem discussed in this paper, could also be of interest when investigating airline cooperation. But it should be noted that the 'slot' as a term mentioned in airport operations means differently, i.e., the time window together with the space that could serve the incoming aircrafts. And the time factor makes more sense in the airline business than it does in the liner shipping industry.

As a matter of fact, we can conclude in a more simple way, most of the valuable resources of an entity could be regarded as 'slots'. Once the resources are not so sufficient to manufacture production or provide services, the entity might, after harsh negotiations, choose to cooperate with its competitors at certain price by sharing certain quantities of resources. Thus, the backward-deduction and price setting mechanism discussed in this paper might be valuable and useful when applied, in an appropriate way, in other business domains.

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APPENDICES

Appendix-1: Top 20 Liner Operators at 11 Feb 2008

Rank	Operator	Total TEU	Total Ships	Owned TEU	Owned Ships	Chartered TEU	Chartered Ships	Chartered Ratio	Orderbook increase
1	APM-Maersk	1,916,880	530	998,181	185	918,699	345	47.9%	21.8%
2	Mediterranean Shg Co	1,228,021	371	710,606	214	517,415	157	42.1%	52.2%
3	CMA CGM Group	893,860	375	268,839	88	625,021	287	69.9%	67.7%
4	Evergreen Line	624,357	176	363,425	102	260,932	74	41.8%	17.4%
5	Hapag-Lloyd	492,058	139	247,831	60	244,227	79	49.6%	21.3%
6	CSCL	433,263	139	251,192	87	182,071	52	42.0%	56.5%
7	COSCO Container L.	430,952	141	232,499	94	198,453	47	46.0%	90.6%
8	APL	407,775	126	139,716	38	268,059	88	65.7%	64.0%
9	NYK	385,751	118	248,580	50	137,171	68	35.6%	58.2%
10	OOCL	347,676	82	200,337	35	147,339	47	42.4%	39.9%
11	MOL	346,870	111	165,038	38	181,832	73	52.4%	53.1%
12	Hanjin / Senator	343,297	83	115,891	22	227,406	61	66.2%	91.0%
13	K Line	308,194	93	163,736	33	144,458	60	46.9%	54.8%
14	Hamburg-Sud Group	284,097	123	110,309	37	173,788	86	61.2%	61.0%
15	Zim	280,860	111	136,009	42	144,851	69	51.6%	103.3%
16	Yang Ming Line	274,281	83	172,825	51	101,456	32	37.0%	68.8%
17	CSAV Group	265,064	89	21,208	4	243,856	85	92.0%	57.6%
18	Hyundai M.M.	200,719	47	50,779	11	149,940	36	74.7%	90.1%
19	PIL (Pacific Int. Line)	170,248	110	104,436	74	65,812	36	38.7%	40.3%
20	Wan Hai Lines	140,750	82	98,591	51	42,159	31	30.0%	41.6%

Appendix-2: Liners and Consolidated Subsidiaries

APM-Maersk includes Maersk Line, Safmarine, APM Saigon Shipping-MCC and Mercosul Line

CMA CGM Group includes CMA CGM, Delmas (with OTAL), ANL, US Lines, Feeder Associate System, Cagema, MacAndrews, Cheng Lie Navigation Co and CoMaNav

Evergreen Line includes Evergreen Marine Corporation, Evergreen Marine (UK) Ltd, Evergreen Marine (HK) Ltd and Italia Marittima

Hanjin includes Senator Linie

CSCL (China Shipping Container Lines) includes Shanghai Puhai Shipping Co

NYK includes Tokyo Senpaku Kaisha (TSK)

Zim (ZISS) includes Gold Star Line and Laurel Navigation

Hamburg-Süd Group includes Hamburg-Süd, Alianca and Costa C.L.

Authors’ own composition based on information provided on:

www.maerskline.com

www.axsmarine.com

www.brs-paris.com

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CHAPTER 11

CONTAINER TERMINAL OPERATIONS UNDER THE INFLUENCE OF SHIPPING ALLIANCES

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ABSTRACT

Nowadays, there is a trend to establish new business linkages and alliances within the shipping industry together with customers, suppliers, competitors, consultants, and other companies. Notably these include terminal operators in major ports worldwide. A number of studies have attempted to explain this phenomenon occurring in the liner shipping industry using a variety of conceptual and theoretical frameworks. We focus on liner shipping strategic alliances and their influence on container terminal operators. Regarding alliances we briefly discuss the motivations of short-run cooperation among several liner carriers, analyse pros and cons of being members in liner shipping strategic alliances, and advise ways to maintain long-run alliance stability by increasing benefits and decreasing risks and drawbacks. Moreover, how do these alliances influence container terminal operators, if there is an influence at all, and what are possible scenarios for mutual advantages? Our goal is to survey possible issues regarding shipping alliances and their influences on terminal operators.

1 Introduction

Even in the simplest supply chain, setting the linkage between liner shipping companies and port operators can be regarded as demand and supply oriented upstream and downstream partnering. Liner vessels visit ports as customers and their desire is driven according to their schedules as well as their hinterland shippers and the technology developments. Port operators try every effort to meet the demands and could attract more and more ships by, e.g., good reputation, reliability and agile responses. Thinking about logistic networks in depth, liner shipping transportations and ports obviously act as threads and nodes (i.e. routes or lines and ports) individually, which built up logistics and supply chain networks. Any minor improvements of the threads or nodes, such as faster mega vessels or newly designed handling cranes, could decrease, e.g., time oriented measures such as total flow times or lead times within the logistics network and increase customer satisfaction.

A more efficient logistics network would certainly be gained by avoiding bottlenecks among the network (Brennan, 2001) and by harmonizing liner transportation and port operation. Based on this, there are strong links among liner shipping companies and container terminal operators, no matter whether they are regarded as customer-supplier or thread-node. That is, port operators should take into account those linkages independent from considering short term operations or long term strategies. The inevitable trend of liner shipping strategic alliances together with dynamic membership pushes port operators towards rechecking their marketing instruments, handling schedule, service provisions, data interchange and information system management and integration, etc.

Many researchers are discussing port operation performance, especially under the influence of liner shipping conferences or alliances. From a global perspective it seems beneficial to distinguish between port economics and shipping economics though the interdependencies turn out to be of utmost importance. That is, many issues related to the port industry cannot be investigated without taking into account shipping companies and the shipping industry as its main customers (cf. Cullinane, 2005). Various important trends are pushing the port and shipping industries and those players within them towards re-thinking and re-shaping their service networks (Notteboom, 2004). These trends include globalisation, deregulation, logistics integration, and containerisation. Moreover, regionalization and associated hinterland concepts need to be taken into account, too (Notteboom and Rodrigue, 2005).

Despite globalization, various areas show individual characteristics such as European ports versus so-called Asian models. For instance, Wang et al. (2004) address Shanghai (China) and Song (2002) discusses Hong Kong's role as the gateway to and from China and the ports' competition in the Pearl River Delta. Meanwhile, the development of Busan (Korea) is also a valuable example as an emergence of so-called mega ship ports (Fremont and Ducruet, 2005).

A very comprehensive treatment of the economics of seaport container handling is provided by Vanelslander (2005). Some further references can be found in Ninnemann (2006). More general concerns are treated by Blauwens et al. (2006). With the ever increasing containerization the number of seaport container terminals and the competition among them has become quite remarkable. An up-to-date survey and literature review on container terminal operations with an operations research focus is provided by Steenken et al. (2004).

In this paper, we consider container terminal operations under the influence of liner shipping strategic alliances. The focus of this paper is to provide a rough overview and to discuss opportunities as well as possible risks and pitfalls. The following sections are devoted to the description of shipping alliances, container terminal operators as well as their linkage.

2 Liner Shipping Carriers: Behaviours and Trends

2.1 Vessel Types, Fleet Composition and Major Trade Lanes

Different types of ships are considered by shipping lines (see, e.g., Steenken et al., 2004). While the number of container vessels has increased during the last decade the most significant change has been the increase in vessel size (Slack et al., 2002) with deep-sea vessels with a loading capacity of up to 8.000 container units (TEU, Twenty-Foot Equivalent Units) and beyond. They were deployed approximately by the end of the 1990s, and serve the main ports worldwide. Those 8.000 TEU vessels are about 320 m long with a breadth of 43 m and a draught of 13 m; on deck containers can be stowed 8 tiers high and 17 rows wide, in the hold 9 high and 15 wide. Feeder vessels with a capacity of 100 to 1.200 TEU link smaller regional ports with the oversea ports delivering containers for deep-sea vessels. Inland barges are used to transport containers into the hinterland on rivers and channels.

Generations	Type of vessels	TEU	Speed (knots) / percentage that speed applied
1. 1960s	17000-20000 DWT	700-1500	15-19 / 58%
2. 1970s	40000-50000 DWT	1500-2500	18-21 / 70%
3. late 1970s	Approximately 70000 DWT, Panamax	2500-4000	20-24/ 90%
4. late 1980s to early 1990s	Panamax	4400-5000	23-25
5. 1996-1998	Post-Panamax (VLCS)	6400-7200	24-26
6. since 1999	Post-Panamax (VLCS)	8000 and beyond	24-26
7. after 2009	Suez-Max (ULCS)	12500-13000	25-26 expected
	Post-Suez-Max	18000	
	Post-Malacca-Max		

Table 1: Container ship generations

(DWT: Deadweight tonnage, VLCS/ULCS: Very/Ultra Large Container Ships)

Source: own composition from http://info.jctrans.com/wl/hy/hyzs/2006726279397.shtml, http://www.nacks.com.cn/shiplist/5400dwt.htm, http://www.globalsecurity.org/military/systems/ship/container-types.htm)

Over the previous decades, six generations of container vessels can be distinguished, mainly according to their capacities but also regarding voyage speeds; see Table 1. This also had and still has a great influence on container terminal operations. The first generation of container ships was designed to be operated in transatlantic and transpacific routes. The second generation of container ships not only ensured bigger capacity but also shorter voyage time due to increased speed. During the oil crisis in 1973 such fast vessels turned out not to be economical any longer because of their huge consumption of fuel and lubricating oil. The third generation of container ships appeared with increased capacity and more economical and efficient market performance. Port operators considerably increased handling efficiency to fit the capacities of new container ships. From the third generation of ships to the fourth one, the number of seamen per vessel decreased which led the port operators to improve their handling technology and to catch up the new seamanship. The dimensional barrier of the Panama locks had constrained the progression of ship sizes to about 4400 TEU, the so-called Panamax limit, until the middle of the 1990s (Slack et al., 2002). Since then the so-called Post-Panamax-vessels began to challenge the depth of the Panama Canal, lock chambers, passing bays and container berths; those were the hardest parts for existing port operators to conquer. Actually, the depth limitations could be regarded as one of the most important differences between terminals. From then on, different container terminals were chosen by liner carriers as hubs or feeder ports based on the natural advantages and prospective berth handling technology.

Nowadays, even mega ships with well over 8000 TEU capacity, called the sixth generation, are not “newly born babies” in the shipping industry. Liner companies tempt to deploy more mega ships in their fleets, though there is a common sense that merchant fleets should not be deployed by, e.g., only huge or only newly built ships. This tendency also strongly pushes container terminal operators to catch up the pace of bigger vessels, apply advanced technology and accomplish better management information systems. It should be noted that some authors see a possible risk in going beyond 8000 TEU (see, e.g., Müller and Schönknecht, 2005) although the currently planned extension of the Panama Canal might render these calculations obsolete. Moreover, one can find the opinion that freight rates of containerized cargo, namely Freight of All Kind (FAK), are not related to the ship type (Shi, 2000). However, the bigger and faster the vessels are, the more efficient they seem to be and the more likely it is to achieve economies of scale.

