Dynamic Shipping and Port Development in the Globalized Economy

Volume 1: Applying Theory to Practice in Maritime Logistics

Edited by

Paul Tae-Woo Lee

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To the parents in the world who devoted their lives to educating their children

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1
Introduction

Paul Tae-Woo Lee and Kevin Cullinane

The global maritime network underpinning the world economy is currently facing critical challenges. These include, inter alia, relatively stagnant economic and trade activity, China's growing impact on international trade, changes in the structural pattern of international trade as a consequence of emerging free trade agreements, the need to further integrate maritime logistics systems, fierce port competition and the influence of mega carriers, terrorist attacks and other security issues, natural disasters and the need for enhanced resilience, as well as global warming and other environmental concerns. Within the context of a globalized world economy, the continued emergence of new developments which fundamentally affect it (such as China's growing engagement in Africa and South America) and aspects such as the pursuit of an integrated logistics environment, the competitiveness of alternative production bases, the potential for the relocation of production lines, and the associated establishment of new supply chains have all attracted the attention of manufacturers, maritime logistics providers, academics, and policymakers. This is the context which has prompted the production of this book entitled *Dynamic Shipping and Port Development in the Globalized Economy*. Consisting of two volumes, the first concentrates on aspects of maritime economics and logistics which revolve around *Applying Theory to Practice in Maritime Logistics*. The second volume is entitled *Emerging Trends in Ports*. As the name suggests, it brings into sharp focus the impact on ports of the contemporary practices in maritime logistics which have been discussed and analyzed in Volume 1. The two volumes encompass a total of 15 contributions from 23 visionary scholars of international repute, which together provide a truly comprehensive scientific, practical, and contemporary perspective on the developments and challenges that have necessitated *Dynamic Shipping and Port Development in the Globalized Economy*.

Volume 1 of this book brings together an eclectic collection of papers which seek to apply a range of different theories to contemporary issues affecting the shipping and port industries. In so doing, a number of new concepts pertinent to maritime logistics have emerged. The first contribution by Jasmine Siu Lee Lam (Chapter 2) is a discourse on strategies for developing transhipment hub status and is based on a case study of the Port of Singapore, the world's largest transhipment hub in terms of overall container throughput. With more than 80% of its total container throughput being transhipment containers, the Port of Singapore faces several challenges in an increasingly competitive business environment. Among the various types of cargoes handled by ports, transhipment containers are considered the most "footloose" in that they are not naturally bound to any specific port. Therefore, as the author points out, transhipment ports probably encounter the most severe inter-port competition. In other words, Singapore and other transhipment ports must continuously improve their performance by providing higher standards of service at competitive prices in meeting the needs of port users. The author's analysis adopts a variety of perspectives in order to identify the key success factors required for achieving and maintaining transhipment hub status. In relation to the Port of Singapore, she highlights its strong links to the global shipping network and its consequent high level of connectivity (Cullinane and Wang, 2012; Wang and Cullinane, 2014) which generates significant benefits for port users. In addition, the author attributes much of the success achieved by the Port of Singapore to several measures introduced by both the Port of Singapore Authority (PSA) Corporation and the Maritime and Port Authority of Singapore (MPA) which have led to its emergence as a highly efficient terminal operator, a customer-centric service provider, a proactive investor in both infrastructure and superstructure within the port, and an innovator and leader in research and development, particularly with respect to the introduction of the port's electronic port community system – Portnet. All of this has strengthened the Port of Singapore's status as a transhipment hub.

In Chapter 2, Lam further highlights key success factors of the Port of Singapore in addressing green port policies and sustainable terminal operations and expansions. These success factors are credited to the port's governance system and its interaction with, and relationship to, national maritime policy. They are quite similar to the key success factors of the Port of Singapore which were identified by Tongzon (2005): strategic location, high level of operational efficiency, high port connectivity, adequate infrastructure/info-structure, and a wide range of port services. Lam emphasized that several challenges remain for the Port of Singapore. The first comes from neighboring countries – for example, Malaysia and Indonesia – which are developing container port infrastructure, in tandem with national policies, to establish load and logistics centers. Consequently, the Port of Singapore may lose some of its transhipment cargoes. Another challenge the Port of Singapore faces is to develop a policy for the country to achieve the status of a premier international maritime center so that the port can mitigate fierce inter-port competition within the region through port diversification and differentiation. In so doing, the author recommends a double-pronged policy of growing both the transhipment hub and maritime services at the same time, by offering four types of maritime cluster in association with maritime ancillary services including marine insurance, ship finance, and ship broking.

Highlighting China's fast-growing engagement in Africa and South America over the last two decades, Paul Tae-Woo Lee (Chapter 3) addresses emerging markets in maritime logistics and in the shipping and port sectors. Greater liberalization and more free trade agreements in the context of regional economic blocs, such as IBSA (India, Brazil, and South Africa), the Regional Comprehensive Economic Partnership (RCEP) led by China and the Association of Southeast Asian Nations (ASEAN) + 3 (China, Japan, and Korea), have contributed to increasing and robust container cargo volumes, causing structural changes in trade patterns on the newly emerging route of China–Africa–South America (CASA). Moreover, these developments have led China to expand her economic and political influence in the emerging markets of Africa and South America. As a result, a new maritime geography is developing on the world maritime map. The author emphasizes the necessity to analyze the impact of greater trade liberalization on container trade volume on the basis of 20-foot equivalent units (TEUs) rather than container value. This is because data on container volume in TEUs and container cargo flows among major trading partners yield greater insights and are more valuable, therefore, for fleet deployment and management, container network development, and port capacity planning. The author introduces an approach for converting trade value data acquired from the Computable (Applied) General Equilibrium (CGE) or Global Trade Analysis Project (GTAP) models into container volumes in TEUs by combining them with UNCOMTRAD data. Examples of how to estimate container cargo volume by container cargo type and flow route on the basis of a series of his research team's work are also provided (e.g., Lee and Lee, 2012; Lee et al., 2008; Lee et al., 2012; Lee et al., 2013). A series of applications of the conversion model to the South Africa case and CASA trade route confirm that the continents of sub-Saharan Africa (SSA) and South America do constitute emerging markets in shipping, port, and maritime logistics. In addition, the confirmed robust increase in the estimated container cargo volume on the CASA route drives stakeholders to consider several challenges and responses, such as the location of logistics distribution centers (LDCs), feeder services in SSA, a relay service between SSA and South America, a multiple gateway port system in South Africa, and China's strategic options.

Following his work on data conversion, Lee explores the best location for LDCs to develop transhipment hub ports, as well as to promote South Africa's engagement with China in SSA, serving the sub-Saharan region and relaying container cargoes to South America. Looking ahead, another objective is to answer the question: What are the likely challenges China is facing, and what are China's options and likely responses? The author concludes that trade liberalization and connectivity developments among regional economic blocs and their members contribute to increasing maritime cargo flows and that, on the basis of several measures such as degree of centrality, betweenness centrality, and clustering coefficients of the hub and gateway functions of ports, South Africa can be seen as a rising container hub in SSA. The author regards the Port of Ngqura as the best location for locating an LDC and as a transhipment hub for China's trade, providing it can create a new dynamic maritime clustering system that combines a maritime and trade cluster with manufacturing and assembly companies, as well as research and education. This is because such a center can lead stakeholders in the private and public sectors to work together and integrate maritime logistics actors, the port, third-party logistics providers, the single window system (SWS), the port management information system, electronic data interchange (EDI), and radio-frequency identification (RFID) into a one-stop service, based on a platform of fusion technology.

Based on recent studies by his research team (Chang et al., 2013, 2014), Young-Tae Chang in Chapter 4 addresses the green issues facing the contemporary shipping and port sectors. The vast majority (95%) of the world's shipping fleet runs on diesel which emits a range of pollutants, not only when operating on the high seas, but also within ports. Because of the impoverished quality of the fuels used, even the most modern marine engines produce higher emissions per power output than regulated on-road diesel engines (Corbett and Farrell, 2002; Cullinane and Bergqvist, 2014). Based on the methodology applied in Corbett et al. (2009) and Chang and Wang (2012), the author estimates greenhouse gas (GHG) emissions within the Port of Incheon in South Korea in order to understand how best to assess emissions in ports in terms of vessel types, stage of vessel movement, and vessel characteristics. The second element of this chapter goes on to assess the emissions of noxious gases (specifically, SO_2, NO_x, and PM) from vessel operations in the Port of Incheon by applying the Tier 3 methodology developed by the European Energy Agency (Chang et al., 2014). Although there currently exist no International Maritime Organization (IMO)-designated Emission Control Areas (ECAs) in Korea, the author examines how much these noxious emissions could be reduced within any future ECA that is applied within the Port of Incheon. Alternative scenarios are tested with variations in maximum allowable ship speed, the size and boundaries of the ECA, and the sulfur content of ship fuel. In a third element of the chapter, Chang measures the pollution abatement cost at ports in currently designated ECAs. By building on the environmental directional distance functions he derives to drive his model, and switching from an additive to a multiplicative version of his model, he measures what volume of cargo and passengers may have been lost at ports due to the imposition of ECA regulations. By taking the Port of Incheon as a reference, together with the vanguard ECA ports within the European Union, the work reported in this chapter addresses some of the major and growing concerns of various stakeholders in seeking to reduce the emissions of GHG and noxious gases in ports.

The contribution from Koichiro Tezuka and Masahiro Ishii (Chapter 5) analyses the applicability of game theoretical models to port policies, by utilizing a case study of Japanese container ports. The authors first identify the types of port competition problems that might be solved using game theory – both cooperative and non-cooperative games – through a comprehensive literature review. De Borger et al.'s (2008) is acknowledged as the first work which investigated the general competition between ports using a two-stage game, and this work has stimulated a series of studies that have modified these models to depict more specific situations among competitive ports. The authors review these subsequent related studies to reveal the relationships and interactions among factors and variables associated with port competition. Tezuka and Ishii move on to briefly outline recent Japanese port policies, namely the Super Core Port (SCP) policy and the International Strategic Container Ports policy, which were introduced to improve the competitiveness of Japanese ports within the East Asian context. By reference to economic structure and, in particular, the nature of the congestion, hinterlands, and vertical supply chains in the region, the authors go on to explain the gap which exists between the actual competitive situation which prevails among East Asian ports and the outputs derived from the game theoretical models they have reviewed. Moreover, the authors focus on the ownership and operational structures of a port to verify the assumptions underpinning the game theoretic models they have reviewed and to evaluate their robustness. Having taken the above into consideration, they examine how to apply the results of game theoretic models to actual situations of inter-port competition and draw inferences relating to congestion and capacity constraints, the final point of demand and port governance structure. In so doing, they account for Japanese port policies in the context of inter-port competition, particularly in relation to that which exists between the Port of Busan in Korea and the SCP ports in Japan. It is interesting to note that lack of capacity is not a problem in the region. Rather, severe price competition occurs because of overcapacity. In addition, because the Japanese central government uses grants and regulations to support container ports which are owned and operated by local governments, recently privatized companies do not necessarily have the discretion to determine port charges. As a consequence, the authors claim that not only should the appropriateness of the objectives of Japanese port competition policy be confirmed and reset, but also the appropriateness of the assumption that a single port entity is simply a private profit maximizer should be questioned.

Recognizing that the study of maritime security as a new dimension of enhancing maritime safety is attracting growing international attention, Zaili Yang, Jin Wang, and Adolf K.Y. Ng (Chapter 6) propose a new conceptual methodology for determining the security requirements of shipping and ports. This work aims to prompt a paradigm shift in maritime security management and advancing the state-of-the-art to a point where robust quantitative security assessment is feasible. The authors draw together and review pioneering research on the analysis of piracy data, maritime security regulations, security risk quantification, the use of uncertainty methods in maritime safety assessment, and the innovative use of economic evaluation in security management. In so doing, the authors apply eclectic methods comprising an extended Analytic Hierarchy Process (AHP) and an heuristic approach which is based on techniques such as Bayesian networks, entropy, the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and System Dynamics in order to develop a novel maritime security assessment (MSA) methodology. The newly proposed MSA methodology contributes to integrating several studies focusing on maritime security risk quantification and safety management, consisting of the identification of threats and vulnerabilities, subjective security risk estimation, security risk mitigation and protection, security cost and benefit analysis, dynamic security-economic evaluation, and security inspection and maintenance. Having said that, the significance of the newly proposed MSA methodology lies in, among other things, the fact that it presents a scientific framework capable of realizing quantitative security risk analysis under uncertainty to aid decision making and rationalizing maritime security management under economic constraints. In addition, the development of this new MSA framework for shipping and ports not only promotes the standardization of the currently diverse practices and standards applied to "secure" facilities in different states around the world, but also facilitates a shift in maritime security management toward a proactive risk-based regime that realizes the optimal use of security resources for maritime security improvement. As such, this chapter lays down a solid and crucial platform for researchers, policymakers, industrial practitioners, and other stakeholders of the maritime sector to collaborate meaningfully to deliver maritime security effectively.

For the purposes of their analysis, Stephen X.H. Gong, Michael Firth, and Kevin Cullinane (Chapter 7) define a "financing method" as representing a joint decision on both governance structure and available financing mechanisms. Based on this premise, the authors propose a new analytical framework for the analysis of financing methods that, it is suggested, should replace the more traditional and orthodox perspective that is usually adopted in neoclassical finance theory. A review of the alternative theories that seek to explain the corporate choice of capital structure leads the authors to conclude that, in terms of explaining real-life behavior in shipping finance decisions, an approach based on transactional cost economics (TCE) due to Williamson (1988) is likely to prove superior to one based either on the capital structure irrelevance propositions (Modigliani and Miller, 1958) or on the pecking order theory (Myers, 1984). The authors go on to outline and advocate an approach to the analysis of financing methods in the shipping industry that fundamentally revolves around the TCE paradigm, but which is informed by a range of eclectic influences from other areas of economics and, most poignantly, by real-life behavior. Specifically, they suggest that the TCE paradigm helps explain the combinations of capital structure and corporate governance decisions that are found to exist in the wider transport industry. The reason why this is the case is because asset specificity, the characteristics of the product (service) market under consideration (in particular, in the case of the shipping industry), and the nature of the seekers and providers of finance in this arena are all fundamentally transactional characteristics that exert a considerable influence on what decisions are taken.

Arguing that a port generates freight traffic by means of its interconnectedness with inland trade routes and with other regional and international ports, Francesca R. Medda and Simone Caschili (Chapter 8) estimate the Port Attractiveness Index (PAI) for the South Pacific Islands in order to identify possible policy recommendations to attract private finance into port investments. The authors define the PAI, which is rooted in the causality relationships among the determinants of port attractiveness, as the combination of the productive capacity of a port and its level of international competitiveness, which together provide direct and indirect economic and financial benefits. In the PAI, the authors assume that the higher the value of endogenous, exogenous, and subjective variables, the higher will be the PAI and hence the consequent increase in a port's capacity to attract private investment. The authors apply the concept to the South Pacific Islands, where shipping is the dominant mode of transport for their international trade, using a combination of port and national data such as throughput, maximum draft, logistics performance index (efficiency of customs), Internet usage, the liner shipping connectivity index, and the ease of doing business. Their test results show that ports in the South Pacific Islands have very low port attractiveness compared to other Asian ports. The South Pacific Island ports with the highest PAIs are Lae in Papua New Guinea, Suva in Fiji, and Noumea in New Caledonia, but they are certainly lower than that of Busan Port which is used as a benchmark comparator in this study. The authors' analysis finds that the capacity of a port to be integrated in the international shipping network is a key determinant for the reputation of a port. They, therefore, maintain that in order to increase port attractiveness and private investments, port operators need to develop a wide network of commercial relationships with other ports and, in particular, improve access and connectivity to international markets. From this perspective of the interconnectivity of ports, the authors also make another interesting observation that the South Pacific Islands need to ensure the provision of adequate access for domestic markets and to implement further coordination between ports, including the consolidation of traffic, for better access to international markets. The authors conclude that the governments in the South Pacific Islands should, therefore, loosen regulations and foster port privatization, with the aim of reducing domestic monopoly positions, prompting greater competition, improving efficiency, and, ultimately, enhancing the participation of private finance.

Maritime logistics in international trade is concerned with flows of cargo, information, finance, and image among stakeholders comprising shippers, consignees, forwarders, third-party logistics providers, land and sea carriers, ports, and government agents including customs offices. In this regard, Paul Tae-Woo Lee and Tsung-Chen Lee (Chapter 9) propose new concepts of *economies of flow*, *economies of connection*, and *economies of fusion technology* arising in relation to the maritime logistics of container cargoes. The seamless and smooth flow of container cargoes between stakeholders contributes to lowering logistics costs and, as a result, to improving the competitiveness and productivity of each individual stakeholder, as well as the national economy with which they are associated. Information technology (IT) such as RFID, global positioning systems, cargo tracking systems, and EDI (Lee et al., 2000) have all been applied to maritime logistics. In addition, the SWS, in tandem with collaboration between private and public sectors in Singapore and Korea, has contributed to accelerating the flow of container cargoes and sharing container information among the stakeholders involved. The SWS is a facility that allows parties involved in trade and transport to lodge standardized information and documents at a single point of entry in order to fulfill all import, export, and transit-related regulatory requirements. The authors propose a concept of *economies of fusion technology* with IT, in tandem with nanotechnology (NT) and biotechnology (BT), all being fused with each other in order to achieve efficient maritime logistics. The authors point out, however, that the SWS is not well-developed in other Asian container ports, particularly those in China (Lee and Lam, 2015; Lee et al., 2013). This leads to increased logistics costs and, as a result, to a deterioration in international trade competitiveness. The authors argue that from their case studies of Busan and Singapore ports, the key benefits to be derived from the three concepts of *economies of flow*, *economies of connection*, and *economies of fusion technology* can be identified. Among other things, these key benefits are the lowering of logistics costs; reducing the handling time of container cargoes; the sharing of knowledge and information among stakeholders; capturing economies of synergy; promoting joint research and development efforts between government and the private sector; obtaining mutual benefits from the combined use of complementary assets and knowledge; and overcoming (or mitigating) social impediments such as bureaucracy and corruption. The authors point to the limitation of these new concepts in that statistical and empirical evidence confirming their presence in, and relevance to, maritime logistics, as a sine qua non, has not yet been developed. However, Lee and Lee argue that this shortcoming does not necessarily invalidate the significance of the new concepts, because the intuitive logic underpinning them is sound. In other words, these *economies* provide a raison d'être for developing efficient maritime logistics systems in tandem with promoting international trade flows, particularly in the ASEAN region where several obstacles exist within customs, immigration, and quarantine processes. The authors suggest that future studies may deal with deriving a tractable formulation for hub and spoke networks and/or inland transport that explicitly accounts for the effects of these three new *economies* concepts, by taking into account factors such as cost, time (e.g., service completion speed), and the number of face-to-face contacts between agents and service users.

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2

Strategy of a Transhipment Hub: The Case of Port of Singapore

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Introduction

Over the past decades, maritime trade experienced significant growth due to globalization and economic development of nations. Maritime transport contributes to the sustainability of the world trade system through its impact on the economic, social, and environmental well-being of nations. Playing a crucial role as trade facilitators, ports and shipping are important parties in the global economic system. Correspondingly to the growth in maritime trade, the port industry encountered tremendous increase in demand with regards to both physical infrastructure investment and cargo handling. Since the birth of containerization, the port industry and cargo handling methods became more standardized and efficient. This development accelerated the expansion of containerized trade.

While there is a positive development in demand growth, the port industry faces an increasingly competitive business environment. More and more ports set their goals as regional hub ports in order to capture higher market shares in the competition. Among the various types of cargoes handled by ports, transhipment cargoes are considered footloose, and therefore transhipment ports probably encounter the most severe competition. The world's largest transhipment port at present is Singapore. In the year 2013, the Port of Singapore reported a container throughput of 32.58 million 20-foot-equivalent units (TEUs) (MPA, 2013) with 85 percent transhipment rate out of the cargo volume handled according to terminal operator PSA Corporation (PSA Singapore Terminal, 2014).

In the academic literature, there are many studies investigating port competition and competitiveness. The focus of these studies largely concentrated on the container port sector. There are relatively few studies specifically addressing the topic of transhipment hubs and the research on the Port of Singapore. Gordon et al. (2005) examined the competitive advantage of the Port of Singapore with the focus on its information system. Lam and Yap (2006) analyzed the overall costs of using the ports of Singapore, Port Klang, and Tanjung Pelepas from the users' perspective and discussed the competition between container terminal operators in these ports. Lam and Yap (2008) performed further research on the three ports in terms of the competition for transhipment containers by analyzing vessel call patterns of shipping lines. Lam (2011) studied the Port of Singapore's shipping connectivity from the perspective of the supply chain system. These studies enhanced our understanding on the competitiveness of a transhipment hub, but they largely addressed a particular aspect of port competitiveness. This chapter adds to a large body of the existing literature examining port competition and competitiveness. Unlike other studies in the literature, we aim to analyze the strategy and competitiveness of a transhipment hub from multiple perspectives through the case study of Port of Singapore. Specifically, we examine port institutions and governance, shipping network and connectivity, innovation and technology, and environmental management of Port of Singapore. The chapter will first provide some background information about the port in the next section.

Port of Singapore: A background

The modern Port of Singapore was founded in 1819 as a center for entrepôt trade by the British East India Company. The port served mainly as a regional distribution center for cargo traffic originating from and destined for the Malayan hinterland. Singapore saw the opportunity in playing a key role in maritime trade in the 1960s. The port thus began to focus on positioning itself as a transhipment center for international cargoes, in addition to handling regional cargoes. Hence, the hinterland of the port now consists not only of local cargo from Malaysia and neighboring Indonesian islands but also include those being transshipped through the port from Europe, East Asia, Australasia, and the Indian Subcontinent.

The container port industry in Singapore has experienced tremendous growth over the past decades since the era of containerization. Singapore is now established as a principal center for shipping activities.

Table 2.1 Container throughput of the Port of Singapore

Year	Container throughput (in million TEU)	Change from 1990 (in %)
1990	5	–
2000	17.1	242
2010	28.4	468
2013	32.6	552

Source: Based on data from Containerisation International, various years.

We can consider the long term developments of the port by appreciating the scale of growth in container throughput handled. The port was consistently ranked in the first and second positions for the past two decades. Table 2.1 shows the container throughput statistics. In 1990, Singapore handled about 5 million TEUs of cargoes. By 2000, throughput for the port had grown by more than three times to 17.1 million TEUs. By 2010, container throughput handled by Singapore was 5.4 times of that handled in 1990 at 28.4 million TEUs.

The Port of Singapore has benefited greatly from its strategic location along one of the world's busiest shipping lanes – the Strait of Malacca. Nevertheless, having a good geographical location alone does not mean that the port can become a transhipment hub. The port owes much of its success to the resident port community who are capable of providing world-class services to meet the stringent requirements of port users. This has enabled the port to remain as the largest transhipment hub in the world. The port is also the world's busiest in terms of vessel arrival and bunker sales. As for container handling volume, the port is ranked second after the port of Shanghai based on the throughput in 2013.

Over the years, Singapore has encountered a higher level of port competition. The port community recognizes that it must improve on its performance by providing higher standards of service and productivity at competitive prices or risk of being replaced by upcoming regional competitors. In 2000, the largest shipping line Maersk Sealand chose to relocate its transhipment hub in Southeast Asia from Singapore to Malaysian port Tanjung Pelepas. This move was regarded alarming as it represented about 10 percent of PSA's container volumes handled in Singapore. Moreover, the third largest shipping line, Evergreen, also relocated its transhipment hub from Singapore to the port of Tanjung Pelepas two years later. On the one hand, the episodes have shown a volatile market and the fierce port competition in Southeast Asia. On the other hand, Singapore is able to bounce back and continue to grow as a transhipment hub. It is interesting to understand the measures implemented by the port to counteract the rivalry.

Therefore, the Port of Singapore provides a very good case in discussing a transhipment hub's strategy. Before investigating the port's strategy, we provide more background information about the port's terminal facilities. Port and terminal facilities in Singapore are mostly concentrated in the south-western part of the country. Containers are mainly handled at four locations at the southern part of the island operated by container terminal operator PSA Corporation. The terminals are called Tanjong Pagar, Brani, Keppel, and Pasir Panjang terminals. There is another terminal operator known as Jurong Port Pte Ltd which focuses on handling non-containerized cargoes such as cement, sugar, steel products, and other break-bulk products. Jurong Port is a multipurpose terminal operator which mainly serves the need of the local industries including manufacturing and construction. Since this chapter confines its study scope to Singapore's transhipment business, it does not examine Jurong Port and the associated terminals.

Port institutions and governance

When one studies strategy, the starting point should be the understanding of the leading entity who charts and implements the strategy since the leading entity largely determines the design and effectiveness of the strategy (Appelbaum et al., 1998; Boin and Christensen, 2008). Of equal importance in strategy studies is the institution-based view which explains the institutional conditions and transitions as the background perspective (Peng et al., 2009). The theory of institutions explains the involvement of the public sector and its ability to institute an environment where enterprises can nurture and prosper (Scott and Davis, 2007). In the same vein, it is essential to investigate the leading entity developing the Port of Singapore and the associated institutional environment when we study the port's transhipment hub strategy.

The overall role of the Singapore government

In the context of Singapore, the government is considered the major driving force of port planning and development. First of all, Singapore has a strong and stable government and political environment. The latest Global Competitiveness Report in 2014 by the World Economic

Forum ranked Singapore as the second most competitive country in the world with a score of 5.65. In fact, Singapore has the highest score from Asia, ranked ahead of Japan, Hong Kong, and Taiwan who are in the 6th, 7th, and 14th positions, respectively. Singapore performs especially well in the areas of infrastructure and institutions. For infrastructure, Singapore scored 6.54 and is ranked second in the world only behind Hong Kong who has a score of 6.69. As for institutions, Singapore scored 5.98 and is ranked third in the world behind New Zealand (6.09) and Finland (6.08) (World Economic Forum, 2014). The overall competitiveness of the country and its institutional environment support the port's development.

The status of Singapore as a leading transhipment hub is attributable to the invention of containerized trade. The era of containerization started in the 1960s whereby the standardization of cargo and handling equipment made the operations of transhipment possible. However, as a brand new concept in international trade, the construction of container berths was highly controversial at the start of containerization. The container port industry was and is still very capital-intensive. It was regarded a risky move to commit such a heavy investment to build container berths at that time since it was uncertain if containerized trade would become widely adopted. In particular, no shipping line had committed to building container vessels for the Europe-Far East trade. While the rest of the world simply observed the development and used the "wait and see" approach, the government of Singapore was decisive to build its first container terminal as early as 1966. It is notable that Singapore just became an independent and sovereign republic in 1965. Singapore was merely a poor and tiny third-world country back in those days. Financial assistance was necessary for the investment project. Lengthy discussions with the World Bank to secure a loan took time before the commencement of the construction work. Eventually, the first container berth was opened at Tanjong Pagar in 1972. By understanding the history of the container port of Singapore, it can be seen that the government plays a leading role in charting the country's direction in maritime trade. The government has strategic foresight in port development and is committed to establish Singapore as a transhipment hub.

As containerized trade began to pick up, the Port of Singapore received more containers and shipping lines over the years. In the 1980s, world trade grew rapidly and Singapore expanded its container business correspondingly. It is not sufficient for Singapore to achieve today's status as the world's largest transhipment hub by making the right move at the beginning. Continuous efforts are required to sustain the port's competitive advantage. In many contexts, port authorities are regarded as the primary organization representing a country's interest in port planning and development. Port authorities coordinate actors and develop ports by infrastructure investment (Bai and Lam, 2014). In Singapore, the port authority is the leading entity in coordinating such efforts and resources. It was the Singapore Harbour Board which managed the old harbor facilities. On 1 April 1964, the Port of Singapore Authority was set up as the official port authority to take over the functions, assets, and liabilities of the Singapore Harbour Board. During these decades of years in port development, Singapore went through port governance restructuring and the following discussion focuses on the major institutions involved in formulating the port's strategy.