Regarding fleet composition liner companies build up their fleets and deploy types of ships (e.g., with respect to size) on purpose. Due to the similarity between liner shipping and airline service, problems and solutions of container fleet composition refer to those of aircrafts; see, e.g., Listes and Dekker (2005) and Adrangi et al. (1999). The problem for container terminal operators is to attract those types of vessels in the fleets which best match their port performance and obtain higher efficiency. In other words, one attempts to fractionise the target markets instead of paying attention to all types of ships.

It should be noted that international shipping is an international trade and globalization born service. Quality and price differentiation make the international goods exchange necessary, meanwhile the trans-ocean lanes make it possible. There are three major long distance lanes: the transpacific lane, the transatlantic lane and the Far East-Europe lane. Those ports located along those three main trade lanes with enough depth have a considerable competitive advantage as they gain higher possibilities to be potential hubs. Other ports have to try every effort to compete by cost leadership, service differentiation, etc.

2.2 History and Trend of the Liner Shipping Industry

The history of liner shipping conferences goes back about 130 years (see, e.g., Wang and Zeng, 1997) since the first conference was set up in 1875. In an attempt to protect carriers in the conferences from the new steam ships serving trades to India and the Far East, the traditional liner shipping companies established cartels to control the important trades between these regions. Under the liner conferences system, which has long been an established feature of the shipping industry, a group of ship-owners of one or several nationalities serve a group of ports on a given route (Branch, 1982). When there were around 150 liner shipping conferences covering all trading routes around the world, the principle of protecting members in the conferences from new competitors remained. Despite opposition from the shippers exemption was granted from competition rules under the Treaty of Rome based on which the conference system yielded the benefits for their customers.

From the late 1980s liner shipping conferences were no longer fully responsive to customers' needs (Yoshida et al., 2001) (referring to, e.g., agility in supply chain management and cost reductions) due to the following factors: barriers to trade freedom, inflation on shipping prices, threats of shipping services and monopolization in price fixing. The liner carriers were trying to meet customer's needs by designing logistics solutions. From a shipper's point of view conferences and the legal protection were seen as antiquated impediments to rational business governed by market forces. Furthermore, the industry suffered from overcapacity on many major lanes. At the beginning of the 1990s, new kinds of vessel sharing arrangements were driven by overcapacity and customer service. It was a less risky way of entering new lanes, increasing the number of sailings and providing wider range of services while reducing overcapacity. At that time, freight forwarders and ocean liner conferences were the ones most affected by vessel sharing arrangements; the more capacity in line with demand, the less need for conferences.

Strategic alliances in the liner shipping area have grown so dramatically in recent years that they have received a great deal of attention from researchers. For instance, the liner fleet planning and scheduling problem was treated by Xie et al. (2000). A more comprehensive literature review is provided by Christiansen et al. (2004). Ryoo and Thanopoulou (1999) suggest liner alliances in the globalization era as an important strategic tool and Song and Panayides (2002) regard members in alliances as game players from a game theoretic point of view. The definition of alliances in a broader context, however, is not as uniform as it is in the area of liner shipping. A liner shipping strategic alliance is a group of liners with a specific agreement to share vessel space and improve service efficiency. Consortia represent operational, technical or commercial agreements between different sea carriers to pool some or all of their activities on particular trade routes (PC, 2004).

However, "alliances represent agreements between carriers to cooperate on a global basis" (Czerny and Mitusch, 2005). That is, the scope and extent of those two kinds of cooperations are different.

Over time alliances between ocean carriers were nothing new by 1995. What had accelerated in the early 1990s was an expansion of those alliances to cover almost all major trade lanes. Although the number of such pacts was small, they involved some of the world's most dominant container ship operators. The goal of alliances is to become more efficient with lower cost. On the one hand, liner carriers are prepared to accept and implement new arrangements, which would reduce their operational costs and provide service offerings at a small extra cost. On the other hand, shippers welcome benefits like the increased sailing frequency.

The name of alliances	**Members**
Grand Alliance	Hapag-Lloyd, NYK Line, NOL, P&O
Global Alliance	MOL, Nedlloyd, OOCL, APL(NOL), MISC
CKY	COSCO, K-Line, YangMing
United Alliance	Hanjin, DSR-Senetor, Cho Yang
Maersk Sealand	
Evergreen	

Table 2: Liner shipping alliances in 1995-1996 (Source: from www.snet.com.cn)

Table 2 shows the original position of liner shipping alliances around 1995-1996. P&O and Nedlloyd merged in January 1997 while APL merged with NOL in November 1997 which showed the combined membership from different alliances (Grand Alliance and Global Alliance). That is, the membership of liner alliances changed as well as their names. For instance, since 1998 the Global Alliance was called 'The New World Alliance' (TNWA).

The name of alliances	**Members**
Grand Alliance	Hapag-Lloyd, NYK Line, P&O Nedlloyd, MISC, OOCL
TNWA	MOL, APL, HMM
CKYH	COSCO, K-Line, YangMing, Hanjin
United Alliance	Hanjin, DSR-Senator, ChoYang
Maersk Sealand	
Evergreen	

Table 3: Liner shipping alliances in 1998-2001

Table 3 presents the relatively stable position of liner shipping alliances around 1998-2001. The Grand Alliance, consisting of Hapag-Lloyd, NYK Line, Orient Overseas Container Line (OOCL) and P&O Nedlloyd, has merged its services with those of CP Ships-owned carriers Lykes Lines and TMM Lines. Similarly, between Maersk Sealand and TNWA carriers like APL, Hyundai Merchant Marine (HMM) and Mitsui OSK Lines (MOL) combined their transatlantic services in 2000.

Approximately three to five years later, the liner shipping market reshuffled to a great extent. Maersk Sealand announced that it annexed P&O Nedlloyd ranked 3rd in May 2005. Meanwhile, China Shipping Container Line (CSCL), ranked 8th in terms of capacity in April 2005, was acquiring Canada Pacific ranked 17th at that time. However, Canada Pacific was finally bought by Hapag-Lloyd in August 2005 (Brent, 2005). These business activities show some turbulence and the resulting situation can be summarized in Table 4. On one hand, the alliances or mergers between large carriers lead to a further concentration of vessel capacity on the long trade lanes. On the other hand, the increased monopoly power of major carriers would lead to large and sustained slots surplus.

The name of alliances	Members
Grand Alliance	Hapag-Lloyd, CP, NYK Line, ,MISC, OOC L
TNWA	MOL, APL, HMM
CKYH	COSCO, K-Line, YangMing, Hanjin
Maersk Sealand P&O Nedlloyd	
Evergreen	

Table 4: Situation from the end of Year 2005-2007 (Sources: Compiled from www.snet.com.cn and Brent, 2005).

Tables 2-4 can be summarized in Fig. 1. We see that members of alliances are not fixed forever. For example, Nedlloyd originally belonged to the Global Alliance, in about 1998 switched to the Grand Alliance and then in 2005 was purchased by Maersk Sealand. Note that Evergreen, as an independent carrier, maintained its independence from the main alliance groupings for decades since its establishment (Slack et al., 2002).

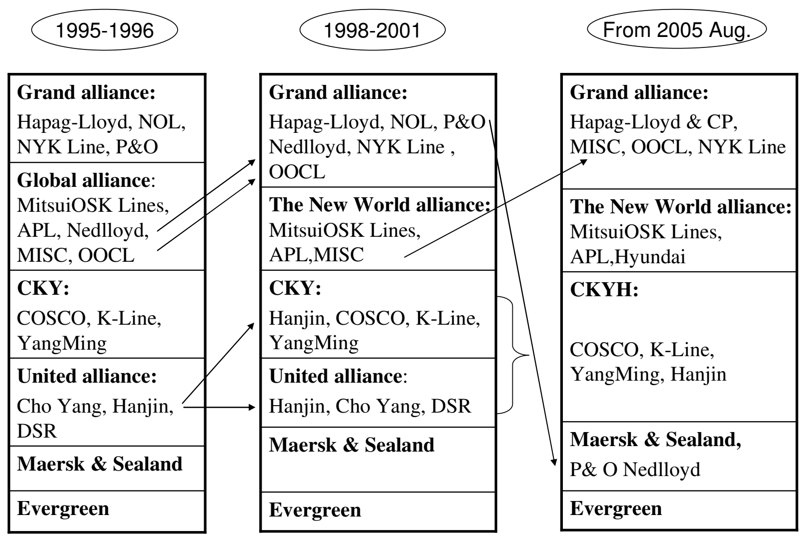

Figure 1: The changing membership in the linear shipping industry

2.3 Motivations for Strategic Liner Shipping Alliances Members to Build Cooperations

For liner shipping alliances as well as liner carriers themselves, the most fundamental motivation may be profit maximization. In order to achieve this goal, there are several ways with the most prominent being revenue exploitation and cost savings. In the sequel we describe ways and outcomes if liner carriers choose to be a member of an alliance.

2.3.1 Revenue Exploitation Aspect

A better transportation network could be achieved when a liner company cooperates with certain partners (Ding and Liang, 2005), which ensure a better transportation service to more coastal ports and inland distribution spots. An increase in revenues may be expected together with a higher customer satisfaction (Doi et al., 2000). The frequency of liner ships' departure could be increased when liner companies cooperate and supply more vessels on the same route. More optional times of departure imply more convenience for forwarder agents and shippers to call upon the shipping service. Agreements and trust among alliance members make common actions such as general rate increases, seal fee collection, etc., much more likely. Those surcharges, just to mention some, could increase freight income.

The bargaining power of suppliers and customers greatly influence the final price of goods or service contracts. Shippers, as the demand side, may face problems regarding shipment, ports, inland transportation as well as ancillary problems (Addico, 2000). Generally speaking, freight rates are negotiated by shippers (or their agents) and carriers (Stewart et al., 2003). To avoid the above mentioned problems, shippers should carefully pursue negotiations. A stronger liner alliance makes it less possible for the shippers to propose varying (e.g., non-profitable loads) and demanding desires when booking slots. Based on Porter's Five Forces Model (Porter 1980, 1991), shippers and forwarder agents have relatively less bargaining power compared to liner carriers regarding negotiations, and prices of the liner services posed by liner carriers are more accepted by shippers rather than shippers controlling the transportation prices themselves. For a discussion of competition policy and pricing see, e.g., Brooks et al. (2005).

2.3.2 Cost Savings Aspect

As the most important part of the total cost of ownership of liner carriers, fixed costs could be sharply decreased if a liner company cooperates with others when necessary. Carriers enter operational relationships to increase their service offerings and, at the same time, to reduce their costs (Sheppard and Seidman, 2001). Liner companies would share vessels and slots with each other to meet the sharply increasing freight desire without too large investments to build new vessels or buy second-hand ships, or even other kinds of ships and then modify them to carry containerized goods, as what had already happened to combined ships (Douet, 1999). Moreover, 'flagging out' is also an adopted means to cut down the total operation cost (Li and Wonham, 1999, Veenstra and Bergantino, 2000). Privatization or part privatization of state-owned carrier firms could be a possible way, too (Roe, 1999). For a detailed and comprehensive quantitive analysis of investments see Veenstra (1999), Goss and Marlow (1997) and Mc Williams et al. (1995).