The major institutions involved

Prior to 1997, the Port of Singapore Authority was a public port authority under the Government of Singapore. Other than owning the terminal facilities, the Port of Singapore Authority also managed and controlled the operational aspects of its container terminals. As both a port regulator and a terminal operator, at that time the Port of Singapore Authority performed many functions including port development, policymaking, terminal management, and cargo operations. Inevitably, there were conflicts of interest especially in terms of regulating the commercial aspect of terminal operations by the same entity. Over the past decade, the trend of port devolution and privatization became increasingly prevalent in other parts of the world. While the government of Singapore has not chosen the route of port privatization, it used the approach of corporatization to decentralize the functions of the port authority. The port governance structure has been transformed since 1996 (see Figure 2.1). The PSA Corporation was formed by the corporatization of the former Port of Singapore Authority in October 1997. This corporatization effectively transformed the Port of Singapore from its previous status as a government body to a port that is an independent entity. The newly formed PSA Corporation is still a government-owned entity with a wholly owned subsidiary of the Government (i.e., Temasek Holdings (Private) Limited) holding a 100 percent stake (Cullinane et al., 2007). The corporatization also marked the split of terminal operations and the port authority function, which came to be respectively performed by the PSA Corporation and the Maritime and Port Authority of Singapore (MPA).

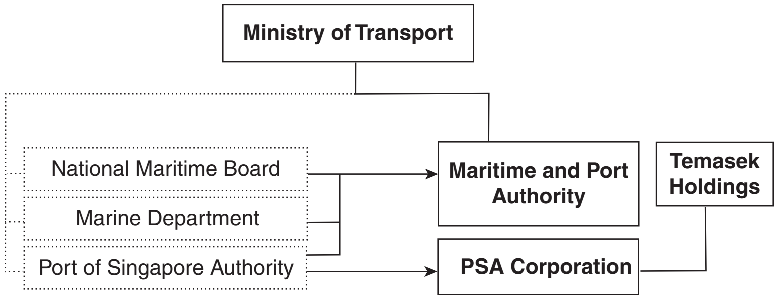

Figure 2.1 Structural changes to the governance of the Port of Singapore
Source: Cullinane et al. (2007).

In the beginning of 2004, the PSA Corporation was reshaped whereby it now covers only Singapore's domestic terminal operations. Then this downsized entity became a 100 percent subsidiary of a new holding company, PSA International. All of PSA Corporation's global business at that time was transferred to PSA International which now runs as a commercial organization. Subsequent to the restructuring in 2004, Moody's increased its rating of PSA Corporation to "Triple A" to recognize the Port of Singapore's response to regional price competition and the economic significance of the port to the government and the country as a whole (Hand, 2004). Along these years and especially since corporatization, PSA International has adopted a strategy of diversifying its portfolio of container terminal operations on a global scale.

After the corporatization, PSA is able to concentrate on terminal operations and management. It has autonomous power to decide the commercial aspect of the port, making it more market-oriented and flexible. For example, PSA Corporation specializes in handling container flows efficiently to attain fast turnaround of vessels. In particular, PSA has identified transhipment as its core business so resources such as equipment, information and communication technology (ICT) system, and human capital are deployed to achieve a high service standard in transhipment. PSA is recognized as a world-class container terminal operator, and this is evident by numerous awards received, such as the Best Container Terminal in Asia for 25 years by Asian Freight and Supply Chain Awards. PSA's expertise in terminal operations and management greatly contributes to the competitive advantage of Singapore as a premier transhipment hub.

Currently, the main government organization overseeing port development and regulatory functions in Singapore is MPA, which is a statuary board under the purview of the Ministry of Transport. MPA was established in February 1996 through the merger of the former Marine Department, the National Maritime Board, and the regulatory departments of the former Port of Singapore Authority. Performing as the port authority, MPA manages and administers the port of Singapore through the regulation of essential port services and facilities. Acting also as the maritime authority, MPA is in charge of the marine, shipping, and navigational matters. To illustrate the role of MPA in a precise manner, we can summarize the major functions of MPA as the following (Cullinane et al., 2007; MPA, 2014).

- Regulating and licensing port and marine services and facilities. This is the basic regulatory function under MPA's responsibilities with respect to Singapore's role as both a Flag State and Port State. MPA ensures that regulations are kept up-to-date and complied with as well as adhering to various International Maritime Organization (IMO) and other international conventions, to which Singapore is a party.
- Protecting the marine environment and ensuring navigational safety and maritime security. This area of responsibilities represents the typical role of a maritime authority or marine department in the government. For example, MPA operates the vessel traffic information system to manage vessel movements in port waters. It also oversees the protection of the marine environment and maritime security through measures such as oil-spill prevention and working with other Singapore government agencies and the industry parties in the implementation of various security measures.
- Managing Singapore's merchant fleet. This includes the promotion and marketing of the Singapore Registry of Ships (SRS) with the focus on promoting Singapore as a high-quality register. MPA performs its role by targeting high-quality shipowners and ships to register with the SRS, ensuring the appropriate qualification and welfare of seafarers employed on board Singapore registered ships, and providing high-quality support services to the shipping community.
- Working with various government agencies and industry partners to develop and promote Singapore as a leading hub port and International Maritime Centre. MPA is not only a port regulator but also a proactive policymaker and port developer. This area of functions includes assessing industry trends and developing strategies which, for example, are aimed at identifying and nurturing new business areas; charting port planning in order to maintain Singapore's status

as a premier transhipment hub; and, by encouraging both local participation and foreign investment, enhancing the breadth and depth of services that Singapore presently offers.

- Safeguarding Singapore's maritime interests in the international arena. This responsibility mainly puts MPA as the representative body of Singapore in areas of maritime-related foreign relations. MPA's role is to enhance Singapore's profile in the international maritime community. This includes building up links with international organizations such as the IMO and major maritime countries.

In addition to MPA and PSA, other institutions with relevant domain knowledge are also involved in the management and development of port and maritime related issues. For example, the Economic Development Board of Singapore oversees the shipbuilding, ship repair, offshore, and marine equipment sectors while the Singapore Tourism Board manages the cruise sector. The Police Coast Guard and the Republic of Singapore Navy contribute to port and maritime security. The Singapore Maritime Foundation acts as a private sector-led organization to work in partnership with various private and public entities to promote Singapore as an International Maritime Centre. It is important to note that the success of a port is intimately related to the overall strength of the maritime cluster (Zhang and Lam, 2013). Taking ship-related businesses as an example, shipping companies continue using the port of Singapore as a transhipment center, among other reasons, because Singapore can provide ship supplies, bunkering, and repair services conveniently. The one-stop services add value to shipping companies when they make vessel calls at the port.

As a whole, the planning and management of the port relies on the coordinated and strenuous efforts of various government agencies and private sector bodies to join force to strengthen the competitive advantage of Singapore. The guiding principle that unites these organizations is the mutually shared goal of creating a competitive business environment where the maritime community can thrive and prosper in a dynamic international environment.

Shipping network and connectivity

A major strategy that a transhipment hub should adopt is to establish a strong shipping connectivity. This section uses the case of Singapore to illustrate how important it is to have a comprehensive network for a transhipment hub, how port users benefit as such and what can be done by terminal operators to support ports to become a transhipment hub.

Importance of shipping network and connectivity for Singapore

As ships are getting larger in size, the international shipping network has changed to favor a hub-and-spoke network (main-feeder) to a point-to-point (origin-destination) network. In the hub-and-spoke network, a hub port links the mainline network over which cargoes are transported in large vessels with sub-networks over which relatively small vessels feeder cargoes to and from the mainline network via a transhipment hub (Talley, 2009). Shipping lines usually choose ports with strong connectivity as their transhipment hub for the purpose of cost-saving generated by economies of scale and scope and better coverage of markets (Chou, 2007).

From the perspective of ports, shipping network and port connectivity raise competitiveness for a transhipment hub in general. To be more specific, the stronger the connectivity it has, the further expanded the hinterland of ports could be, via feeder networks. Singapore is a very small island country. The local hinterland covering domestic production activities and consumption needs is limited. However, a port is not merely subjected to the local hinterland thanks to the transhipment concept. As a result, a hub port has a better access to handle the cargoes transported both in feeder networks and in mainline networks and thus reach a wider market and gain more profits. Tapping on the excellent geographical location, Singapore incisively uses its strength to overcome its major weakness of having a small domestic market. Its hinterland is extended to the overseas markets to cover both regional maritime trade routes and international ones. According to the slot capacity analysis of liner shipping companies, Lam (2011) found that the top five shipping trade routes connected to Singapore are the Europe–Far East trade, the Intra-Southeast Asia trade, the Far East–Middle East trade, the Mediterranean–Far East trade, and the Southeast Asia–Far East trade. We can see that many economies from different parts of the world are included in these maritime trade routes. The sphere of influence of Singapore as a transhipment hub is indeed extensive. The port is benefited from international supply chains crisscrossing even very remote regions. According to the Association of Southeast Asian Nations (ASEAN), the ASEAN Economic Community should achieve regional economic integration by 2015. Moving toward higher trade liberalization, intra-Asia trade would experience tremendous growth in the near future. This creates opportunities for Singapore to handle more transhipment cargoes in the region on top of the existing major shipping trade routes.

Strong connectivity offered by Singapore is credited with the acquisition of the substantial amount of transhipment cargo. A case in point investigated by Lam (2011) is that Maersk Line continues to transship a significant amount of cargoes at the Port of Singapore, after it relocated its transhipment hub to Port of Tanjung Pelepas in 2000. A reasonable explanation is that the shipping connectivity of Tanjung Pelepas is not strong enough to solely support Maersk's global shipping network. It is insufficient to attract mainline operators to call at a transhipment hub. Having large amounts of feeder vessel operators connecting to wide geographical coverage is also very important. In this case, Singapore has shown its attractiveness as a well-connected transhipment hub. What's more, Singapore demonstrates that the shipping networks it has built over the years are not easy for other ports to replicate. For this reason, the Port of Singapore is resilient when it is faced with head-on competition. Even transhipment cargo is generally footloose, the risk of relocating transhipment operations by shipping lines can be mitigated if shipping connectivity of the incumbent hub is strong. In this sense, a critical mass of vessel calls should be attained for a competitive transhipment hub port.

Benefits for port users from transshipping at a hub

Singapore, the world biggest transhipment hub, has excellent shipping connectivity with links to 600 ports in 123 countries in the world (MPA, 2013). Transhipment goods enjoy the economies of scale and scope by transshipping at the hub of Singapore. This is particularly helpful in the era of globalization and supply chain management.

For shipping lines, the strong connectivity of Singapore fully supports their global shipping network, and enables them to enjoy economies of scale by enhancing the utilization of mega vessels plying in major shipping routes. Having global network coverage is the fundamental market requirement exerted on liner shipping companies nowadays (Lam and Van de Voorde, 2011). Furthermore, shipping lines gain more bargaining power versus shippers due to the large amount of slot capacity connected to the hub of Singapore. In general, point to point shipping services are not able to provide global and inter-regional coverage cost-efficiently. Designing a hub-and-spoke shipping network enables the liner operators to increase their network coverage with only marginal increase in cost. Consequently, lower cargo handling cost per TEU could benefit both shipping lines and shippers.

For shippers, excellent connectivity of Singapore makes it possible to ship cargoes from their factories to almost everywhere in the world. Moreover, the wide choices of carriers contribute to competitive freight rate and cost saving. Finally, high frequency of ship visits in the Port of Singapore provides more flexibility for shippers to schedule transportation of cargoes. Tongzon (2009) identified that frequency of ship visits is important from shippers' perspective because it influences transit time. This is especially essential for global shippers who can benefit from a port which is well connected to global supply chains (Lam and Yap, 2011). As a whole, it can be derived that port users including shipping lines and shippers can substantially benefit from the shipping network and connectivity offered by Singapore. The supply chains that these port users operate in also benefit from the greater efficiency achieved.

Measures strengthening Singapore as a transhipment hub

As the main terminal operator in the Port of Singapore, PSA plays a vital role in establishing the position of Singapore as a transhipment hub. PSA in Singapore considers transhipment as its core business (PSA Singapore Terminal, 2014) thus made great efforts to maintain and enhance the competitiveness of Singapore as a transhipment hub in several respects.

To begin with, PSA has earned its reputation as a highly efficient container terminal operator in Singapore by constantly optimizing operations, taking advantage of advanced ICT, and encouraging R&D and innovation. According to Jiang et al. (2015), Singapore has the highest level of connectivity with respect to transportation time and is renowned for its efficiency and fast turnaround time at its terminals.

Secondly, PSA vertically collaborates with major shipping lines to enhance the connectivity of PSA Singapore terminals and to secure the cargo volume transshipped at the hub of Singapore. Major shipping lines are more willing to choose Singapore to conduct their major transhipment operation if they can take advantage of having dedicated facilities. At present, PSA Singapore has four joint venture terminals, namely COSCO-PSA Terminal, MSC-PSA Asia Terminal, PIL-PSA Singapore Terminal, and Asia Automobile Terminal (Singapore).

Furthermore, PSA keeps investing in new terminal infrastructure and superstructure to meet the demand for future. Given the present situation that all hub ports are facing challenges arising from mega ships and global alliances, the decision of developing new terminals in Singapore is considered to be far-sighted and ambitious. Nowadays, mega ships from liner shipping alliances take much more time and berth space to be served and wait for transhipment containers due to the huge size involve. Terminal operators may have to use additional quay cranes to turn ships around in a relatively short-time window. As a result, potential problems, such as yard congestion, truck traffic, and stressful gates in peak time could be heightened. Under this circumstance, on top of optimizing operations, ports would have to invest in berth and terminal expansion for longer term growth. As for Singapore, after the expansion of Pasir Panjang Terminal phase 3 and phase 4, the total terminal capacity of PSA will increase by about 50 percent – to 50 million TEUs (PSA Singapore Terminal, 2014). In the next section, we will further discuss Singapore's strategy with regards to port innovation and technology.

Innovation and technology

Singapore as a transhipment hub also embraces innovation and advanced technology to make continuous improvement in port operations and management. The strategic direction is to stay ahead of the industry norm and maintain as the leader in the transhipment business. This section will illustrate the main motivation of employing innovative solutions in the port industry and the developments in Singapore.

The major drive for port innovations

By nature the port industry is trade driven. As such, innovations and technology advancement in ports and terminals should generally correspond to market changes at both the demand side and the supply side of maritime trade activities. In the maritime industry, there is an increasing demand for ports to house larger liner ships and to handle larger volume of cargoes efficiently by the terminals. Along with escalating regional port competition, it is crucial for Singapore to maintain its position as the world's busiest transhipment hub by perpetually engaging in research and development (R&D) so as to stay ahead of its competitors. Innovations adopted should then ensure greater efficiency and productivity for the port and its terminals. The market players in the port industry are well aware that the need for efficiency for a transhipment hub, the need to deal with port competition and innovation in the Port of Singapore are elements that are closely related.

Shipping lines as major customers and port users have the main concern on the efficiency level of a container port, especially a transhipment port. The fundamental function of a transhipment hub is to provide connecting services to liner shipping companies of various sizes. As such, a transhipment hub adds value by providing such connecting services in a timely manner. On the other hand, a transhipment port would be phased out if this basic function cannot be fulfilled. Shipping lines are concerned with how efficiently the port can finish operating the ships. In the perspective of ship operators, if their ship is able to leave the selected port a few hours earlier as compared to a less efficient port, the companies will save fuel cost due to the time saved (Maersk Line, 2014). Since fuel cost is the largest component in the ship operating cost to a shipping company, ports play a role of reducing cost for shipping companies by lowering the cargo handling time required at the port. Therefore, in order to match up with rising port competition, it is essential for the Port of Singapore to increase efficiency of port operation through innovation in order to prevent shipping lines from switching to a more efficient regional port. From this, we can see that the three elements of port efficiency, competition, and innovation are interlinked and are important factors that determine if the Port of Singapore can continue staying ahead.

Innovations in Singapore are not only driven by the need for efficient operations in port. They are also driven by the competition faced because of rising regional ports especially in Southeast Asia. Major factors that affect port selection decisions are examples such as cargo size, frequency of vessel call, port infrastructure and superstructure characteristics, and port charges (Chang et al., 2008; Lam and Dai, 2012). Many of these factors will determine if a port will be able to achieve economies of scale. As economies of scale is being achieved, a port will be able to offer a more efficient, more productive, and lower-cost deal for port customers and users. Through innovations, port infrastructure and superstructure can be upgraded, allowing ports to accommodate larger vessels and deal with larger amount of cargoes. These capabilities are particularly essential for transhipment hubs.

The collective idea is for ports to lower their generalized costs from the port users' perspective. The level of port charges is not the only determinant in choosing a port. Due to higher costs including land and labor costs in Singapore than its Malaysian counterparts, among other reasons, there is higher price (in absolute monetary terms) charged by terminal operator PSA Corporation in Singapore. Nevertheless, Singapore is being able to provide better quality of services so port users actually enjoy lower generalized costs when they use the port (Lam and Yap, 2006). As a result, the Port of Singapore is considered more competitive as compared to regional ports once they are able to offer a lower generalized cost option to users and customers. Therefore, the port will be able to continue being forward-looking and meet the ever-changing business complexity and demand.

Container port technologies and research and development in Singapore

The port industry, especially for the container sector, is in general a technology-driven industry. To face the challenges and competition posed by the ever-changing industry, Singapore has been actively innovating through R&D. First, Singapore has shown strong commitments by capital investment in R&D. For instance, innovation of the Remote Crane Operations and Control allows up to a six times increase in productivity with automated overhead bridge cranes along with real-time monitoring and control. To provide a more recent example, PSA and MPA collaborated in a port technology research and development program in 2012 (Tay, 2012). A sum of SGD 20 million was funded into the project and the focus was to include test-bedding projects on Automated Guided Vehicle (AGV) so as to rely lesser on the need for human labor, thus, increasing efficiency and productivity through automation and autonomy. This program was then extended and research funding increased by SGD 30 million under the consensus of PSA and MPA by signing the memorandum of understanding (PSA, 2014a). Such capital investment in R&D is necessary in order to retain Singapore's position as a leading transhipment hub through research relevant to port automation and intelligent planning and control stations.

Secondly, Singapore is forward-looking in the port's infrastructure development. The country is currently in the midst of building more container terminals in order to cater to higher demand for maritime trade. PSA and MPA in fact, combined efforts for the development of Pasir Panjang terminal phases 3 and 4 and Tuas terminal. It is expected that once phases 3 and 4 are completed, the terminal will be able to accommodate up to 50 million TEUs as compared to the handling capacity of 35 million TEUs currently (PSA Singapore Terminal, 2014). Associated with R&D as discussed above, the Port of Singapore endeavors to achieve a quantum leap in port performance through innovation in various aspects. An intelligent container terminal operation system will support an automated container yard and unmanned rail-mounted gantry cranes in the newly completed terminal. PSA also aims to leverage all operations to the fullest by seamlessly connect all areas of the terminal. A greater synergy between human and non-human interfaces through revolution of ICT will be expected in the future. Hence, a more integrated and efficient port can be expected because of such technology improvement.

Other than the collaboration of the two port organizations PSA and MPA, Singapore is also active in establishing nation-wide collaborations in the area of port innovation. For example, the Singapore Maritime Institute was jointly founded by MPA, the Agency for Science, Technology and Research, and the Economic Development Board in partnership with Institutes of Higher Learning in Singapore in 2011. The overall aim of this government-led institute is to set up nation-wide coordinated efforts in maritime R&D, education and training, and thought leadership in policy formulation. It is specified by the Singapore Maritime Institute that its vision is to accomplish a thriving maritime industry driven by knowledge and innovation. Within a relatively short time span of four years since the start of the Singapore Maritime Institute, it has organized many activities and programs. A good example is the ongoing R&D seminar series. Seminars act as a platform to promote the exchange of ideas relevant to improvement of technologies on a global scale by researchers and industry professionals. This will aid in encouraging more collaborations in R&D for technologies applicable to the port industry. Another example is the organization of the "next generation container port challenge" which is an open competition of the future port design. Concepts from the challenge such as a double storey container port will be explored and developed (Singapore Maritime Institute, 2013). Hence, this program does not only aim to increase productivity and efficiency of the port, but also hope to use innovative concepts and designs to resolve business complexities arising from Singapore's physical limitation in space.

Electronic port community system: Portnet

In addition to container port technologies and R&D, the Port of Singapore is also at the forefront of ICT innovations. The very fundamental function of a port is to serve as an interface connecting networks. The parties involved include terminal operators, port authorities, customs, ocean carriers, consignors, consignees, inland transport providers, freight forwarders, logistics service providers, and other ports in the foreland (Lam and Song, 2013). Major modern ports face a common challenge of dealing with a huge amount of data and information transmission due to the complexity involved (Kia et al., 2000). As a transhipment hub, the port has to handle large vessel volume and cargo volume very efficiently. The problem of managing data and information transmission would be even more challenging.

An electronic port community system which can enhance data and information flows is an innovative solution. Portnet, which is a subsidiary of PSA Corporation aims to achieve higher levels of productivity and efficiency in shipping processes through the integration of advance ICT and the Internet. Portnet is globally the first nation-wide business-to-business (B2B) port community solution. Through consistent flows of data and information, this solution seeks to streamline coordination among multiple parties and regulates integration and optimization among the different communities. Altogether Portnet serves several major groups of communities, namely the haulier and logistics community, the carrier community, the shipper community, and government agencies.

To achieve the objective of providing an integrative data and information solution, Portnet applies the concept of single-window system, that is, integrative one-stop service platform. A single-window system allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfill all import, export, and transit-related regulatory requirements (Lee and Lam, 2015). Portnet offers benefits to the port community by simplifying and standardizing processes through integration with various government agencies' systems as well as port users' individual systems. Such a platform allows the port to link various stakeholders involving trade to create a collaborative business environment.

Furthermore, there are various innovative functions offered by Portnet to cater to the needs of different user groups. Services by Portnet such as Cargo D2D allow customers to make better informed decisions before engaging in a shipping process due to the easy access of real-time information of freight rates of different liner shipping companies (Portnet, 2000a). Hence, this effective solution provides the benefit of allowing better control and planning. Also, efficiency increases due to the avoidance of repetitive data entries and reduction in possibility of having errors. On top of that, PSA has the Haulier Community System, which automates up to 70 percent of the port documents by integrating Portnet and haulage workflow. The Haulier Community System uses technology such as the General Packet Radio Services (GPRS) and web services in view of improving the level of efficiency in the haulage industry through offering a platform that helps to better manage their truck orders and planning of their day-to-day operations. By doing so, there will be faster submission of port documents, job deployments and also enabling almost immediate and round the clock haulage operations (Portnet, 2000b).

Portnet is also connected to Singapore's TradeNet system, which allows parties from both the private sector and the public sector to transfer accurate and timely structured messages and information through the use Electronic Data Interchange (EDI) system. This hassle-free system improves efficiency as approval for permit by the customs is significantly reduced (Portnet, 2000c). To add on, Portnet also keeps its solutions constantly up-to-date by offering new services to port users. Portnet Mobile acts as another alternative for customers to receive real-time information and interface with the community on their mobile phone (Portnet, 2000d). Critical operational information from the status of container to vessel's location can be pushed to subscribers automatically, thus, easily obtainable. Innovations as such improve customer services and better usage of resources. Through offering innovative services, PSA not only performs transhipment operations efficiently but also creates and adds value to port users' ship operations and cargo handling.

Environmental management

Maritime trade and the port sector in Singapore have experienced phenomenal growth over the past decades. For the sustainable development of the port, Singapore does not only pursue the economic and commercial strategies but also higher environmental performance. This direction conforms to the overall trend in the port industry. While port governance, shipping connectivity, and innovation are important topics, the recent years have seen growing interest in the environmental impact of port operations and development due to pressing global ecological issues. The port industry faces increasing challenges since it is subject to closer scrutiny in terms of environmental regulatory compliance. The focus on environmental issues is especially felt at the level of vessel and cargo handling operations, industrial activities in ports, port planning, and extension initiatives and hinterland accessibility (Lam and Notteboom, 2014). At the same time, providing adequate capacity, quality services and cost-effective solutions is essential. The critical issue is to strike the right balance among economic, social, and environmental values in order to achieve sustainable development of the port and the local community.

Green port policies

Tan (2002) suggested that environmental problems could only be solved through strong political will within the respective government leaderships to incorporate environmental concerns into developmental decision making and to effect a greater balance between environmental and developmental imperatives. The environmental success in Singapore stems from its highly centralized but closely coordinated approach to policy decision making (Ooi, 1994). Such political initiatives are clearly evidenced in a way which specific government ministries are charged with the responsibility of protecting the environment. For example, the establishment of the Ministry of Environment in 1972 (now known as Ministry of the Environment and Water Resources) is a clear signal of the government's early recognition of environmental concerns as a national issue. It is especially significant because back then few countries in the world had some sort of organized environmental administrations. In this sense, Singapore provides a noteworthy example of the successful integration of economic development and environmental planning and management in the port sector.

As mentioned previously, Singapore is the world's busiest port in terms of shipping traffic. Correspondingly, Singapore is active in exercising both regulatory control and incentive schemes on vessel's environmental impact. In particular, ports and shipping companies should collaborate in order to achieve sustainable outcomes (Lam, 2015). Initiated and funded by the MPA, the Green Port Programme (GPP) was started in July 2011 to motivate ocean-going vessels calling at the port to reduce the emission of pollutants like sulfur oxides and nitrogen oxides. GPP is under the overall Maritime Singapore Green Initiative for establishing a more environmentally friendly maritime sector. The incentive given by GPP is a 15 percent concession in port dues to those vessels that use type-approved abatement/scrubber technology or burn clean fuels with low sulfur content beyond the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL) during the entire port stay (of 5 days or less) within the Singapore port limits (Acciaro et al., 2014). Environment conservation is a public issue. Hence, when establishing a green port, the involvement with the public is not only indispensable but also beneficial for the port's image and community support. The Port of Singapore has web pages specifically for its Maritime Singapore Green Initiative. Increasing number of forums and seminars about sustainable development are conducted in recent years.

The Port of Singapore also monitors its carbon footprint in terms of greenhouse gas emissions and takes it as a starting point where future measures could bring the port closer to a green port. Singapore adopts a systematic footprint-monitoring project including three steps: determining emission baseline year, collecting emission data, and tracking emissions over time (Goh, 2010). Singapore also cooperates with neighboring countries to combat environmental degradation together. There is a cooperative mechanism scheme between the littoral states and the user states in managing the issues on safety of navigation and the control of vessel-source pollution in the straits of Malacca and Singapore (Rusli, 2012). These are proactive measures which show the port's commitment to environmental sustainability. It can be seen that the Singapore government and the public authorities play a crucial role in this port strategy.

In terms of legislative control to stipulate environmental standards, Singapore has ratified an IMO convention MARPOL Annex VI on air pollution and uses national laws to regulate oil-pollution casualties and dumping of wastes from vessels at the port (Lam and Notteboom, 2014). For example, heavy fines are imposed on marine oil spills. This reflects the port's directive to prevent the potential disastrous damage of oil spills on coastal and ocean environment. As De Borger et al. (2004) found, heavy penalties are indeed effective in deterring environmental pollution. Based on the various examples given above, incentive pricing and penalty measures are used simultaneously in the Port of Singapore to enhance the effectiveness of environmental management.

Tapping on the opportunity as a transhipment hub, Singapore is also the world's largest bunkering port and has maintained the highest bunker sales for many years (Lam et al., 2011). The ship bunkering sector is backed by Singapore's oil refinery and petrochemical industry, which is one of the largest in the world. Due to the large-scale operations, accident, and pollution control is particularly important. The government of Singapore exercises monitoring and quality control in this aspect. For instance, MPA stipulates the Singapore Standard Code of Practice for Bunkering by bunker barges/tankers (SS600) for documentation and equipment requirements and verification procedures during a bunkering operation.

Sustainable terminal operations and expansion

Furthermore, terminal operators also play their part in the port's environmental management, especially in the aspect of cargo handling operations. PSA has embarked on energy conservation and cleaner energy policies. The main goal of these policies is to reduce energy usage and replace fossil fuel usage with cleaner energy (e.g., electricity) in port facilities and operations. For example, the container terminals are upgraded with energy-efficient asymmetrical lighting since 2008. The upgrade replaced all conventional floodlights with asymmetrical light fittings. This system contributes to establish Singapore as a greener port by reducing energy consumption of terminal lighting. Another example is the deployment of a series of rubber-tyred gantry cranes which run entirely on electricity, thus do not generate any carbon emissions (PSA, 2014b).