Electronic Data Interchange (EDI) and related information sharing of course saves companies' cost. There is a trend in key-organizational relationships in the community going along with the emergence of E-Business (Martin and Thomas, 2001). EDI offers economic and strategic advances and can be regarded as an advanced tool for modern logistics (Lee et al., 2000). Moreover, more efficient handling and stowage could also result in the ability of handling a considerably larger amount of freight in the same amount of time under the restriction of limited resources (Ambrosino et al., 2004, Steenken et al., 2004). To minimize the total time of stay at port of a vessel, an optimized container stowage planning is, without any doubt, necessary, which calculates the suitable placement of containers in a container-ship (Wilson and Roach, 2000, Steenken et al., 2004). Here we may consider, e.g., space restrictions at many major ports that do not allow for considerable expansion of terminals in many ports worldwide. This may include automatization processes with highly qualified back-office personal instead of low cost workers for manual handling processes. Furthermore, more and more shipping carriers are willing to share pertinent data with port operator companies. It could save not only the shipping companies' cost but also the operator companies' cost.

Besides information sharing among shipping carriers and port operators, members in alliances sometimes share their port operation services as well. They share the same authorities and rights of fast handling to save total waiting and handling time when container vessels visit ports. A stronger liner alliance pushes port operators towards re-thinking and re-judging the bargaining power of the liner carrier companies as they are very important customers. Actually, successfully attracting one liner company does not mean its other cooperators in the alliance would come to visit the port as well, while loosing one liner company may lead to a worse situation of loosing all the liner companies in this alliance as customers. This is one of the reasons why port operators pay lots of attention to the influence of shipping alliances.

Till now, as sketched in Fig. 2, we have discussed two main aspects which motivate liner shipping companies to set up short-run cooperations and long-run alliances (see also Shi and Voß (2006)), including revenue exploitation and cost savings as mentioned above. Especially service sharing and bargaining power are related to port operations. Liner companies (sometimes on behalf of shippers) set forth their desires of vessel visiting, cargo handling, short-time storage and logistics services (Steenken et al., 2004), while port operators undertake great efforts to provide timely and agile services. It is significant for port operators to predict trends of container transportation and analyse the influence of shipping alliances advertently.

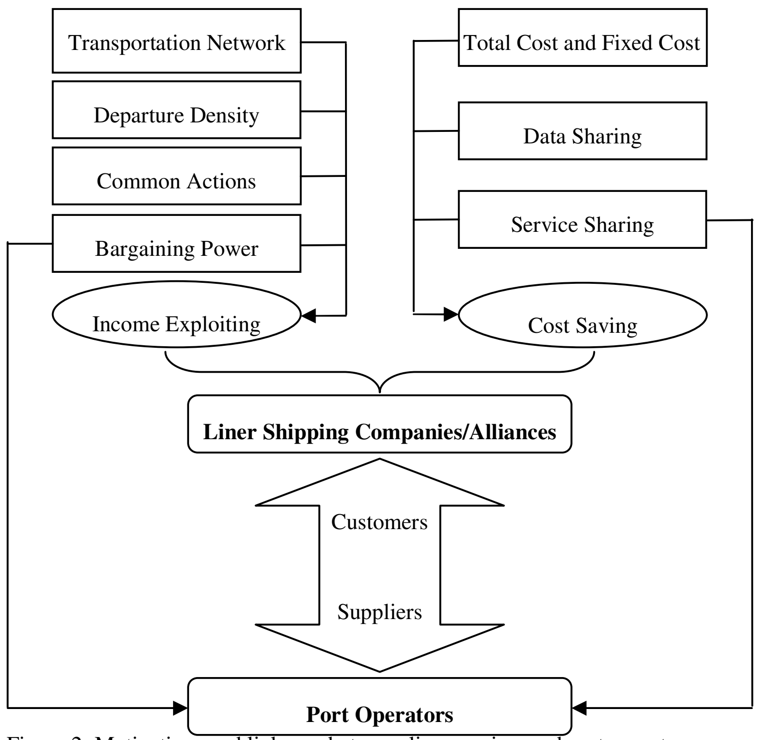

Figure 2: Motivations and linkages between liner carriers and port operators

2.4 Resistance to the Strategic Liner Shipping Alliances

Forming an alliance can definitely offer various benefits but at the same time contain some drawbacks due to turbulence, unpredictable circumstances and various objectives (Song and Panayides, 2002). Moreover, risk considerations are of utmost importance (see, e.g., MacDonald, 2004).

First, overcapacity is blamed for the poor financial performance and economic inefficiency over the long-term history of the liner shipping industry (Yoshida et al., 2001). Some liner carriers differentiate themselves in terms of services offered, low freight price (e.g., China Shipping and MSC) or high quality service (e.g., Maersk Sealand). Integrating these different kinds of liners too tightly into an alliance with the corresponding requirement for "seamlessness" may pose problems. In alliances there is still much uncertainty and ambiguity. Sheppard and

Seidman (2001) discuss that liner carriers prefer to gain the benefits without having to ally on or to merge with other carriers. Therefore, the real long-term goal of large carriers is to improve their own service offerings, regardless of whether the improvement is through an alliance or a merger. Furthermore, a series of cross-alliance mergers and acquisitions had forced the alliances to restructure and/or modify their partner base (see above as well as Midoro and Pitto, 2000). Based on this one may conclude that relationships between partners are hard to predict; today's partners may be tomorrow's rivals (Kleymann and Seristo, 2001).

Second, even if a liner shipping company becomes a member of an alliance, it might not behave or share the profit as fair as it is supposed to be. There are possible factors that make the relationship among members in an alliance "unfair," which later could lead to some turbulence of the membership and the alliance itself. Podolny and Morton (1999) examine whether the social status of an entrant owner impacts the predation behaviour of the incumbent cartels. They show that so-called high social status entrants are significantly less likely (40%) to be preyed upon than low social status entrants. Social status could be regarded as one of those factors which resist the development of liner shipping alliances.

Third, the United States Government still regarded shipping lines as a "controlled-carrier" under the Ocean Shipping Reform Act 1999 (Rimmer and Comtois, 2002). As a result, state-owned liner companies have to give their 30 days notice of any changes in freight rates, while other private-owned liner companies also have to provide a 24 hours notice to the American Communication Administration. This is a means of the American government to prevent or reduce monopoly in the shipping industry. Their aim is to build up free and fair market structures all around the world.

Not only the USA but also some European countries claim the anti-cartel authorities to decrease the possibility of cartels, conferences, alliances and other kinds of monopoly. As reported by the OECD "the liner industry is no different than other global industries and, therefore, they require no special protection or privileges particularly in the area of setting prices" (ESC, 2004). In other words, liner conferences are not welcome in the shipping industry if one considers shippers' requirements and governments' regulations. Then, as the successors of liner conferences, consortia and alliances are still under the threat of being challenged by anti-cartel or anti-trust regulations, the existing liner shipping structure would change if those kinds of regulations take effect as strongly as they are expected.

No matter whether there are liner alliances or only independent carriers (suppose the alliances come to an end under anti-cartel regulations) in the liner shipping industry, port operators follow what the carriers and shippers demand. It seems that there are no explicit links between anti-cartel regulations and port operations. However, if we take into account the behavioural differences of liner conferences, alliances, consortia and independent carriers, there is an indirect effect, which even comes from regulations, on port operators. Usually members of liner conferences want to earn as much revenue as possible by fixing the freight price (ESC, 2004) together with a considerable bargaining power when negotiating with port operators, which let port operators always try hard to cut down the handling costs (labour and operational). If liner shipping structures would be destroyed by anti-cartel regulations, alliances and consortia turn to be individual carriers who should attract shippers not only by cost leadership but also service differentiations. Then port operators switch to provide specific and agile handling services to carriers and shippers instead of only low handling charges.

However, if anti-cartel or anti-trust regulations do not take effect, there would be great threats and challenges to the existing port operators because liner alliances and consortia tend to be much more powerful without barriers of the regulations. Those top liner corporations would like to enlarge their berth investment and maybe even build large dedicated ports all around the world, which make the regional port operation competition much fiercer compared to the current situation. To summarize, port operators should pay attention to those "indirect" regulations as well.

3 Linkage Between Liner Shipping Carriers and Container Terminal Operators

Vessel types, port handling methods and cargo characteristics are three vital factors which affect the freight rate and market trend a lot. Those factors even affect each other revealing that port operator company's decision makers should be conscious of both of the other two sides simultaneously. Fig. 3 shows the triangle connection of carriers, operators and shippers, which could be a more comprehensive explanation. Based on this figure, we attempt to deepen our discussion by ordering shipper/cargo, carrier/vessel and operator/handling processes.

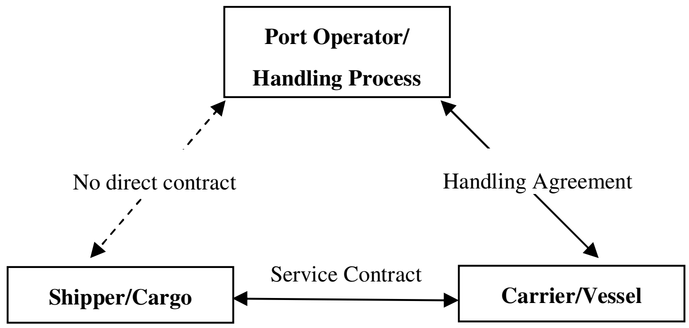

Figure 3: Triangle connection within the shipping industry

The shipper charges the cargo transportation fee and puts forward the transportation desire, too. There is an explicit contract between the shipper and the carrier, namely a service contract, which is always represented as bill of lading (B/L). From the aspect of maritime law, the B/L should not be called service contract itself (Si, 2005), but it is an important certificate of a liner service contract, which notes and defines the port of origin, port of discharge, place of delivery, vessel name, voyage number, cargo description, seal and container number, service type (CY-CY, CFS-CFS, Door-Door, etc.), insurance, risk allocation, payment method (prepaid or collect) and sometimes the freight rate, too. Among those, service types and handling processes force container terminal operators to think about an optimal utilization of their instruments and resources.

Even if there is no direct contract between the shipper and the port operators, the shipper informs about his desire regarding a service contract, which is between him and the carrier. Then the carrier signs the handling agreement with the port operator, which means that there is at least an indirect linkage between shipper and port operator. Meanwhile, the handling processes may still be affected by cargo characteristics, such as bulk cargo, chemical cargo, liquid cargo and liquefied gases, etc. Different cargo may require totally different transportation needs and handling processes. For instance, the transportation and handling of oil products are related to local and regional supply/demand imbalances, refinery inputs, outputs and utilization rates, storage considerations, product quality differences, price differentiation, seasonal variations, and port traffic, etc. (Yamaguchi, 1999). Even if we focus on container terminal operations, there are many different kinds of containers which contain a variety of goods, such as normal dry container, hang container, flat container, high cube, open-top container, reefer container and dangerous cargo container, etc.