As the Port of Singapore has to grow in terms of cargo handling capacity, there is a severe problem of land shortage. Being a small country, Singapore usually has to resort to land reclamation for terminal infrastructure expansion. The major conflict between port development and urban planning is the lack of suitable and sufficient land and sea space for expansion of ports (Yap and Lam, 2013). Currently, the four container terminals, that is, Brani Terminal, Keppel Terminal, Pasir Panjang Terminal, and Tanjong Pagar Terminal, are located around the areas in the city center. Concerns include traffic congestion and pollution arising from port activities in areas adjacent to ports, as well as increasing competition for land use between port and urban development. Policymakers thus face a major challenge of dealing with trade-offs. In this regard, Singapore's next-generation mega container terminal will be located in suburban area Tuas in the next ten years, and the existing terminals will be relocated thereafter (BMI, 2013). This is considered an appropriate long-term strategy for the sustainable development of the port and the city as a means to minimize the conflicts between them.

Major challenges and opportunities

This chapter has presented the success of Singapore as a transhipment hub. Notably, challenges faced by Singapore should not be neglected. The port faces greater competition from existing neighboring competitors who are capable of offering ever-improving services quality at competitive prices. Singapore should also take note of emerging ports in the region as new competing ports. Particularly, Malaysian and Indonesian ports are fast developing their infrastructure and expertise. Moreover, most of these competitors benefit from the additional advantage of being designated as national load centers which generate sufficient cargo volumes in their own right to attract direct mainline calls by liner shipping companies. In view of the economic development of these countries, the pace of growth of their maritime trade and port development would accelerate in the near future. The Port of Singapore faces major challenges due to the increasingly competitive environment.

Port competition within Southeast Asia is likely to continue to center on transhipment containers, with price being the key determinant of port choice decisions. The shipping industry has experienced oversupply and low freight earnings for a number of years. Hence, cost-cutting is a major agenda of most shipping lines at present. These shipping lines highly prefer calling their vessels at a cost-competitive port. As noted before, Singapore's terminal handling charges tend to be higher than neighboring ports in terms of monetary value. Singapore's ability to overcome the challenges it is now facing as the outcome of port competition within Southeast Asia depends significantly on its capability to leverage on the competitive and comparative advantages of each ASEAN member and to maintain its position as the region's premier maritime hub.

The very unique competitive advantage of Singapore's transhipment hub is its shipping connectivity. Therefore, it is crucial for the port to uphold this competitive advantage. This will include the need to strengthen its feeder connections in the region, bringing customers a high quality of provision across all the services provided and at competitive prices. It is an incessant task for MPA and PSA to keep close connections with the market players.

Singapore should also be proactive in seeking for future opportunities. This includes cooperating with relevant regional authorities with the purpose of trade generation. Asia is considered as the most thriving region in terms of economic integration and cooperation at present (United Nations Conference on Trade and Development, 2013). In the latest development as mentioned above, the ASEAN Economic Community shall be the goal of regional economic integration by 2015. With the promotion of free movement of goods and services, liner shipping within Asia would experience tremendous growth with the development of maritime connectivity (Lee et al., 2013). This strategy yields the advantage of creating greater opportunities for handling cargoes not just for Singapore but for all the region's major port players and to mitigate, at least to a certain extent, the detrimental impact of price competition across the region's port sector as a whole. This planned cooperative approach is also likely to bring better management of monetary resources that are presently devoted to intense port competition and enable the region's ports to engage in competition through greater economic and sustainable means.

The Singapore government is actively pursuing a policy of developing the country to achieve the status of a premier International Maritime Centre. Since Singapore will be disadvantaged to compete mainly on cost and price, developing a one-stop maritime center is a strategic approach to enhance the relative competitiveness of the Port of Singapore. This helps overcoming the intensifying port competition within the region via diversification and differentiation. The underlying principle for this policy is to move up the value chain by focusing on knowledge-intensive activities that are more difficult for competitors to emulate and, as a result, propel Singapore's maritime industry onto the next level of competence. The same higher-level activities also have the potential to generate stronger and wider positive multiplier effects for the maritime cluster and the national economy.

It is paramount to note that a premier International Maritime Centre is expected to provide a wide range of maritime services that exhibit no particular dependence on a single or narrow group of activities. Both the extent of service coverage and professionalism of these services are important. It is a challenging task to attain such a high level of sophistication, and it takes time and resources to develop the maritime services. According to Zhang and Lam (2013), there are four major types of maritime clusters in relation to their major functions. Type 1 maritime cluster focuses on cargo loading and discharging; type 2 maritime cluster focuses on value-added processing for trade and logistics; type 3 maritime cluster serves as a key node in global/regional supply chains; and type 4 maritime cluster is regarded as an international maritime service center. Singapore was classified as a type 3 maritime cluster (Zhang and Lam, 2013). The Singapore maritime industry has very vibrant port and shipping sectors. To elevate Singapore's status, the government has been focusing much effort on increasing the breadth and depth of other maritime ancillary services including marine insurance, ship finance, and ship brokering. It is a duo policy to grow the transhipment hub and maritime services at the same time.

Conclusion

High cargo volumes and shipping tonnage are generally equivalent to more opportunities of having maritime businesses for the port. For the past decades, the Port of Singapore has maintained its position as a premier transhipment hub in Southeast Asia by providing high operational efficiency and strong connectivity from which shipping lines and shippers enjoy remarkable benefits when transshipping in Singapore. The maritime cluster in Singapore as a whole has also grown rapidly. As the main port organizations, MPA and PSA have made significant efforts to enhance the competitiveness of the Port of Singapore such as encouraging innovations and sustainable development.

In summary, the analysis and discussion in this chapter provided various perspectives in order to formulate a comprehensive picture of Singapore as a transhipment hub. The Port of Singapore faces both challenges and opportunities in the future. The government and the maritime community are working hand in hand to meet the challenges and attempt to tap on the opportunities. We recommend more research on Singapore's maritime cluster in the future.

Acknowledgments

I wish to dedicate this chapter to the late Mr Lee Kuan Yew, the founding father of the Republic of Singapore. Mr Lee was instrumental in shaping Singapore into becoming the largest transhipment hub in the world. As illustrated in the chapter, the government of Singapore, under Mr Lee's leadership, takes a proactive approach and is a major driving force in port planning and development.

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3
China's Growing Engagement in the Emerging Maritime Logistics Market in Africa

Paul Tae-Woo Lee

Introduction

China's engagement in the transportation infrastructure and energy sector in Africa and South America has grown dramatically over the last two decades. Chinese companies, both state-owned and private, along with influxes of Chinese workers and capital, have spread throughout Africa (Shinn and Eisenman, 2012). In March 2013, China invested USD 10 billion into the construction of a port in East Africa, with the aim of strengthening economic relations with Tanzania and landlocked countries such as Malawi, Zambia, Democratic Republic of Congo, Burundi, Rwanda, and Uganda. In addition, in May 2014, China concluded a USD 13.1 billion investment in Nigeria for a high-speed coastal railway (1,385 kilometer of single-track line). These investments reveal the fact that as a new lender and investor China is becoming a "locomotive" developing the African economy. Indeed, China pledged to more than triple aid to Africa during the period 2006–2014. In line with economic ties with Africa, visits by President Xi Jinping in March 2013 and Premier Li Keqiang in May 2014 have increased China's political influence in Sino-African relations, demonstrating that international trade and international politics go hand in hand.

China has also been moving forward with BRICS, the economic bloc comprising Brazil, Russia, India, China, and South Africa, which is expected to generate more maritime cargo on the China–Africa–South America (CASA[1]) routes if liberalization measures among the members are effective. IBSA, an economic bloc comprising India, Brazil, and South Africa, is also closely associated with the CASA route.

Moreover, international trade between African and South American regions and between the members of the Association of Southeast Asian Nations (ASEAN) and the ASEAN–Australia–New Zealand Free Trade Area (AANZFTA) requires maritime connectivity with the CASA route. These developments have led China to expand its economic and political influence in these emerging markets. The implementation of free trade agreements (FTAs) and liberalization policies among the members of such economic blocs has contributed to a robust increase in container cargo volume and structural changes in trade patterns. As a result, a new maritime geography has emerged. Therefore we must first analyze the impact of trade liberalization on container trade volume, because container cargo flows among major trading partners are more useful for the purpose of fleet deployment management, container networking development and port capacity planning than trade value flows. Lee et al. (2008) converted trade value acquired by a global Computable (Applied) General Equilibrium (CGE) model named Global Trade Analysis Project (GTAP)[2] to trade volumes in terms of 20-foot equivalent units (TEUs). Since then, there have been a series of applications of the conversion model, including case studies of IBSA (Lee and Lee, 2012), the Economic Cooperation Framework Agreement (ECFA) between China and Taiwan (Lee et al., 2011), Korea–ASEAN FTAs (Lee et al., 2013), and Korea's FTAs (Cheong and Cho, 2013). The rest of the chapter is structured as follows. We first address China's engagement in Africa, focusing on maritime logistics, shipping, and ports. Then the trade value to trade volume conversion approach is systematically articulated. We answer the following questions:

- How are South African ports emerging on the CASA trade route in tandem with China's growing engagement in Africa?
- What would be the best location for a distribution logistics center (DLC) to promote China's engagement in sub-Saharan Africa (SSA), serving the sub-Saharan region and relaying container cargoes to South America?
- Looking ahead, what are the possible challenges and responses China is facing, and what are China's options?

China's growing engagement in the globalized economy

Recognizing the combined impacts of the two giants, China and India, Engardio (2007) acknowledged the exponential power of "Chindia": in his book entitled *Chindia How China and India Are Revolutionizing Global*

Business.[3] Growth in trade volumes and new joint ventures between Indian information technology (IT) service firms and their Chinese counterparts has accelerated to build up a formidable bilateral economy. Sheth (2008) raised two questions: How will China and India benefit the global economy? Is the rise of China and India inevitable? He concludes that the rise of "Chindia" is not only inevitable, but it will be beneficial to the world economy. Consequently, the integration between China and India will have a positive impact on global supply chains.

China's growing concerns are not limited to the above. Figure 3.1 shows members of various regional economic blocs involving the United States and China. Responding to the United States' move to develop a regional economic bloc of the Trans-Pacific Partnership (TPP), China has been making profound efforts to implement the Regional Comprehensive Economic Partnership (RCEP) in Asia, trying to draw collaboration from ASEAN, Korea, Australia, New Zealand, and India. In tandem with bilateral FTAs, these formations have been resulting in structural changes in international trade patterns, volume and flow of cargo, demands for container port capacity, and container fleet deployment. International trade and international politics go hand in hand because TPP and RCEP have been economically and politically driven by the two superpowers, the United States and China. If TPP

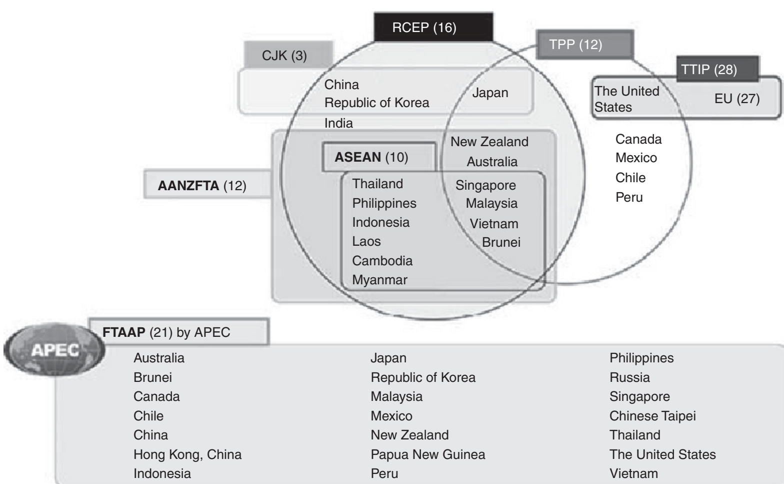

Figure 3.1 Major economic blocs with trade liberalization including free trade agreements

is viewed primarily as the roadmap to an eventual Free Trade Area of the Asia-Pacific (FTAAP), there are risks in deferring Chinese participation (Drake-Brockman et al., 2011). If the TPP chooses "open regionalism," and China is not excluded, it will contribute to regional integration. Otherwise, China will try other routes to regional leadership, and the AANZFTA will be divided into a US-centered bloc (TPP) and a China-centered bloc (RCEP), leading AANZFTA to face key challenges in politics, economics, securities, transportation, and logistics.

Furthermore, China's economic engagement with Taiwan was established in 2010 through the ECFA between Taiwan and mainland China. The ECFA has affected maritime transport and aviation thanks to its core elements of liberalization in trade and investment and economic cooperation. In particular, the ECFA has an "early harvest" clause which outlines an earlier or immediate tariff concession on particular products and services at the initial stage of trade liberalization. In tandem with "Three Direct Links" across the Taiwan Strait (see, e.g., Chang et al., 2006; Chiu, 2007; Lau et al., 2012), the ECFA has accelerated growth in direct transportation volumes between mainland China and Taiwan. Lee et al. (2011) confirmed the impact of the ECFA on maritime transportation cargo across the strait by estimating the new seaborne cargo volumes using a trade value to volume conversion model simulating the removal of the asymmetric tariff. The development of the ECFA, driven by China, has triggered several stakeholders on the CASA routes (such as shipping liners, port developers, terminal operators, logistics service providers, and policymakers) to develop proactive strategies and policy as follows:

- establishing manufacturing centers in an industrial development zone in South Africa;
- relocating existing production lines in China to South Africa;
- developing container hub port and mega-carrier services in South Africa;
- creating inland transportation corridors to connect sea ports to the landlocked countries in SSA in Africa;
- increasing transhipment networking between South Africa and South America and within the SSA; and
- determining the best location for a DLC for the SSA region.

Above all, one fundamental requirement of the above stakeholders is an estimate of container cargo volumes in terms of TEUs. Therefore, the next section introduces the container cargo conversion model.

Converting trade value to trade volume in TEUs

Although the Computable (Applied) General Equilibrium (CGE) and Global Trade Analysis Project (GTAP) models are widely adopted to analyze the economic impacts of trade liberalization, their application in maritime shipping studies concerning trade liberalization is rare. The GTAP model is a global CGE model that consists of multi-regions and multi-sectors. Its main assumptions are:

- perfectly competitive markets, that is, price-taking behavior for all economic agents;
- constant returns-to-scale technology;
- demand for primary factors based on Constant Elasticity of Substitution (CES) functions;
- Leontief functions specified to determine the demands for intermediate inputs and the primary factor composite; and
- adoption of the "Armington approach" (Armington, 1969) to determine the optimal mix of imported and domestic goods.

The first trial of converting trade value estimated by GTAP to container volume in TEUs with the help of the United Nations Commodity Trade Statistics Database (UN COMTRADE) and conversion assumptions is rooted in Lee et al. (2008). This trial aimed to estimate trade value among trading partners and convert it into trade volume in container boxes (TEUs), arguing that container box number is more important than trade value and weight when considering container fleet deployment strategy and estimation of port capacity. A literature survey by Lee and Lee (2012) shows that container cargo flow forecasts are mainly based on econometric analyses with historic time series data and business-as-usual assumptions, and there are no attempts to forecast the variations in cargo volumes resulting from asymmetric tariff removal caused by trade liberalization. As far as the increasing container trade is concerned, the forecasts should also provide details about routes (origin/destination) of commodity trade flows for better planning of maritime transport capacity and international logistics services and integrated transportation, including dry port, dedicated berth capacity, and logistics distribution centers.

Recognizing that few forecasts have been conducted with these features, the author's joint research team developed a quantitative model by integrating the GTAP model with the well-known, publicly available UN COMTRADE, which can convert container cargo trade value in monetary terms to container trade volume in terms of TEUs, and they tested the model with the following case studies:

- port economics in South Africa (Lee et al., 2008);
- container hub port in South Africa (Lee et al., 2009);
- impact of the ECFA on maritime transportation in Taiwan (Lee et al., 2011);
- impact of trade liberalization of IBSA on maritime cargo volume (Lee et al., 2012); and
- impact of Korea–ASEAN FTA on seaborne trade volume (Lee et al., 2013).

In the above studies, six types of container cargoes are estimated: export and import, gateway, transhipment (T/S), interlining, containerized, and containerizable (see the types of container cargoes estimated by the conversion model in Table 3.4).

In summary, Lee's converting approach using the global GTAP model and external computation based on the official statistics extends the CGE applications to forecast variations in cargo flows as a consequence of trade liberalization and provides an alternative predicting methodology in the field of transportation planning. Recently, Cheong and Cho (2013) applied the container cargo conversion model (hereinafter, Lee and Lee's model) to an investigation of the impact of Korea's FTA network on seaborne logistics. Lee and Lee's model is an effective tool that quantifies the impact of removing tariff rates on container cargo volumes and container cargo movements between trading partners and on the sea routes; it enables policymakers and managers to access useful information on their container port and regional shipping developments.

How to convert the trade value flow into container trade volume in TEUs

The focus of Lee and Lee's model is on the conversion of trade value flows into trade volume flows. The converting process is described with figures showing its conversion calculation steps.

> **Step 1**: *Conduct the regional and sectoral aggregations with GTAP data according to the research direction and the significance of trading partners.*

The aggregation criterion is determined by trading route and type of container cargo. For example, in the study on the impact of the ECFA on seaborne trade volume (Lee et al., 2011), the 113 regions in the GTAP database are aggregated into 15 countries/regions, consisting of Taiwan, China, Hong Kong, Japan, Korea, ASEAN 4, Singapore, Vietnam, the rest of the Asian countries, Oceania, the United States, Canada, the EU, Central and South America, and the rest of the world. Considering the early harvest list is mainly concerned with tariff removal, the 17 manufacturing sectors (sectors 26–42) in the GTAP database are disaggregated, while the agricultural and food processing sectors (sectors 1–25) are aggregated into one sector, as they are the service sectors.[4] For further details about the aggregations, see the IBSA case (Lee and Lee, 2012) and the Korea FTA cases (Lee et al., 2013).

Step 2: *Specify simulation scenarios associated with tariff removal according to level of liberalization and FTAs for a given region.*

Step 3: *Evaluate the change in trade value flows by shocking the expected changes in tariff rates.*

Step 4: *Check UN COMTRADE data.*

The UN COMTRADE data source and structure are as follows:

- data source: http://comtrade.un.org/;
- use UN COMTRADE data; and
- both trade value (USD) and weight (kilogram) are available.

Step 5. *Map between UN COMTRADE data and GTAP data.*

- Commodities in UN COMTRADE Data are classified based on Harmonized System (HS) codes or Standard International Trade Classification (SITC) codes.
- Concordances between commodities in HS2002 codes and GTAP sectors are available on the GTAP website: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1916.

Step 6: *Make assumptions about container weight (ton per TEU) by commodity type based on concordance in Steps 4 and 5.*

Lee et al. (2008) made four major assumptions and data sources for the conversion model (see Table 3.1):

- average weight/TEU data from Korean Customs Office and Stellenbosch Report;

Table 3.1 Major assumptions made for converting trade value flows into trade volume flows

Year	Average weight (ton/TEU)	Containerization ratio of the total import and export	Empty container % of the total export and import	T/S cargo % of total container cargo
2001	*Export* ConG: 13; ConA: 8; BMB: 10 *Import* ConG: 11.5; ConA: 7; BMB: 11	*Export* ConG: 68%; ConA: 63%; BMB: 8% *Import* ConG: 73%; ConA: 68%; BMB: 18%	*Export* 30 *Import* 15	10
2004	*Export* ConG: 12; ConA: 7; BMB: 10 *Import* ConG: 11; ConA: 8; BMB: 11	*Export* ConG: 70%; ConA: 65%; BMB: 10% *Import* ConG: 75%; ConA: 70%; BMB: 20%	*Export* 30 *Import* 15	10
2008	*Export* ConG: 12; ConA: 7; BMB: 10 *Import* ConG: 11; ConA: 8; BMB: 11	*Export* ConG: 72%; ConA: 68%; BMB: 13% *Import* ConG: 77%; ConA: 72%; BMB: 22%	*Export* 30 *Import* 15	10
2015	*Export* ConG: 13; ConA: 9; BMB: 11 *Import* ConG: 12; ConA: 9; BMB: 12	*Export* ConG: 75%; ConA: 70%; BMB: 20% *Import* ConG: 80%; ConA: 75%; BMB: 30%	*Export* 30 *Import* 15	20
2020	*Export* ConG: 14; ConA: 10; BMB: 12 *Import* ConG: 13; ConA: 10; BMB: 13	*Export* ConG: 80%; ConA: 75%; BMB: 25% *Import* ConG: 85%; ConA: 80%; BMB: 35%	*Export* 30 *Import* 15	25

Note: ConG: containerizable general commodities; ConA: containerizable agriculture commodities; and BMB: break bulk and minor bulk.
Source: Lee et al. (2008).

- containerization ratio (CR) of total exports and imports from *UNCTAD Maritime Report*;
- percentage of empty containers in the total exports and imports according to South Africa National Port Authority (NPA) data;
- percentage of transhipment container cargo in the total throughput from South Africa NPA data;
- additional assumptions of the containerizable ratio of major bulk and break bulk cargoes are made for converting projected trade value flows into volume flows; and
- average weight/million USD from UN COMTRADE data.

Figures 3.2–3.5 illustrate the process of converting gateway cargoes and interlining cargoes in South Africa in 2004, 2015, and 2020, based on the assumptions shown in Table 3.1. To validate the model, the 2004 data acquired by this conversion model is compared to the historical data in 2004. The 2015 and 2020 data provide estimations of trade volume in terms of TEUs. This is further explained in subsequent examples of Lee and Lee's conversion model.

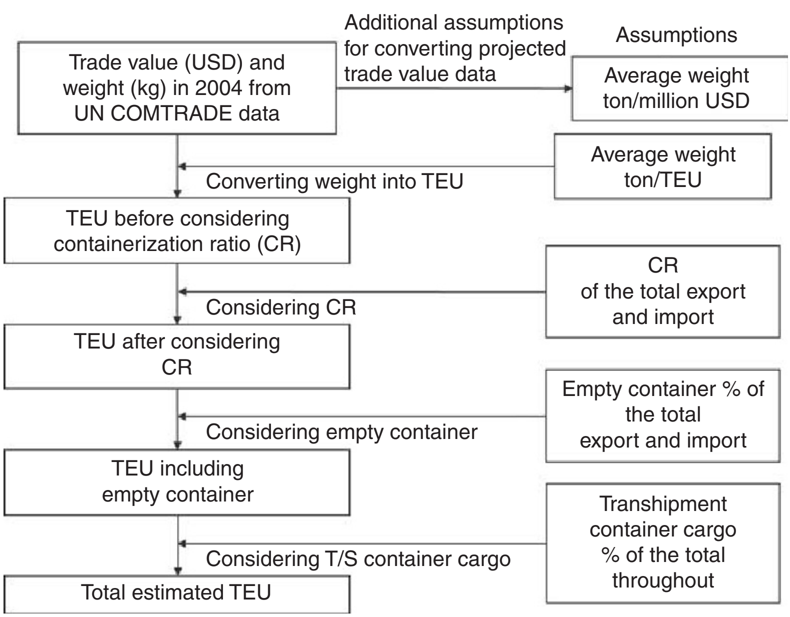

Figure 3.2 Historic data conversion in South Africa and sub-Saharan Africa, 2001 and 2004

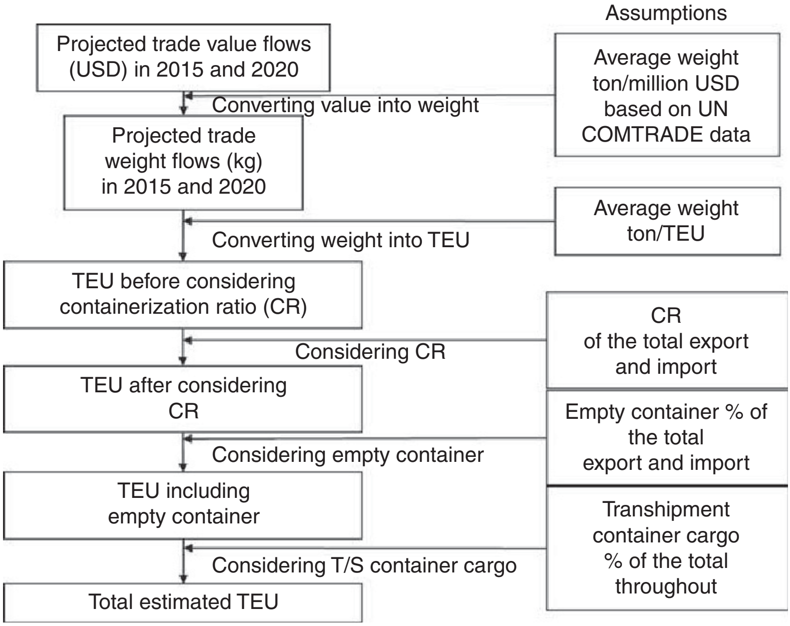

Figure 3.3 Projected data conversion in South Africa and sub-Saharan Africa, 2015 and 2020

Step 7. *Provide the changes in trade volume flows by commodity type and by route subject to required research direction and implications*

Applications of Lee and Lee's conversion model

India, Brazil, and South Africa (IBSA) have formed a regional economic bloc of free trade, leaving aside international politics. It has attracted considerable attention from world economies because the three countries are the leading economies in the continents of East Asia, South America, and Africa, respectively. In addition, freer South–South trade has been recognized as a vital engine for the globalized economy, and one that causes a substantial change in the movement of cargoes, consequently influencing demand for shipping and container port services, as well as international logistics services (Lee et al., 2012; Puri, 2007). Recognizing the significance of their trade activities and interrelationship with BRICS on the CASA route, this chapter applies Lee and Lee's conversion model to IBSA and South Africa.