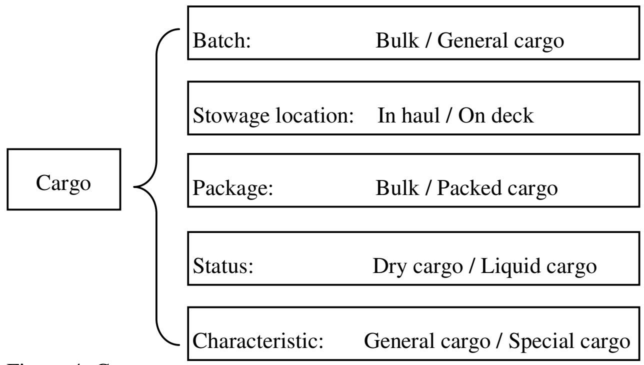

Figure 4: Cargo types

Among the cargo types mentioned in Fig. 4, dry and packed cargo, especially if it is clean cargo, would be the most normal one transported by container carriers. Some containerised bulk, such as rice and corn, could also be suitable to be containerised. Furthermore, fresh cargo needs to be transported in reefer containers, which need special locations with respective equipment. As mentioned by Steenken et al. (2004), dangerous cargo in containers is not a frequent issue in every port, and it is more demanding with respect to the temperature control, pressure check-up, manifest location etc. To be an efficient berth providing satisfactory handling and short-time storage, the terminal operator should first choose its target customers, especially if it does not get enough investment to develop plugs and special yard equipment. Even if it is possible to manage special cargo handling, operational managers still need to estimate and analyse when demanding cargo is going to visit and be handled. Briefly, the linkage between carriers and port operators does not only rely on the carriers' vessel, but also on specific transportation desires promoted by shippers and cargos.

The number of ports that a fleet visits depends on the length of trade routes together with the number of vessels in the fleet. Because of the trend of VLCS, the price of new ships increases accordingly which pushes the liner companies to strive towards reducing the number of vessels in a fleet if possible (Yang, 2004). Based on that, the time period of round voyage is shortened to ensure periodical (say, weekly) services with reduced number of vessels; the number of port callings decreases, however, the lifts per call increase (Yang, 2004). It is certainly desirable for a port to become one of those reduced from the alliance's former calling of ports, which leads, to a great extent, to revenue decrease, too. This is seen as a major linkage between the trend of liner carriers and the future of port operators. In other words, this is why port operators concern so much about terminal operations under the influence of shipping alliances.

4 Container Terminal Operators: Behaviours and Trends

Considering the history of port operations, different development stages can be observed; see Table 4. Before the 1950s, ports were acting as centres of transshipment and delivery, also including the storage of cargo. During the 1950s up to the 1980s, ports provided more functions, such as value added service and commodity export and import clearance, which let the shippers and carriers feel more convenient. Since the 1980s, ports more and more act as distribution centres in the whole logistics network while, at the same time, also serving as information platform.

Generation 1	**Before the 1950s**	**Centre of transshipment, delivery, short time storage**
Generation 2	1950s-1980s	Centre of services, value added function, commodity area
Generation 3	After the 1980s	Centre of logistics, distribution and information

Table 4: Port operations development

It should be noted that storage is always a function of utmost importance. However, in order to increase berth efficiency, storage functionality should only be available for short term storage. For long term storage it seems advantageous for containers to be delivered to special container yards or container freight stations.

The role of ports exceeds the simple function of services to ships and cargo. Apart from their role as the traditional sea/land interface, ports are a good location for value-added logistics, in which members of different channels can interact (Bichou and Gray, 2004). Besides acting as centres of transshipment and services (Generations 1 and 2 in Table 4), the ports of the third generation also act as dynamic nodes in international production and distribution networks (Carbone and Martino, 2003). Furthermore, the separation of responsibility for infrastructure and services and the transfer of regulatory power from landlord ports to independent regulatory authorities are what European and world ports face currently or will face in the near future (Farrell, 2001). Nevertheless, how far a port can develop not only relates to the regulations it take and the ambition of its decision maker, but also depends on the following factors: port tradition and organization, port accessibility, state aids, port productivity, port selection preferences of carriers and shippers, comparative locational advantage (Fleming and Baird, 1999).

After analysing the existing container terminal operators' behaviours (see Table 4), a brief summary of the cooperations is given. Vertical cooperation with liner companies, horizontal cooperation with other top-standard port operators and other possibilities with 3PL or 4PL are all of great importance, recently. Actually, the liner shipping strategic alliances consist of liner shipping companies; similarly, horizontal cooperations consist of port and terminal operators, such as, e.g., Hutchinson Port Holdings and PSA (Port of Singapore Authority). Then there are similarities between those two kinds of cooperations, say, shipping alliances and port operators' cooperation: both of them are set up among those who provide nearly the same services; members all have relatively large capitals to manage; members are partners, to some extent, and competitors as well.

4.1 Vertical Cooperations

We define vertical cooperations as cooperations with other players in a supply chain, e.g., shippers, carriers, freight forwarders, vessel maintenance, etc. In the sequel, advantages that could be gained from vertical cooperations are listed and explained.

Decrease the total service time and waiting time in port

When port operators cooperate with carriers with respect to the sharing of data, e.g. through EDI, and information system integration, remarkable time and cost saving could be expected. For a more detailed and comprehensive literature review see Steenken et al. (2004) whose survey focuses on optimization of port operation processes. Note that there may be arguments why mega ships should choose longer routes and visit highly efficient ports in order to save total service time in ports and waiting time in anchorage grounds (Xu, 1996).

Compete with carriers on bargaining power

On one hand, the more members an alliance has, or the bigger its fleet is, the stronger oligopolistic economic power and competitive advantages it has when negotiating with port operators (Panayides and Cullinane, 2002). Port operators are supposed to accept and offer a lower wholesale price rather than a higher retail handling price; port operators, as any company in general, do not only concern the short-term profits but also long-term profits. That is, their objective is net present value maximization (Kamien and Schwartz, 1971).

On the other hand, we could also view terminal operations as the centre of the Five Forces Model. Certainly this could lead to another competitive structure. But those structures should be interrelated and useful for both, the terminal operators and liner alliances. Based on the above discussion, if port operators cooperate with liners and set up a vertical cooperation, which could be a better means to apply common profits instead of contradictory bargaining powers, then both, liner companies and terminal operators, could obtain a ‘win-win’ result (see Table 5).

Fixed Costs	**Direct fixed cost**	**Operating cost**	**Labor cost**
			Repair & maintenance cost
			Lubricant storage
			Administration fee
	Indirect fixed cost	Capital cost	Vessels depreciation
			Lending cost loan interests
Variable Costs	Voyage cost		Fuel cost
			Port service cost
			others

Table 5: Cost composition of carriers

When cooperations exist between carriers and port operators, they could sign long-term handling agreements or even port facilities investment and utilization agreements, which benefit both sides. For example, COSCO and HIT set up a new company COSCO-HIT, which is a typical vertical alliance as they combined the carrier-COSCO and its terminal service supplier HIT. Vertical alliances could largely develop international competitive advantages.

Service-oriented district allocation in port

Nowadays, carriers attempt to provide different transportation services to their customers, shippers, booking agents, and cargo owners, including long lane services and short lane shuttling service. Due to the differences between those two services, their service areas should be allocated accordingly in order to reach higher efficiency. Vertical integration between global carriers and terminal operators is regarded as a good means to achieve better financial power and technical capability (Midoro et al., 2005). For example, mega ships should choose deep, long berths and big container yards. But as for the average handling rate, those shuttling vessels are more demanding. That is, all of the berths should firstly set the oriented target customers and set up their values, versions and missions accordingly. Berths without sufficient depths and without sufficiently large container yards should provide fast handling service to shuttle vessels (for considerations regarding hinterland container terminals see Gronalt et al., 2003). Considering the similarity between the airline industry and the liner shipping industry, we could expect those short lane shuttle services as successful as some of the so-called low-cost carriers in the airlines industry.

Investment in container building and renting

Most of the top liner shipping companies, such as Maersk Sealand, COSCO, CSCL, are stock holders of some container building companies. Liner companies try to reduce cost and achieve stability to defend against the turbulent market by building containers themselves or renting containers from the companies in which they invest. While the capability to defend against the turbulence is an advantage, there are also some disadvantages. The investment and the complex control of container return usually concerns managers of liner companies. Then there may be a good chance for port operators to attract liners by improving empty container renting and returning services. Liner shipping companies, in general, bought a number of containers and provided them to those shippers who do not have containers themselves. Those containers are costly, especially when they could not be returned in time, delaying in some unknown ports due to inefficient management information systems. To solve this problem to some extent, some of the liner shipping companies, e.g. COSCON and CSCL, even invested in container building factories. On the contrary, the liner shipping companies would save lots of capital if they do not need to pay attention to and invest in the container building industry. The limited capital should be used to build new mega ships and enlarge fleets, which might bring larger revenues.

Port operators already have experiences to store and handle empty containers making it more likely and much easier for them to enter the container building and renting sub-industry. Furthermore, experienced storage and handling of full and empty containers make it possible for shippers and carriers to accomplish timely clearance and departure. In short, besides those traditional activities and services (e.g. stores, water, medical aid, telephone service, bunkering, ship waste disposal) (Yahalom, 2002, Vanelslander, 2005), investing in the container building and renting sub-industry might also be a good way for port operators to improve services and attract carriers.

4.2 Horizontal Cooperations

We define horizontal cooperations as those cooperations with other port operators who should actually be competitors and partners at the same time. In other words, two or even more port operators set up a cooperative structure or even invest in a joint company providing handling service, based on regional cooperations or international cooperations, if any.

Regional Cooperations

When comparing the regional cooperations among world top ports and local governments, some similarities can be found and the incentives of regional cooperations deserve discussion as well. In the survey of Slack et al. (2002) there appeared 470 additional ports of call in 1999 compared to 1989, which indicates an intensification of liner service offerings during that decade. As bigger container vessels are launched and being deployed, the constraints of berth depth, considering cross-sections of ULCS, become an utmost factor of being regional hubs. Those ports with enough depth, aiming at becoming regional hubs, are conscious of the importance of distribution networks. They attempt to cooperate with local governments and other ports to ensure fast customs clearing and shuttling services for the feeder lanes. Meanwhile, smaller ports in the same regions welcome this kind of cooperation; otherwise they are loosing future throughput due to their depth limitations. This can be seen as incentive of regional cooperation among local governments, potential hubs and feeder ports.

As an example (from the USA in 1990; Hershberg, 1995) consider the Philadelphia Regional Port Authority (PRPA), which was created between the State and Bucks, Delaware and Philadelphia Counties. The cooperation proved to be a win-win situation which benefited both the city and the port. For the port aspect, its competitive position was greatly improved by the financial support from the city and the affiliation of PRPA and South Jersey Port Corporation under the auspices of Delaware River Port Authority.

Regional cooperations not only exist between a port city and a port authority, but also among a few port operators who originally compete along the same seacoast and its hinterland. For example, in Europe, ports are confronted with a closer integration in the maritime and shipping industry (Heaver et al., 2000). An interesting case happens to be the so-called North Range in Europe. Despite fierce competition between different harbours, e.g., a terminal operator may in fact operate terminals in different ports such as Hamburg and Bremen (Germany). Moreover, there is a controversial discussion whether shares of the HHLA (Hamburger Hafen und Logistik AG) may be sold to regionally close "competitors."

Regional cooperation also happens in the Yangtze River Delta (YRD), mid-east coast of China. Wang and Slack (2004) analyze the competition, cooperation and governance of Shanghai and Ningbo. It is mentioned that the foundation of this cooperation was not enough; lack of good regional port governance, caused by structural problems in administration, was still a burden for larger throughput in YRD.

Realizing the competitive advantages of Shanghai port, Hongkong and Shenzheng port faced the challenges by decreasing throughput (Cullinane et al. 2004). Shenzhen port cooperated with Hong Kong for experienced management skills at the same time. These two ports, certainly with several port operators provide handling services there, set up regional cooperation though they are, as a matter of fact, still competitors to great extent.