As far as the increasing container trade is concerned, the forecasts should also provide details about routes (origin/destination) of

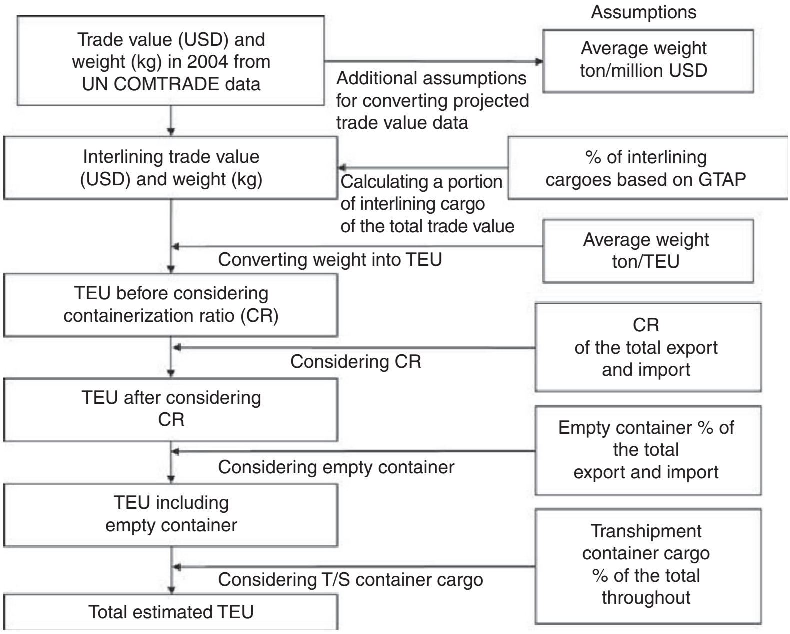

Figure 3.4 Conversion of historic interlining flows, 2001 and 2004

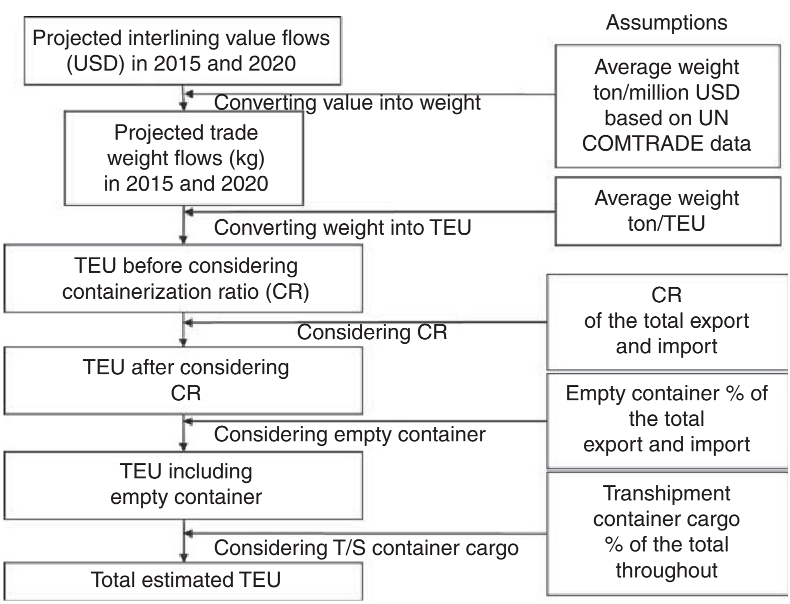

Figure 3.5 Conversion of projected interlining flows, 2015 and 2020

Table 3.2 Numerical results: Volume flows among IBSA countries (unit: TEUs)

Routes/ commodities	**Containerizable general**	**Containerizable agriculture**	**Break bulk and minor bulk**	**Sum**
Trade within IBSA countries				
India–Brazil	2,134	1,506	2,103	5,742
	(6,530)**	(1,265)*	(3,911)**	(11,705)**
Brazil–India	4,195	77,114	29,383	110,691
	(6,670)**	(1,157,475)**	(1,050,718)**	(2,214,863)**
Brazil–South Africa	8,851	57,456	17,142	83,449
	(2,301)	(35,048)*	(8,914)*	(46,263)*
South Africa–Brazil	2,001	838	7,340	10,180
	(4,123)**	(721)*	(6,239)*	(11,083)**
India–South Africa	3,891	14,639	17,997	36,526
	(10,504)**	(2,635)	(10,798)*	(23,937)*
South Africa–India	6,896	2,024	101,544	110,465
	(8,068)**	(4,332)**	(70,066)*	(82,466)*

Notes: 1. For the numerical results of value flows, see Lee and Lee (2012).
2. *Indicates a change exceeding 50 percent; **indicates a change exceeding 100 percent.
3. Numbers within parentheses are the changes in volume flow caused by IBSA liberalization.

commodity trade flows for better planning of maritime transport capacity and international logistics services and integrated transportation, including dry port, dedicated berth capacity, and logistics distribution centers. Table 3.2 shows partial results of such a test from Lee and Lee (2012). IBSA trade liberalization would increase the loaded container shipping on the six IBSA trade routes by 2.4 million TEUs. A significant increase occurs in the exports from Brazil to India (2.2 million TEUs), mostly from containerizable agricultural commodities (1.2 million TEUs) and break bulk and minor bulk (1.2 million TEUs) (Table 3.3).

In Lee and Lee (2012), the estimation of gateway cargoes in South Africa is 1.68 million TEUs in 2001 and 2.1 million TEUs in 2004 (see Table 3.4). The actual (historical) gateway cargoes in 2004 are 2.6 million TEUs. Note that the estimate is sensitive to major assumptions such as average weight, containerization ratio, percentage of empty cargoes, and percentage of transhipment cargoes. Given the fact that the major assumptions are highly reliant on real-world data, the estimate is not significantly different from the historic data. Lee et al. (2012) estimate that the projected gateway cargoes for South Africa in 2015 and 2020 are 5.5 million TEUs and 7.5 million TEUs, respectively. These figures are not significantly difference from those in the Stellenbosch Report version 14 (5.3 million TEUs in 2015 and 7.3 million TEUs in 2020, respectively). The authors estimate maximum volume of transhipment

Table 3.3 Numerical results: Volume flows between China and IBSA countries (unit: TEUs)

Routes/ commodities	**Containerizable general**	**Containerizable agriculture**	**Break bulk and minor bulk**	**Sum**
India–China	13,800	36,851	79,871	130,523
	(1,242)	(2,211)	(7,987)	(11,440)
China–India	75,671	11,291	53,697	140,659
	(–2,270)	(–5,081)	(–19,868)	(–27,219)
Brazil–China	35,438	493,346	84,651	613,435
	(–6,379)	(–49,335)	(–12,698)	(–68,411)
China–Brazil	24,818	5,131	14,986	44,934
	(1,241)	(410)	(1,199)	(2,850)
South Africa–China	10,968	4,705	48,747	64,420
	(–439)	(–47)	(–1,950)	(–2,436)
China–South Africa	18,339	10,120	29,739	58,197
	(–183)	(–304)	(0)	(–487)

Notes: 1. For the numerical results of value flows, see Lee and Lee (2012).

cargoes from SSA. The projected volumes of trade (export + import), empty containers, and transhipment cargoes are 21.4 million TEUs in 2020. The estimates of interlining cargoes represent the maximum volume, that is, the trade flows between South America and Asia, and between South America and the Middle East and India that might pass through South Africa. The estimates are 7.8 million TEUs in 2015 and 11.1 million TEUs in 2020. These figures are not significantly different from those of interlining estimates by Lee et al. (2008) (6.5 million TEUs in 2015 and 10 million TEUs in 2020).

The implications of the above test results are, first, that we can estimate several types of container cargo volume in TEUs with a scientific method, which consequently contributes to filling the research lacuna between the model and previous studies of estimation of container cargo volume (e.g., Fung, 2001, 2002; Lam et al., 2004; Mak and Yang, 2007; Moon, 1995; Zhang et al., 2005). Second, for policymakers, maritime logistics service providers, fleet managers, port authorities, and terminal operators, container volume data in TEUs are more useful than container cargo value data for the development of their business capacity plans, strategies, and policies. Finally, the estimation of a robust increase in container cargo volume on the CASA route drives the above stakeholders to consider several challenges and responses such as location of DLCs, feeder services in SSA, relay services between SSA and South America, China's strategic options including China Ocean Shipping (Group) Company (COSCO) business strategy, and

Table 3.4 Volume flows of gateway, transhipment, and interlining cargoes for South Africa in 2001, 2004, 2015, and 2020 (unit: TEUs)

Types of cargoes	**Source**	**2001**	**2004 in GTAP** / **2006 in Stellensosch V.14**	**2015**	**2020**
Gateway cargoes	*GTAP Estimates*	*2001*	*2004*	*2015*	*2020*
	Trade (Imports + Exports)	1,126,503	1,429,004	3,264,070	4,195,111
	Trade + Empties + T/S	1,680,871	2,118,707	5,487,763	7,536,123
	Historical Data		*2004*		
	Total		2,615,000		
	Stellenbosch Report V.14		*2006*	*2015*	*2002*
	Total Gateway Demand		2,809,810	5,306,878	7,296,317
Transhipment cargoes from SSA	*GTAP Estimates*	*2001*	*2004*	*2015*	*2020*
	Trade (Imports + Exports)	3,539,362	3,451,057	10,159,141	12,989,895
	Trade + Empties + T/S	4,936,367	4,880,221	15,775,496	21,428,900
Interlining cargoes	*GTAP Estimates*	*2001*	*2004*	*2015*	*2020*
	Trade (Imports + Exports)	2,119,297	2,749,449	4,704,831	6,271,239
	Trade + Empties + T/S	3,074,333	4,008,385	7,806,143	11,090,626
	Interlining Estimates by Lee et al. (2008)			*2015*	*2020*
	Trade Excluding Empties			4,120,000	6,010,000
	Trade Including Empties			6,520,000	10,040,000

Source: Lee et al. (2008).

multiple gateway port systems in South Africa. The next section considers these challenges and responses, focusing on the viewpoints of South Africa and China.

Distribution logistics centers in sub-Saharan Africa

A series of applications of Lee and Lee's conversion model to the CASA trading route confirm that SSA and South America are emerging markets in shipping, port, and maritime logistics. Table 3.5 shows container throughput in terms of TEUs of the top ten container ports in the

Table 3.5 Leading container ports in the world and sub-Saharan Africa by throughput, 2014

Rank	**Port**	**Country**	**Region**	**Container Throughput (TEU)**
Global rank				
1	Shanghai	China	Asia	35,285,000
2	Singapore	Singapore	Asia	33,869,300
3	Shenzhen	China	Asia	24,030,000
4	Hong Kong	China	Asia	22,226,000
5	Ningbo	China	Asia	19,450,000
6	Busan	South Korea	Asia	18,683,283
7	Qingdao	China	Asia	16,624,400
8	Guangzhou	China	Asia	16,160,000
9	Dubai	UAE	Middle East	15,200,000
10	Tianjin	China	Asia	14,050,000
African (sub-Saharan) rank				
1	Durban	South Africa	Sub-Saharan	2,664,330
2	Richards Bay	South Africa	Sub-Saharan	892,557
3	Djibouti	Djibouti	Sub-Saharan	864,027
4	Ngqura	South Africa	Sub-Saharan	705,377
5	Walvis Bay/ Luderitz[1]	Namibia	Sub-Saharan	339,000

Note: [1] Estimate volume.
Source: Compiled by the author.

world and top five container ports in Africa in 2014. South Africa has three of the top five container ports in SSA: Durban, Richard Bay, and Ngqura.

Rodrigue et al. (2014) evaluated the competitiveness of 60 ports by measuring degree centrality (DC), betweenness centrality (BC), and clustering coefficients (CC) of the hub and gateway functions of the ports.[5] They found that South Africa had almost doubled maritime connectivity since 2004 thanks to the development of transhipment activities and has the highest level of maritime connectivity of SSA (Rodrigue et al., 2014, p. 19). It is interesting to note that Ngqura, which opened in 2009, has the highest CC scores, implying that the port has high potential to develop maritime clustering, which has been addressed in the fifth generation port model.[6]

Another study indicating the potential of Ngqura is Caschili and Medda (2013). They applied the port attractiveness index (PAI) to African ports using three sets of determinants (endogenous, exogenous, and subjective) that influence attractiveness. Their empirical test results showed that out of 41 container ports in 23 African countries in 2006–2010, the top ten positions were as follows: Port Said, Durban, Damietta, Tangier, Alexandria, Cape Town, El Dekheila, Port Elizabeth, Ngqura, and Sokhna. South Africa has three ports on the list: Durban ranks second, Cape Town ranks sixth, and Ngqura ranks ninth. Ngqura's strength is that it has an industrial development zone (IDZ) adjacent to the port. China's dramatic economic growth has been ascribed to numerous trade zones established along its coast. Therefore, IDZs in South Africa are a magnet to China's investors, not to mention the well-established British legal system, political stability, and social security compared to other countries in the SSA. Caschili and Medda (2013) showed an interesting result from the PAI test: Nacala port in Mozambique jumped from 32nd position in 2006 to 8th in 2010 thanks to recent improvements in multimodal transport infrastructure, its strategic position (as a corridor to landlocked neighbors such as Zimbabwe, Zambia, and Malawi), reduction of transport costs, and logistics efficiency. This finding illuminates China's aggressive investment in transportation infrastructure such as seaport and railway construction in Nigeria and Tanzania.

However, in contrast to the above studies, there is a recent study suggesting a negative view of the position of South African ports in the global network. Fraser et al. (2014, p. 2) tested a central hypothesis that "Southern Africa has moved from a remote shipping region to a more central shipping region in the global network" by calculating betweenness centrality, maritime degree, and eccentricity measures of the ports over the past three decades. They showed that despite steady increases in container cargo throughput thanks to China's engagement and increased liberalization with the EU, the ports have become more remote from the global container network. This test result would not discourage foreign direct investment and China's engagement in SSA. The combination of "supply side commitment" with "demand side initiatives" (Fraser et al., 2014) will mitigate the peripherality of the ports in the global container shipping network. Demand side initiatives include China's growing engagements in the SSA, EU trade liberalization, IBSA, and BRICS, while supply side commitments are embodied by the leading role of Transnet in activating market factors (pricing and non-pricing measures), together with collaboration between Transnet and foreign terminal operators and shipping liners. These factors would accelerate China's involvement in establishing a distribution logistics center within the IDZ in Ngqura port.

The port of Maputo is also connected to Gauteng by a rail corridor. Therefore, it can be said that Durban and Ngaura compete with Maputo

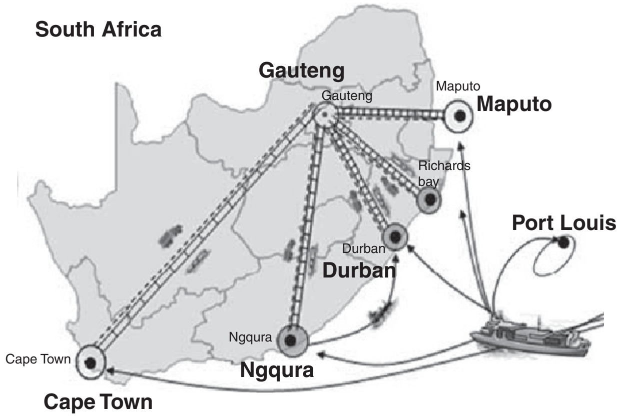

Figure 3.6 Major container port–rail link corridors to Gauteng in South Africa

because the distance of the Maputo–Gauteng corridor is the shortest among the three corridors in the same hinterland (see Figure 3.6).