Partners of regional cooperation among ports should be carefully selected. As Thorhus and Lindstad (2006) mention, the difficulties in cooperating with other companies are an important factor that let the cooperations finally split. A better and effective way to keep the cooperation in a relative long duration is to choose those potential partners with similar characteristics (Pando et al., 2005), who admit similar business values, visions and missions.

International Cooperations

Although based on the facts of the increase of ports of call together with intensification of visits of hubs, a very different picture of international cooperations is presented compared to the incentive of regional cooperations. For international cooperations, among best practice terminal operators, technology transfer, management skill improvement, risk pooling and profit sharing seem to be reasonable motivations.

PSA engages in mergers and acquisitions and 'globalises' its activities through overseas ownership of port terminals and logistic firms (Rimmer, 1998). In 2004, PSA and SCT (Shanghai Container Terminal Company) gave the port industry a new way of international cooperation by holding stocks of each other instead of cash investment, take over or merger and acquisitions. As shown in Fig. 5, the stock exchange ensures that both partners jointly share the profits and benefits in the recently opened Shanghai Yangshan port (cf. www.nanfangdaily.com).

From SCT's perspective, cooperation with PSA provides a good chance to learn advanced management skills of top standard terminal operations, and newly invented technology. From PSA's perspective, investing in SCT ensures better profits in the future no matter whether Singapore or Shanghai becomes the regional mega hub along the Asian coast.

A crucial foundation to any type of cooperation mentioned above, such as vertical or horizontal, regional or international, are advanced management information systems and appropriate system integration.

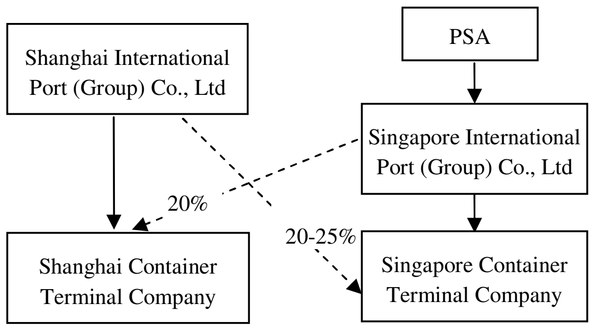

Figure 5: SCT & PSA – cooperation

4.3 Technology Progress of Port Handling Processes

Outstanding hinterland linkages, super multimodal networks, well structured distribution centres are those usually mentioned points, which would make port performance more efficient. Based on the existence of a great variety of newly developed technologies, advanced port operators might be eager to apply newly invented technologies as was the case with any type of innovation (see, e.g., (Suh and Lee, 1998, Voß and Böse, 2000, Steenken et al., 2004). APEC, as the largest regional economic cooperation organization in the world, formed by 18 members in Asia and the Pacific Region, proposes its members to access and harness latest transportation technologies (Sun and Zhang, 2000). Although it takes time and risk the outcome may be attractive. For instance, HHLA has experienced benefits while investing in double rail mounted gantry cranes for efficient yard handling and is going to advance on this when restructuring further. Ningbo Beilun Container Port has kept testing (semi-) automated double rail mounted gantry cranes since April 2005. Recently, Shanghai Waigaoqiao port made a successful trial to accomplish automated crane handling without on-the-spot labour; all moves are controlled from a backoffice located two kilometres away (http://www.sjtu.edu.cn/newsnet/newsdisplay.php?id=9457, access date 20th Sep., 2006). Brisbane (Australia) is experiencing a fully automated straddle carrier system (http://www.kalmarind.com/show.php?id=1041368, access date 08th Jan., 2007).

Last but not least, without doubt port operators should develop management information systems themselves or outsource and cooperate with professional software and IT-Services providers. Information technology beyond EDI is still seen as the great battleground not just among carriers, but also forwarders, logistics based integrators and, potentially, pure technology companies (see, e.g., Hans, 2001, www.dakosy.de). Most importantly, port operators always face unscheduled incidents beyond any schedule, either by preventive or by reactive strategies. In this case, advanced management information systems (see, e.g., O'Brian, 2002) should be useful.

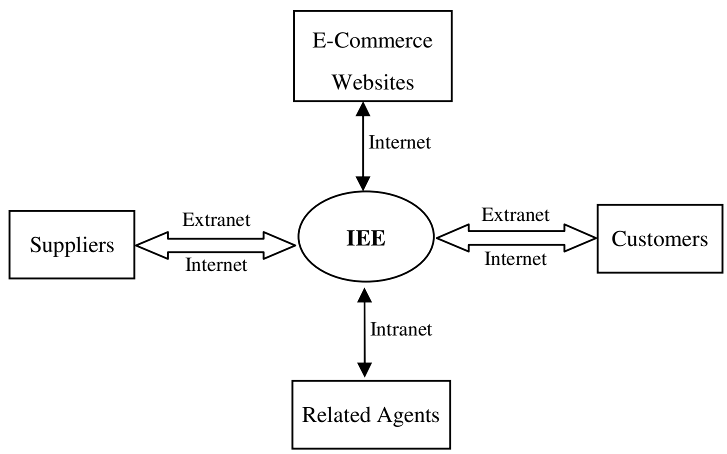

Figure 6: Internet worked e-Business enterprises (IEE)

Setting an information system shared with customers (in this case, carriers, shippers, customs, forwarders and so on) does not mean that they have the same authorities. Networks should distinguish intranet, extranet and internet to make the information and business efficient and secure (see Fig. 6). For instance, the carrier could authorise his forwarder or freight agents by digital signature to issue a B/L on behalf of the carrier himself; customs, carriers and port operators share cargo status and container/seal numbers, etc.

4.4 Possible Restructuring of Transportation Services

A successful port operator, like a successful player in a business game, must be well prepared to constantly both meet the existing desires and adopt the coming new roles in order to cope with the changing market environment (Notteboom and Winkelmans, 2001). Attention has to be paid to the competition of the port in new environments in restructured markets (Heaver et al., 2000) including end-to-end services, pendulum visit lanes (Notteboom, 2005), and hub-feeder/spoke networks

(Hayuth and Fleming, 1994). A proper integration of any player in shipping and port economics needs to cope with the recent challenges in globalization and supply chain management (see, e.g., Wang and Cullinane, 2006). As mentioned by McCalla et al. (2005), it is the growth of transshipment that drives the most important developments in port traffic and facilitates the selection of hub ports. It is even speculated that more and more ports could lose existing positions as hub ports until finally only very few mega hubs survive (Payer, 1999 and De Monie, 2001, Baird, 2005).

5 Conclusions

Shippers are discovering that in today's ever-changing liner industry, the question is not where your cargo is but who is carrying it. Furthermore, the carriers are paying more attention to who the port operator is together with the location of the port. As a result, port operators should take into account those shippers and carriers desires, improve their handling services by vertical and horizontal cooperations to increase customers' satisfactions and loyalties as much as possible by means of re-structuring their service processes, management information systems, etc. Based on related background that we have provided in this paper our exposition may also be seen as a research outline when discussing the shipping industry as well as port economics. One of the further research directions could be the social status' effect on the cooperation among the port operators. Similar to the effects on shipping alliances this factor could affect the relationship, negotiation, development of port cooperations as well. While this paper cannot be comprehensive to touch all possible issues in-depth, we strongly believe that the thoughts as well as the pointers to appropriate literatures and the references therein can serve as helpful entry into this field of research with important real-world implications.

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THE IMPACT OF THE PANAMA CANAL EXPANSION ON LINER FLEET DEPLOYMENT AND OPERATION—A NEW AGENDA

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ABSTRACT

From the first utilization of the Panama Canal in the late 1910s, it plays a significant role not only in world trade but also in the shipping industry and its progress regarding containerization. With the technical innovation and development of ship building, larger and larger ships are built and deployed in the shipping markets, also resulting in fierce competition and demanding requirements. The decision to expand the Panama Canal would, to great extent, re-shuffle the situation and enhance the competition of the shipping industry.

Decision makers of any liner fleets need to survey and evaluate the re-structuring of fleet composition by booking different types of ships step by step with ship building companies, organizing capital and chartering or buying second-hand ships, re-setting the liner fleet deployment, negotiating with authority on ship operations so on and so forth.

Based on the existing literatures we attempt to focus on the impact of the expansion of the Panama Canal on global container fleets taking into account the turbulent circumstance. Furthermore, container vessels deployment and liner fleets operations deserve worldwide attention from aspects of both academic researchers and business practitioners. The theoretical framework as well as the empirical outcome of this paper provides advice to decision makers of liner fleets and be of usage and interest to others who are involved in the shipping industry as well.

Keywords: the Panama Canal, Fleet, Liner, Containerization

1. INTRODUCTION

The boom in globalization raises up the international shipping, while the international shipping, in turn, helps to accomplish the trade activities. Therefore, the liner fleets are becoming more and more important since they transport the sharply increased inbound and outbound trades. Furthermore, regarding the policy and regulations of multi-lateral trade and transportation, e.g., cabotage limitation, each fleet competes and cooperates with other fleets all around the world in the same way as all the other top liners do. Based on this, decision makers of any liner fleets need to survey and evaluate the re-structuring of the fleet composition by booking different types of ships step by step with ship building companies, organizing capital and chartering or buying second-hand ships, re-setting the service networks, negotiating with port operators, etc.

This paper considers the impacts of the Panama Canal expansion, which is an effective means to conquer congestion experienced by those vessels passing through there. In particular, shortening transiting time and quickening planning process of the Panama Canal would be appreciated by the liner carriers taking into account factors like vessels deployment as well as fleet composition and competition among rivals.

In the late 1990s, the original expansion program regarding the Panama Canal was slated for completion in 18 to 20 years (1). Later in an invited speech of IAME2002, Vasquez mentioned that a major shift to the frontier should be the result of a major expansion in plant and channel capacity of the Panama Canal (2). Furthermore, it has recently been promoted to shorten completion by around 2010. Once the expansion of the Panama Canal is accomplished, the cargo-handling operation might undergo revolutionary changes in the near future due to the deployment of bigger vessels and the liner's desire of speedy loading/discharging during their stay in the ports of call.

The through capacity of the Panama Canal is mostly occupied by the increasing commodity trade between Asia and America, with China playing a pivotal role as goods manufactured in China are delivered to America as well as to other parts of the world increasingly (3). Since the trade between China and America would keep increasing in the near future, the expansion of the Panama Canal will greatly affect the sea borne transportation by means of enlarging quantity per shipment, saving unit cost, shortening transit time, etc., and later affect the trade value of cargos accordingly.

As for the main liner carriers of this route, including Asian liners and American liners who compete and cooperate at the same time, to some extent, should pay attention to the trend and make decisions both for the short run and for the long run.

It should be noted that, besides the liner shipping that we mainly discuss in this paper, the expansion of the Panama Canal could have a dramatic impact on dry bulk trade carried by Capesize and Panamax bulk vessels as well (4) though the tramp shipping is not yet included in this paper. Some other relevant issues such as the administration reforms and operation management of the Panama Canal (5), despite of great importance as well, are not main points of this paper either.

Once the expansion of the Panama Canal is accomplished, the cargo-handling operation might undergo revolutionary changes in the near future due to deployment of bigger vessels and desire of speedy

loading and discharging. In late 1990s, the original expansion program was slated for completion in 18 to 20 years (1), but has recently been reduced for completion by 2015.
As mentioned in a speech of IAME2002, a major shift to the frontier should be the result of a major expansion in plant and channel capacity of Panama Canal (2). As for main liner carriers who compete and cooperate at the same time, to some extent, should pay attention to the trend and make decisions both for the short run and for the long run. Other issues such as the administration reforms and operation management of the Panama Canal (5), though of great importance as well, are not main points of this paper.

2. BACKGROUND

2.1 History of the Panama Canal

In this section we briefly introduce the history of the Panama Canal and the capacity limitation of it, and the new issues arising from the Panama Canal expansion are illustrated.

Before using the Panama Canal, more than two months were required to sail from California to New York by way of Cape Horn. Completion of a canal would reduce that voyage by 8,000 miles (6). At the moment that the Panama Canal was designed and built, there was a clear military aim kept in mind. That mission was reflected in the design of the Panama Canal, with planners in the early 1900s designing the locks of the Panama Canal with a length and width specifically to accommodate those potential battleships. That meant a canal much larger than required at the moment for commercial vessels, which in turn meant that the life of the Panama Canal was greatly extended, as it could handle ships considerably larger than any of the commercial vessels which existed during its construction (6). As a result, the Panama Canal appeared set to retain its value for almost 85 years long.

The present Panama Canal, providing an important connection between the world's two largest oceans (7), built between 1904 and 1914, is a 'Lock-type' waterway with both economical value and geopolitical significance, where ships are raised by a series of locks to the Canal, 85 ft above the sea-level rather than navigating a sea-level passage from ocean to ocean (8). The 'Lock-type' design turns to be one of the reasons that make the ships wait too long time once attempt to transit it.
Since the opening of the Panama Canal, attention has been given to steamship conferences, freight rates of that route, traffic volume, and related regulations (9).

Later on, since the 1970s the commercial value of the Panama Canal was stressed again. The handover of the Panama Canal took place in 1999, which promoted free trade agreement with the US and the countries concerned. Thus, the shifts of Asian cargoes from west coast to east coast port via the Panama Canal and the Suez Canal routings underscore the problems of inadequate transport capacity. At that moment, the Panama Canal was running at 95% capacity, in other words, it was running almost close to full capacity (10). Concerning the capacity limitation, as we mentioned before, the main constraint is the size of locks, which limits the size of ships that can transit the Panama Canal (4). Thus, the Panama Canal cannot handle the new mega-ships with a beam of 100ft and an overall length of 1,000ft, not even to say the bigger ones. The above mentioned limitation of Panama's throughput could be viewed as an emblematic bottleneck of the globally integrated logistical chain corresponding to the main trade route from East Asia to the East coast of America. In order to boost the trade flows running through the global supply chain and transportation network more efficiently, it is quite necessary to conquer the size limitation of the Panama Canal by means of expansion, which is advocated to be accomplished by 2010, together with further modernisation and its preparation of a master plan to provide the company a road map for the next 20-25 years (2).

Nowadays, the water pilots have complete control of all ships passing through the Panama Canal. They determine which ships get through and when they get through, which makes the advantage and disadvantage coexist. On one hand, the pilot and the authority could control and arrange the schedule from the perspective of safety; however, on the other hand, it also implies the long waiting time where those liner carriers always complain.

2.2 Limitation of the Panama Canal

It should be noted that international shipping is an international trade and globalization borne service. Quality and price differentiation make the international goods exchange necessary, meanwhile the trans-ocean lanes make it possible. There are three major long distance lanes: the transpacific lane, the transatlantic lane and the Far East-Europe lane. With the technical innovation and development of ship building, larger and larger ships are built and deployed in above mentioned shipping lanes, also resulting in fierce competition and demanding requirements.

Over the previous decades, different types of ships are considered by shipping lines (see, 11, 12). While the number of container vessels has increased during the last decade the most significant change has been the increase in vessel size. The following Figure 1 illustrates the trend of ship size during the last four decades.

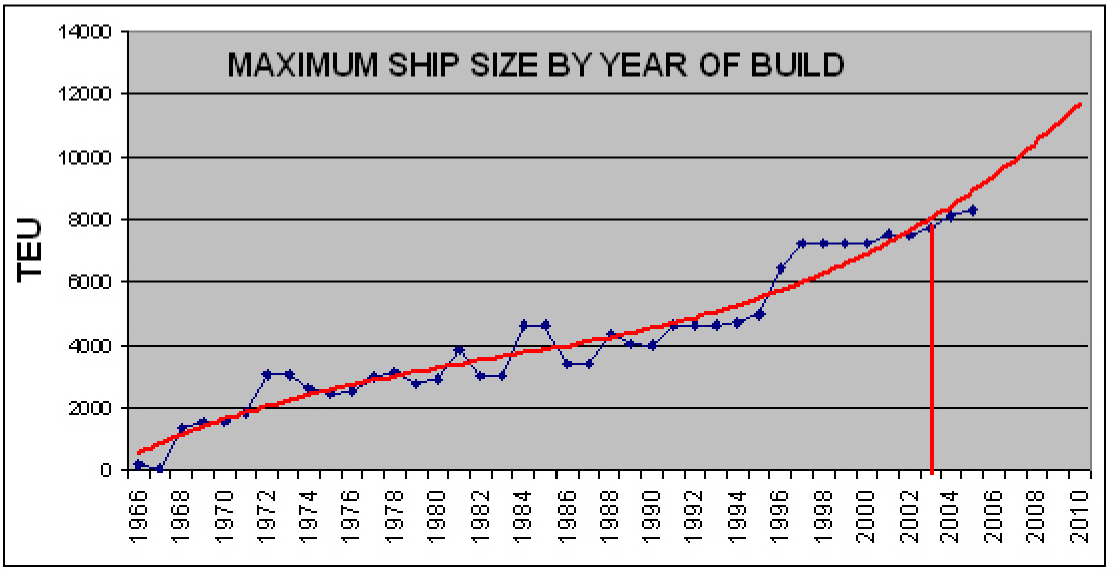

Figure 1: The ship size trend in the last four decades

Source: Shipping World & Shipbuilder, David Tozer, Lloyds Register, available online (13)

Table 1: Generations/classifications of container ships (TEU: Twenty-foot Equivalent Unit)

Generations/Classes	Years	Type of vessels	TEU	Speed (knots) / percentage that speed applied
4th generation	late 1980s to early 1990s	Panamax	4400-5000	23-25
5th generation	1996-1998	Post-Panamax (VLCS)	6400-7200	24-26
6th generation	since 1999	Super-Post-Panamax (VLCS)	7800 and beyond	24-26
7th generation	after 2009	Suez-Max (ULCS)	12500-13000	25-26 expected
		Post-Suez-Max	18000	
		Post-Malacca-Max		

(DWT: Deadweight Tonnage, VLCS/ULCS: Very/Ultra Large Container Ships)

Source: Shi and Voß, 2007 (14).

At least six generations of container vessels, so far, can be distinguished, mainly according to their capacities and voyage speeds; see Table 1. The first generation of container ships was designed to be operated in transatlantic and transpacific routes. The second generation of container ships not only ensured bigger capacity but also shorter voyage time due to increased speed. During the oil crisis in 1973 such fast vessels turned out not to be economical any longer because of their huge consumption of fuel and lubricating oil. In the late 1970s, the third generation of container ships appeared with increased capacity and more economical and efficient market performance.

Until the mid-1980s, the upper limits on the size of cargo ships were determined by the dimensional constraints of the Panama Canal. The dimensional barrier of the Panama locks had constrained the progression of ship sizes to about 4400 TEU, the so-called Panamax limit, until the middle of the 1990s (Slack et al., 2002). The largest ships able to transit the Panama Canal are known as Panamax class, and such ships are characterized by a capacity of approximately 4000-5000 TEU. In terms of another measurement, ships capable of transiting the Panama Canal have a maximum displacement of approximately 70,000 DWT.

Since the 1980s, however, the new built ships (Post-Panamax ships) have been too large to transit the Panama Canal. Already 30% of the world’s fleet, by capacity, belongs to the Post-Panamax class, while 60% of the ships on order are Post-Panamax class as well. Since then the so-called Post-Panamax-vessels began to challenge the depth of the Panama Canal, lock chambers, passing bays and container berths. This trend toward much larger container ships is currently well established and implemented. Currently, judged by the propellers and the layout designs, the largest on-order-ships have capacities of more than 13,000 TEU. However, they are always conventionally announced to be only 10,000 TEU. Actually the freight demands and the advanced engineering capability have been available to construct even larger ships.

Although about 90% of the world’s non-oil trade already moves in containers, the demand for containerization continues to grow, which is derived from two aspects: the containerisation of the remaining 10% and the newly increased freight requirements. Shipping lines have responded by expanding the global container fleet by about 10% per year. The Panama Canal is able to accommodate only a minority of the new ships because most of the new tonnage involves ships with a capacity of 6,000 to 8,000 TEU and beyond.

However, the currently planned expansion of the Panama Canal might render the old calculations on liners' unit cost obsolete by means of letting the so-called Post-Panamax vessels go through the canal to reach better economies of scale. Moreover, one can find the opinion that freight rates of containerized cargo, namely Freight of All Kind (FAK), are not related to the ship type. However, the bigger and faster the vessels are, the more efficient they seem to be and the more likely it is to achieve economies of scale.

At the end of October 2006, about 80% of Panamanians appeared and voted, which later approved a 5 billion US Dollar plan to widen the Panama Canal. The extension is expected to accommodate a new generation of cargo ships, many originating in China, seeking a quick route between the Atlantic and Pacific Ocean (www.cnn.com).

Regarding fleet composition liner companies build up their fleets and deploy types of ships (e.g., with respect to size) on purpose. For more technical details of the different generation of container vessels, readers may refer to (14). It is notable that since the late 1980s, the name of the container vessel generations applies 'Panama' to indicate how big and how different they are from each other, for instance, Panamax, Post-Panamax, etc. Later on, other canals or channels like Suez and Malacca are applied in names too. In short, Panamax could be regarded as the fourth generation, Post-Panamax as the fifth and sixth generation, and Suez-Max/Post-Suez-Max as the seventh generation; meanwhile, Post-Malacca-Max is under design and model testing process which might be regarded as the eighth generation both by practitioners and by researchers in the future.

Regarding generations of the container vessels, it is obviously defined and constrained by the traversing capacity of the canals and channels. Actually those narrow lanes play a positive role of 'short-cut' connections as well as negative role of geographical 'bottle necks'. However, as the Panama government decided to extent the Panama Canal, which shed light on the ship building design from the aspect of technology and would definitely lead to reshuffling of the liner shipping industry from aspect of commerce.

Four of the world's greatest ocean routes that directly affected by the Panama Canal (9) are: the Magellan or Cape Horn route, the South African or Cape Town route, and the Suez Canal route. In addition, the five primary routing factors which operate in favor of the Panama route are: the distance or length of the voyage; the length of time required to reach destination; fuel cost; the relative ease of obtaining profitable cargoes; the absence or presence of transshipment costs (9). Therefore, new issues will arise along the related routes based on routing factors, which are discussed in detail in Section 3.

3. NEW ISSUES ARISING FROM THE PANAMA CANAL EXPANSION

3.1 From the Perspective of the Panama Canal Authority

At the beginning of 2007, the Panama Canal Authority announced a rate increase for passages across by more than 12% per annum until 2010 (14). By 2025, the passage toll could eventually be doubled. The increasing passage tolls might not surprise the players in the shipping industry because they all took into account the following fact: the money is urgently needed to fund the Panama Canal's large-scale capacity expansion scheme. However, based on the mentioned fact, these players could choose how to response and further behave.

The new tolls follow a tapering scale: the highest rate is applied to first 10,000 gross tonnes; the next 10,000 tonnes are less costly and so on. This could be interpreted as a way to decrease transit intension of smaller vessels. Therefore, the transit capacity for bigger vessels could be, to some extent, assured. If the increasing passage toll does not matter too much the shipping lines' operation costs, the shipping lines might not change the existing routes. However, if the increasing passage toll does make great difference regarding operation costs, then the shipping lines might give up the Panama Canal as a connection between two oceans. An alternative could be linking Asia and the US east coast via the Suez Canal and then the Atlantic Ocean.

Based on the literature review mentioned in previous section, the liner fleets of those main players who provide transportation services would definitely obtain bigger container vessels that accommodate the Panama Canal after its expansion. Several main issues then arise, which are worth of researching.

- ways to obtain bigger container vessels or capacities, i.e., build new ships, purchase second-hand vessels or share slots with other carriers
- identifying fixed cost and operational cost once those expected vessels are to be deployed
- Competitive behaviours of other liners as rivals who are facing similar circumstance

Based on classical economics, only the freight transport desires of the player himself are to be calculated and predicted, and the action of next stage would be taken subject to the fleet capacity constraints together with time window constraints on ports. However, regarding the interrelationship among these top liners, the freight transport requirements from competitors' customers would also been predicted comparing with the competitors' fleet constraints: that actually reflects the beauty of game theory. Once the player realizes that his competitors' fleet amplifying plan is much faster than their booking requirements, the following should be thought about: 1) whether the player himself predicts the market in a too conservative way; 2) whether the competitors are too optimistic on the market so that their idol capacity, sometime later, could even be applied by the player by means of slot sharing agreements. As for the player himself, two advantages arise from this tactical method-slot sharing agreements. On one hand, it saves investments on new-built vessels, instead, renting capacity from the other liners. One the other hand, more flexibility and freedom is obtained when the market deteriorates.

As for the negotiation and decision making process of slot sharing agreements, refer to the authors' parallel working paper under this topic.

Regarding the uncertainties and unenclosed information of fixed and operational cost of new vessels, the behaviours of those involved players could be regarded as game under incomplete information circumstance. Comparing to what they faced before, even if the costs of former fleets were definitely kept as the business confidentialities as always, however, their competitors could to great extent define thin intervals of the expected cost of fleets, especially those who compete in the same route, by operating relative long time and checking the released freight rates in non-peak seasons. The lowest freight rates among non-peak seasons, which are quite transparent in the market, could be viewed as approximated amount of fixed cost because that is lowest bound that they would like to still provide services. As we assumed, they could only be viewed as approximated amount of fixed cost of the competitors, hence, they are the ‘common knowledge’.

3.2 From the Perspective of Transportation Demand

Naturally increased transportation demand is depending on the cargo flow between trading zones. Ships transit the Panama Canal to move between the Atlantic and Pacific Oceans. The volume of ship traffic at the Panama Canal is determined largely by world economic conditions and global trade routes between Thus, planned expansion and pricing of the Panama Canal must be considered. If the unit transportation cost is decreasing for the cargo, it might amplify the total cost difference between trading zones, therefore, further motivates more cargo flows. Luo and Grigalunas (2003) (16) investigates and concludes that cargo value as 10,000 $/TEU is a threshold; cargo with lower value than 10,000 $/TEU would use as much water transportation as possible by going through the Panama Canal and using a Gulf Coast port directly, however, cargo with higher value than 10,000 $/TEU has more option to use North Pacific Coast for import and export together with using multi-modal facilities to and from the port. In addition, new technologies are expected to add more value to goods, and the according high-value-added cargo may bear higher transportation cost. Therefore, together with technology innovations, naturally increased transportation demand is promising.

Trade in both goods and services increased at a global scale with China playing a pivotal role as goods manufactured in China are delivered to other parts of the world increasingly (17, 18). Especially the trade between China and America would keep increasing in the near future, which means that the expansion of Panama Canal will greatly affect the sea borne transportation by means of enlarging batch, saving unit cost, shortening transit time, etc., and later affect the trade value of cargos accordingly

Attracting cargo flows originally transported by other modes is depending on the pricing of the Panama Canal as well. For instance, goods from Europe destined for the West Coast, or goods from West Asia being shipped to the US East Coast can use the all-water route through the Panama Canal or be transported by train using the mini-land bridge across the US. The unit cost a certain TEU beard is assumed to be decreased when deploying Super-Post-Panamax containership after the expansion, however, the price of using the Panama Canal is going to be more expansive as announced by the Panama Canal Authority. The route chosen depends upon the total transportation cost charged to a certain container of using all-water route compared with the multi-modal route.

3.3 From the Perspective of Transportation Supply

There are many factors that motivate the shipping lines to amplify their containership fleets. Besides those factors, the expansion of the Panama Canal enables the deployment of mega-containership, which in return further accelerates the shipping lines' booking on mega-containership.

Table 2: Deliveries from 2006 to 2010

Year	TEU	Start 2006 No. ships	Capacity (TEU)	Deliveries No. ships	Capacity (TEU)	End of year No. ships	Capacity (TEU)	Increase
2006	7800+	63	520320	65	564200	128	1084520	108.4%
	total	4194	8695837	343	1325741	4513	9990578	14.9%
2007	7800+	128	1084520	52	452400	180	1536920	41.7%
	total	4513	9990578	472	1454433	4947	11400011	14.1%
2008	7800+	180	1536920	51	463785	231	2000705	30.2%
	total	4947	11400011	353	1440620	5261	12785631	12.2%
2009	7800+	231	2000705	47	441800	278	2442505	22.1%
	total	5261	12785631	256	1153900	5517	13939531	9.0%
2010	7800+	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	total	N/A	N/A	N/A	N/A	N/A	N/A	8.7%

Source: authors' own composition based on Containership Annual Review 2006-2007 and Alphaliner

Furthermore, the decision makers of the liners are concerned about the perturbation even if it actually not often happens, especially when it relates to huge amount of investment, for instance, once the Panama Canal expansion occurs or even since the intension was announced, many related transactions of new built ships and contracts of time charter agreements are to be signed. The supply aspects including ship building yards and sellers of second-hand ships as well as the demand aspects including fleet owners and operators reshuffle the market and price of mega-vessels, e.g. the Post-Panamax container ships, which might make the former assumptions and estimations of fixed costs of competitors inaccurate. Based on that, those former assumptions and estimations are not 'common knowledge' any longer. Then the key point of this situation is that how to transform unclear, incomplete knowledge and information as well as figure out optimized response not only to the perturbation but also to other players' actions.

Taking into account the differentiations of investment strategies, the purchase prices of new ships might differs a lot. Thus, accurate or approximate expectations of fixed costs of competitors may not 'common knowledge' any longer. Below is our knowledge on the indicative fixed cost of deploying mega-container ships, as far as what we are concerned.

As indicated in the above Table 2, the total number of Super-Post-Panamax (7800+ TEU) containership has been 180 at the beginning of 2008. And the fright rate of Asia-Europe route, where most of the Super-Post-Panamax containerships are deployed, decreases sharply to 400-500 US Dollar per TEU. Taking into account the booking order, at the beginning of 2009, the total amount of Super-Post-Panamax will be increasing as 231, which may result in a cut-throat competition. An urgent problem arises: how to improve the load factor of such mega ships.

3.4 From the Perspective of Cost if Using the Panama Canal

The total cost of a mega-container vessel consists of fixed cost and operational cost.
The fixed cost mainly relates to the new-built price, while the operational cost mainly related to the length of the voyage and the Canal Toll, to be discussed in detail, respectively.

3.4.1 Fixed cost of the vessel

The below Table 3 shows the estimated cost of using the Panama Canal

Categories	Value	References
Ship speed	20 mile per hour	Martin Stopford *Maritime Economics* (1997)
Shipping cost	0.09 $ /TEUmile	Cullinane and Khanna (2000)
Rail cost	0.02 $ /TEUmile	USDOT, BTS (1999,2000)
Rail speed	64 mile per hour	Luo and Grigalunas (2003)
Panama Canal speed	1.667 mile per hour	interview
Panama Canal fix cost	10 $ / TEU	Luo and Grigalunas (2003)

Source: Authors' composition based on various references and mainly ()

Table 4: Indicative New-built Prices

	Price	Price/TEU
500 TEU	USD 15 M	30.000
1000 TEU	USD 22 M	22.000
1600 TEU	USD 32 M	20.000
2500 TEU	USD 44 M	17.600
3400 TEU	USD 50 M	14.700
4300 TEU	USD 66 M	15.350
5100 TEU	USD 77 M	15.100
6700 TEU	USD 100 M	14.925
8100 TEU	USD 120 M	14.800

* Prices are for gearless vessel with standard design and 5x20% payments
Source: Howe Robinson (2007)

Getting Super-Post-Panamax containerships can be facilitated by following three manners: new building, Time chartering, and second-hand purchasing (which is not expected in the short run). However, in this paper, we only extract new building as an example for predicting fixed cost.

Try to decrease fuel price and ship price could be options to take advantage of lower-cost. Fuel price could be cleverly controlled by being supplied either in cheaper port among all ports of call, or in those efficient ports if the total operating time in the port is regarded as 'price' too. Port visit price, from the operational level, includes the handling charge for both loaded and empty containers based on the negotiated handling agreements. Note that at the tactical level, the new-built vessel' price and the second-hand-vessel' price interdependent on each other, and most of the time the former is upper-limitation of the latter one. Sometimes exception might also happen if the second-hand vessel is too popular when market boom up quickly. And for the strategic level the total or average unit costs are business confidentialities, which need to be evaluate follow what we discussed in Section X. Meanwhile, the hub location selection and infrastructure investment are, without any doubt, sensitive signals to the market.

3.4.2 Operational cost of the vessel

Panama Canal tolls are assessed on the Panama Canal Universal Measurement System (PC/UMS) Net Tonnage, which is based on the internal volume of the vessel and also hether the vessels is laden or in ballast as determined by the Admeasurer, but the Panama Canal charges small craft by standard fees based on their length overall. In order to pay tolls, directly, one must present the proper Admeasurement clearance and Handline Inspection form. The total deposit fee includes the transit fixed fee and the buffer. The buffer is to be used in case additional charges are incurred during transit. This buffer is refunded if it is not used. The total deposit fee is based on length overall. Compared with data provided by (19, 20), i.e., total deposit fee for ship with length between 80 and 100 m costs 1950$, and that for ship with length longer than 100 m costs 2450 $. We can find that the deposit fee does not increase too much while the vessels turns bigger.

Other related charges are also listed here. Whenever owners or representatives of handling vessels that would normally transit with transit advisors request the assignment of a regular pilot instead, that assignment will be charged at the rate of $2,250.00, if sufficient notification has been provided, as specified on Tariff 1060.0040, or otherwise at the rate of $4,500.00, as specified on Tariff 1060.0045. Whenever handling vessels present some deficiency or condition that prevent the completion of their transit as scheduled, they will be assessed the tariff for transit delay of $440.00 and other related charges, such as launch and moorage.

Whenever owners or representatives of handling vessels request to stop in the Canal interrupting their transit, they will be assessed the tariff for transit delay of $440 and other related charges, such as launch and moorage. However, if a transit is interrupted due to Canal scheduling considerations, these charges will not be applied.

The efficiency of canal operation is measured two ways: ship transits per day and the average Canal Water Time (CWT) of a vessel, which is a time measurement of a vessel from the moment it is ready to transit the canal until it exits canal waters. The canal waters include those areas beyond the canal locks on the Atlantic and Pacific Oceans and include the breakwater or anchorage areas. Once a vessel enters the first set of locks on either side of the Panama Canal, the transit time reaches 9 hours on average. The time waiting to enter the first set of locks increases the CWT (20).

The maximum allowable capacity of the canal is 37 to 42 ship transits per day. Daily ship transits indicate the effectiveness of ship lockage and vessel speed through the canal waters. The benchmark is a 24-hour CWT. A lower CWT gains efficiency, while an increase is a loss in efficiency.

The CWT can fluctuate with increased traffic volumes, larger ships transiting the canal, and mechanical delays operating the locks. But as transit traffic increases, the CWT will most likely continue to increase - pressuring the Panama Canal Authority to expand the canal while maintaining its present system. In order to finance future canal expansion, the Panama Canal Authority may increase tolls or obtain financing through capital loans. In the past, the PCC financed capital improvement projects through toll-generated revenues.

The transit capacity of the canal, under normal operating conditions, is a function of vessel sizes, lock outages, and direction of transits. Panamax vessels increase CWT because they are limited to daylight transits and one-way passage through the Gaillard Cut and take longer to traverse a set of locks. During daylight hours, the number of ship transits ranges from 10 to 15 per day, depending upon ship sizes. Daylight transits make up less than half of the canal's maximum daily capacity. Lock outages and interruptions in the canal also increase CWT.

By 2005, a major capital improvement program to increase capacity, costing nearly $1 billion, was completed, and the sustainable operating capacity increased 20 percent. The program included widening the Gaillard Cut, augmenting the tugboat fleet, adding locomotives, modernizing the vessel traffic management system, converting the miter gates and rising stem valves to hydraulics, and automating the machinery controls.

As traffic at the canal reaches capacity and transit time increases, ship operators and owners consider alternate maritime routes. To keep the canal competitive with other routes, the PCC conducted several studies to expand the canal's capacity beyond just widening the Gaillard Cut. Once the widening is complete, Panamax vessels were able to pass each other throughout the canal waters, although ships of any size and type still will have to wait through the longer lockage times of Panamax vessels.

4. SHIP OPERTAIONS AFTER THE PANAMA CANAL EXPANSION

4.1 Transit Procedures of the Panama Canal

Regarding the expected admeasurements and clearances conducted at the Panama Canal, they can be summarized as follows.

Assuming there is a ship which tends to transit from the Atlantic Ocean and it enters the Panama Canal waters of Limon Bay from the breakwater at Cristobal. Upon arrival in Panama Canal waters, if a vessel is not scheduled to transit that day, it has to drop anchor and wait for its scheduled transit time. Otherwise, the vessel will sail toward the first lock. The vessel steams 10.4 km under tug assist to the Gatun Locks, the first set of locks. Three "steps" at Gatun Locks, individual chambers into which ships are maneuvered, raise the vessel 26 m to Gatun Lake. Each chamber is 34 m wide and 305 m long. This first set of locks is about 2 km long.

The vessel moves into the first chamber under help of the locomotives and tugs and under its own power, where miter gates close behind the vessel's stern to lock it into the chamber. Water from the second chamber flows into the first chamber and lifts the vessel to the water level of the second chamber. Once the vessel has stopped rising, the miter gates at the vessel's bow open, and the vessel moves forward into the second chamber with assistance from the locomotives and under its own power. The process repeats for the second chamber. In the last chamber, the vessel is lifted to the level of Gatun Lake. In each chamber lockage, raising a vessel requires about 15 minutes, and each lock transit will last from 45 minutes to more than an hour. Transit time, however, will vary with daily vessel traffic.

Once the miter gates of the last chamber open and the vessel has cleared the gates, the cables from each locomotive are released, and the vessel steams through the tropical waters of Gatun Lake under its own power 37.8 km from the Gatun locks to the Gaillard Cut.

The Gaillard Cut traverses 12.6 km through the Continental Divide of Panama at the highest point of the isthmus. Before construction of the canal, the cut was more than 123 m above sea level and 91 m wide.

One portion was widened to 152 m during the 1930's and 1940's, and the remaining portions were completed by 1971. Starting in the 1990s the cut was widened to 192 m in the straight sections and 223 m at the curves to allow double passage of Panamax vessels. Once past the Gaillard Cut, the vessels encounter the first of two locks that will lower the vessel to the level of the Pacific Ocean. The first lock, Pedro Miguel, has one chamber, 11/3 km long, which will lower the vessel 9 m. From Pedro Miguel, the vessel sails into Lake Miraflores and proceeds about 2 km to the Miraflores Locks, whose two chambers lower the vessel to sea level. From the Miraflores Locks, the vessel moves toward the Pacific Ocean under the Bridge of the Americas, where the pilot returns the vessel to the captain and boards the launch boat. A complete transit takes 9-12 hours after entering the first set of locks, although a vessel may anchor in the canal waters, waiting to transit the canal, from a few hours to a few days (19).

4.2 Bounds for Accepted Price of the Auctioned Service

Since June 1999, double passage of Panamax vessels began. The widening of the cut was finished by 2002 and increased transit capacity by about 20 percent. Even based on this fact, congestions occur now and then at the entrance of the Panama Canal. The Panama Canal Authority then adopts auction mechanism to sell the transit service as well as time windows. Otherwise, the ship operator has to figure out alternative routes.

The additional total costs in case the container vessel is planned to take alternative routes would be the upper bound of the auction price that one vessel is will to pay. Otherwise, the vessel might simply deviate from the Panama Canal and take the alternative routes if time allows.

There are basically two alternative routes, i.e., Horn route and the land-bridge route.

1) The canal is a preferred alternative for ship operators if the average daily revenue of a vessel's transit through the canal is more than an extra 10-day routing. Although the vessel avoids paying the canal toll by sailing around the Cape of Horn, it requires 15 percent more bunkers and revenue distributed over an additional 10 days.

2) Mega ships that transport containers to the United States call on two or three ports for unloading and loading containers. The larger ships carrying containers from an Asian country to the US East Coast would be too large for the Panama Canal. The ships would call on a US West Coast port, where the containers are unloaded and then transferred onto rail cars for an intermodal delivery across the United States to final markets. This service, called the "land-bridge," eliminates an all-water delivery of a container and avoids use of the Panama Canal. Containers land-bridged across the United States from the US West Coast to New York, for instance, save about 7 days.

Furthermore, expansion of the third lane is planned to be accomplished by 2015, which allows Post-Panamax container ships to transit with a 270 - 280 m length, and a 40 - 45 m width. Consequently, it will open the Panama route to new markets that, due to the present size of Canal locks, have not been able to develop.

The proposal consists of adding a third lane, through the construction of two lock facilities, one at each end of the Canal. Each of the new lock facilities will have three consecutive chambers, designed to move vessels from sea level to the level of Gatun Lake and back down again. The new lock's chambers will be

427 m long, by 55 m wide and 18.3 m deep (20).

4.3 Possible Container Ship Operation in the future

Figure 2 is drawn based on information collected based on interviews with practitioners.

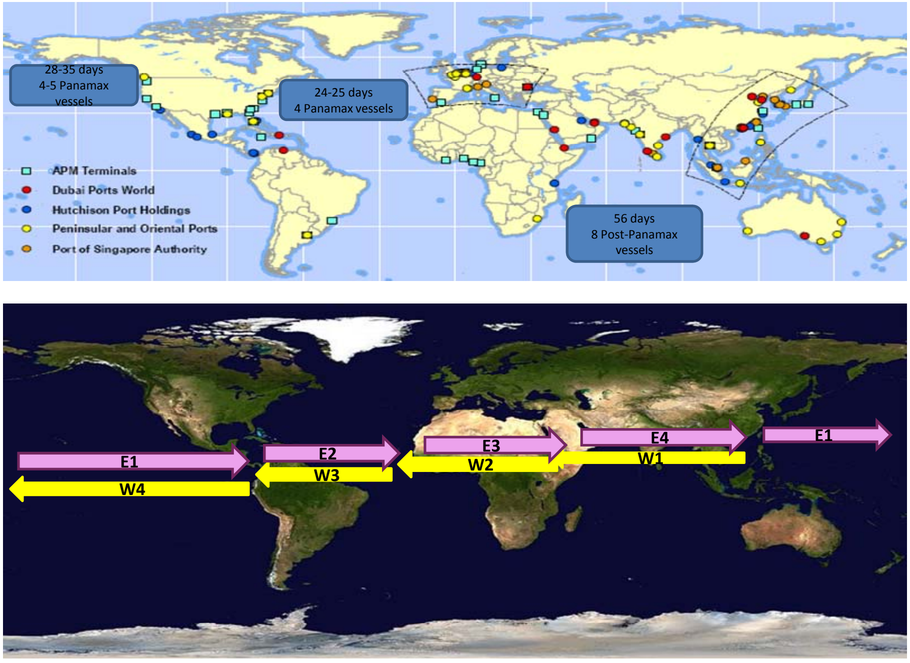

Figure 2: Comparison between current liner fleet composition and possible trend
Source: Authors' own composition

Taking into account high operational cost when the expanded Panama Canal allows mega-container vessel to be deployed in this route, the time factor (21) has to be considered as one of main factors affecting the way how liner shipping companies operating the America related routes, especially when auction mechanism is involved. There might be a trade-off effect.

On one hand, mega-container vessel bears high operational cost. Therefore, it tends to shorten the voyage time, i.e., adopting auction mechanism, so that the total time transiting the Panama Canal would not be too long. On the other hand, the liner shipping company is eventually offering liner service. Therefore, it tends to fix the voyage time, e.g., under its control. In another word, the liner company may pay relative high transit price to ensure its priority of transiting the Canal instead of adopting auction mechanism for each time. As a compromise, it is likely that in general, the liner company would fix the transit rate by signing agreement with the authority of the Panama Canal. On top of this agreement, in case unexpected congestion happens, the liner company auction for obtaining fast transit service.

5. CONCLUSION AND FURTHER RESEARCH INTEREST

Shipping industry is quite dynamic due to those relevant markets and factors involved. Once one or some of those relevant markets and factors change, e.g., price of new buildings, fuel price, and strikes at some port-of-calls, change of economic or geographic environments, etc., then liner shipping industry could not keep stable any longer. As a result, the expansion of the Panama Canal, as one of the above mentioned factors, would definitely push liner carriers to think about optimizing strategies in order to survive in the turbulent market by means of multimodal networks, agility of fleets, diversity of service offerings and so on.

In this paper, we describe a potential liner fleet deployment based on integration operation of fixed service price and auction. However, we have not discussed what might be better off in case one waiting container vessel ask for 'borrowing' priority of transiting the Canal from its commercial partners, taking into account the fact that there are liner shipping strategic alliances existing in this market for decades. Such assumption and further commercial operations would amply complexity of this problem, however, which might be one of the further research interests in this field.

Furthermore, if we restructure this decision making processes subject to incomplete information released by the Panama Canal Authority, a new food for thought might occur. If other factors and perturbations besides expansion of the Panama Canal change or occur, the same theoretical application stated in this paper can be valid as well when analysing the rivalry within the liner shipping industry. In summary, container vessels deployment and liner fleets composition deserve worldwide attention from aspects of both academic researchers and business practitioners.

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