In addition, Ngqura is in an inferior position to attract gateway cargoes compared with Durban because the distance of the Ngqura–Gauteng corridor is more than double Durban–Gauteng. However, out of seven ports shown in Table 3.6, although Ngqura has low scores of BC and DC, the port has the highest CC (0.51) compared with Durban (0.19) and Maputo (0.31). This implies that Ngqura is the best location to attract foreign direct investment in manufacturing or a logistics park in the IDZ adjacent to the port. In this regard, Ngqura port has the capacity to handle transhipment cargoes, relay manufactured goods to South

Table 3.6 Port centrality indexes

Port name	**CC score**	**CC rank**	**BC score**	**BC rank**	**DC score**	**DC rank**
Durban	0.1963	30	37,833	37	176	51
Cape Town	0.3090	266	5,754	272	87	253
Maputo	0.3106	270	1,173	640	33	727
Port Elizabeth	0.3737	483	2,085	515	47	549
Walvis Bay	0.4215	651	3,185	428	26	849
Port Said	0.4763	858	5,761	271	100	193
Ngqura	0.5161	1,004	367	894	31	775

Note: Excerpted from Rodrigue et al. (2014), p. 24.
Source: Calculations and elaborations of the OECD secretariat based on data from Lloyd's Marine Intelligence Unit (LMIU).

America, and provide a feeder service within SSA. Ngqura port has been a fast-growing container terminal in 2012 and 2013.[7] This implies that the more throughputs the port handles, the higher the scores for BC, DC, and CC will be. From the above observations and analysis, we draw one conclusion with some positive reservations: the best DLC location is Ngqura. One of the reservations is related to the supply side commitment (Fraser et al., 2014), which will be created by Transnet's innovative and proactive actions. Transnet is a state-owned enterprise under the Department of Public Enterprises. The strategic objectives of Transnet are, among others, to reduce the total cost of transport logistics as a percentage of GDP and to effect and accelerate a modal shift by maximizing the role of rail in the national transport system. There are five companies under Transnet: Freight Rail, National Ports Authority, Terminal Operations, Engineering, and Pipelines, as well as specialist units related to real estate and project development.

There are four major rail corridors linking ports to the hinterland in South Africa: (i) the Cape Town–Gauteng corridor, (ii) the Port Elizabeth/Ngqura–Gauteng corridor, (iii) the Natal Corridor (Natcor: Durban (Bayhead)–Gauteng (City Deep)), and (iv) the Waterberg–Richards Bay corridor. Corridors (i)–(iii) take container cargoes from each port to Gauteng. Those corridors are the essential link between ports and continental hinterlands. Efficient and reliable transport services are key factors to guarantee the attractiveness of a port–corridor combination (Fraser and Notteboom, 2014). One supply side commitment that Transnet may consider is to develop an integrated commercial pricing mechanism. For example, having rail and terminal services under the same arm of Transnet so that preferential tariffs can be applied to cargoes on the Ngqura–Gauteng route and liners carrying these cargoes. This helps not only to reduce the disadvantage of distance but also mitigate the congestion problem in Durban in peak season, encouraging liners to divert their ships from Durban to Ngqura. This is feasible and practical because complimentary port service applies in South Africa. So the following business strategy would apply to Transnet: how to develop Ngqura as a transhipment hub port in SSA and how to promote the Ngqura–Gauteng corridor in conjunction with a port pricing model and rail pricing model. In particular, a cross-subsidization approach[8] can be applied between rail and port sectors under the same arm of Transnet to mitigate the disadvantage of the corridor distance compared with the Durban–Gauteng corridor. Cross-subsidization contributes to increasing utilization of existing railway and port facilities, giving the

Ngqura–Gauteng corridor a more competitive position, as it would otherwise have to impose uncompetitively high logistics costs reflecting high haulage distance and time costs. Furthermore, a "de-congestion pricing" (DCP) model can be implemented to reduce congestion in Durban and consequently, container cargoes affected by DCP could be directed to Ngqura (Lee et al., 2011). On top of that, Transnet may need to invent non-pricing measures as a supply side commitment to attract port users to Ngqura, such as longer storage periods of transhipment containers at the dock yard. Similar incentives can be applied to dry ports in Gauteng so that container cargoes which are time insensitive or freight sensitive can be diverted from Durban–Gauteng to Ngqura–Gauteng.

International maritime logistics in Africa is organized along key trade and transport corridors originating from the ports of entry and exit to the hinterland. The various transport corridors are characterized by geography (entry ports and landlocked areas served), corridor institutional structure and the degree of competition between corridors and transport modes, short sea shipping (SSS) connections, regulatory regime, and market structure across borders in the region. Table 3.7 shows four corridors from the seaports to neighboring countries. Durban and Ngqura together with Maputo, Beira, and Dar-es-Salaam serve seven landlocked countries.

Fundamental impediments to maritime logistics in Africa are as follows:

- extremely high congestion in west African ports;
- poor inland rail and road network;
- low productivity of the trucking industry in Africa, due to infrastructure constraints;
- low levels of competition between service providers and weak infrastructure;
- underdeveloped port management information systems (cargo tracking system) and radio-frequency identification (RFID) systems;
- bureaucratic customs offices; and
- low port efficiency compared to major Asian container ports and underdeveloped SSS networks (collaboration between logistics providers and major liners).

The above factors cause high logistics costs (time and freight costs), surcharges and higher doing-business costs. To cope with the above

Table 3.7 Four key transport corridors in Africa: Ports and countries

	Corridors			
	West Africa	**Central Africa**	**East Africa**	**Southern Africa**
Main ports of entry	Abidjan, Tema, Lome, Cotonou, Dakar	Douala	Mombasa, Dar-es-Salaam	Durban, Ngqura Maputo, Beira, Dar-es-Salaam
Landlocked countries served	Mali, Burkina, Niger	Chad, Central African Republic	Uganda, Rwanda, Burundi, Democratic Republic of Congo (east)	Botswana, Malawi, Zambia, Zimbabwe, Democratic Republic of Congo (south)

impediments, a suitable DLC location in conjunction with hub/feeder service development is imperative.

China's strategic options on the CASA route

China Ocean Shipping (Group) Company, known as COSCO or COSCO Group, is a Chinese shipping and logistics services supplier. The company is the backbone of China's modern maritime history, supporting China's foreign policy over the past three decades (Lee et al., 2003) and now playing a key role in maritime transportation in the globalized world. Expansions of the maritime logistics network on the CASA route since 1990 can be briefly summarized as follows:

- Phase 1: China–Singapore–West Africa: COSCO did not call in Durban and Cape Town in the early 1990s.
- Phase 2: China–Singapore–South Africa–West Africa: since 2000 COSCO has called in Durban/Cape Town. As of June 2011, the container liner service between China and South Africa took 26–33 days from Shanghai to Durban/Cape Town.
- Phase 3: China–Singapore–West Africa–South Africa–South America: since 2010 COSCO has extended its service to South America. As of June 2011, an emerging new service line on the CASA route took 30–35 days from Shanghai to South America.

The changes in COSCO's shipping service routes between Phases 1 and 3 have been chronologically synchronized with China's Open Door

Policy in economic and international political development (Lee et al., 2003). COSCO container shipping is a key player in the expansion and promotion of maritime logistics and a catalyst to promote the CASA trade routes in the context of IBSA and BRICS FTAs and trade liberalization policies. As the development of China's maritime logistics network has been expanding thanks to China's growing engagement on the CASA route, COSCO has been transforming from cosseted national player to a global champion (Lee et al., 2003).

A key finding on the CASA route by Chen et al. (2013) shows that, out of seven major trade routes including South Africa, the Asia–South Africa route is the most important one, totaling 48 percent of market share in South Africa. The authors also observed that around 85 percent of container-ship space on Asia–South Africa routes has been assigned to ports in Greater China. As a result of reduced container-ship supply in South East Asian ports, sea freight rates in South East Asia ports are higher.

One of the ways to reduce operating losses and increase ship turnaround time at the same time is to reduce the number of ships deploying on a route. In Phase 3 of COSCO network development on the CASA route, there is one business option for COSCO to optimize operating costs; it keeps a piston service between Shanghai and South African ports (i.e., Durban, Ngqura, and Cape Town) where COSCO ships discharge all the cargo bound for South America and COSCO launches a relay service for the discharged cargo (i.e., transhipment cargoes) between South Africa and South America. On top of that, COSCO may consider feeder services in collaboration with local liners to serve the east and west coasts of SSA without following the current multiple gateway system. This idea was articulated in Notteboom (2010). He argues that shifting the current system to transhipment hub and large gateway feeder ports could generate benefits for the South African port system. The benefits that attract COSCO are, among others, to increase the turnover rate of ships on the CASA route, to reduce the number of port calls in South Africa, to increase cargo consolidation effects such as liner connectivity in the hub port, and to develop an interlining/feeder network in the SSA region. Figure 3.7 is a visual depiction of the above arguments.

Discussions and policy implications

In 2009, Transnet's terminal division TPT designated Ngqura as a sole hub port for South Africa on the basis of a series of studies (Lee et al.,

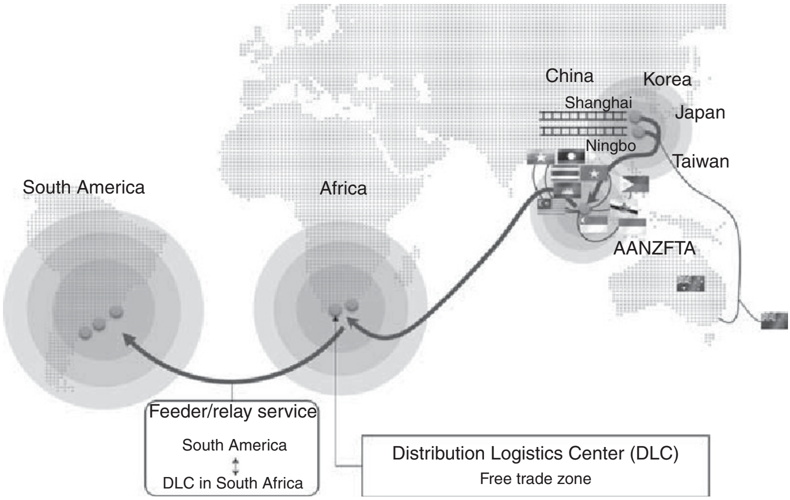

Figure 3.7 China's maritime connectivity on the CASA routes

2008, 2009, 2011). Therefore, the following service lines can extend the transhipment hub and large gateway feeder ports to become a feeder/relay service for South Africa and the SSA together with providing relay services to South America, as depicted in Figure 3.8:

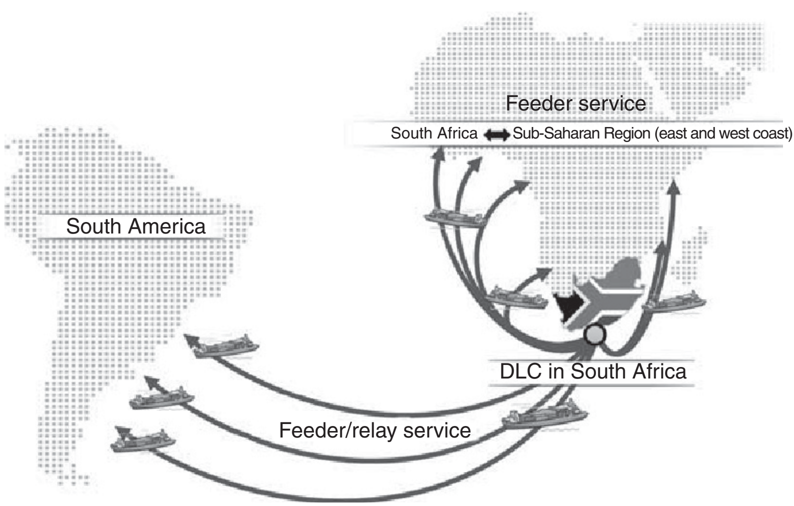

Figure 3.8 Feeder/relay service for the sub-Saharan region and between Africa and South America
Source: Lee (2011).

- for South African transhipment, a mainline to Durban/Ngqura and feeder to West SSA;
- for the South American relay service, a mainline to Durban/Ngqura and feeder/relay to Brazil.

The above two services support the argument that COSCO is expected to reduce the number of ships deploying between South Africa and South America and, consequently, to reduce operating costs and to increase ship turnaround time, enjoying economies of scale. In summary, the expected advantages to both COSCO and South Africa are as follows:

- South Africa sees the potential to provide transhipment container port capacity and a free trade zone near to Ngqura (Lee et al., 2009 and 2011).
- It is feasible to connect the SSS network and inland transportation in SSA.
- South African ports are well located to capture transhipment cargoes, interlining cargoes, and gateway cargoes.
- The CASA route covers Shanghai/Ningbo ports to Gauteng and inland corridors in SSA and a relay service to South America through transhipment and a large gateway feeder ports system.

The foregoing discussion and observations lead us to the conclusion that Ngqura transhipment hub port in tandem with a DLC could create a new dynamic maritime clustering system (DMCS) as a maritime and trade cluster. It could also be combined with manufacturing and assembly companies, a research and education center, maritime logistics players, port authority and terminal operators, shipping liners, and third-party logistics providers (3PL) (see Figure 3.9). This clustering system requires a single window system (SWS), port management information system (MIS), electronic data interchange (EDI), and RFID to establish a one-stop service and, consequently, to enjoy economies of flow, connection, and fusion technology.

The concept of DMCS broadly represents a geographical metropolitan area with its main function being a logistical platform providing appropriate logistics infrastructure and physical facilities (roads, rail tracks, terminals, and IT infrastructure) together with logistical services (warehousing, distribution, and freight forwarding). Therefore, there is

> convergence of Maritime Transport and Maritime Logistics, and this can be attributed to the physical integration of transport modes

> driven by containerisation and the evolving demands of end-users that require the application of logistics concepts to the use of these modes and the achievement of logistics goals.
>
> (Song & Lee, 2009, p. 1)

This chapter defines that statement and argues that maritime logistics does not only cover the flow of cargo, information, ideas, and money on sea trading routes, but also maritime and inland transport and logistics activities among international trading partners, applying logistics concepts to the use of these modes and the achievement of logistics goals. Therefore, it is to be emphasized that *maritime logistics and maritime transport should go hand in hand*. Additionally, as far as "connectivity" among the members of regional economic blocs – for example, TPP, RECP, ASEAN, AANZFTA, and APFTA – is concerned it can be said that *international trade and maritime logistics should go hand in hand*. As shown in Table 3.8, to achieve targeted goals we need to view global trends, the current situation, and problems and challenges in trade and maritime logistics and then establish a vision for an integrated maritime logistics system at a national and global level.

The above discussion and policy implications highlight the following challenges and responses for China:

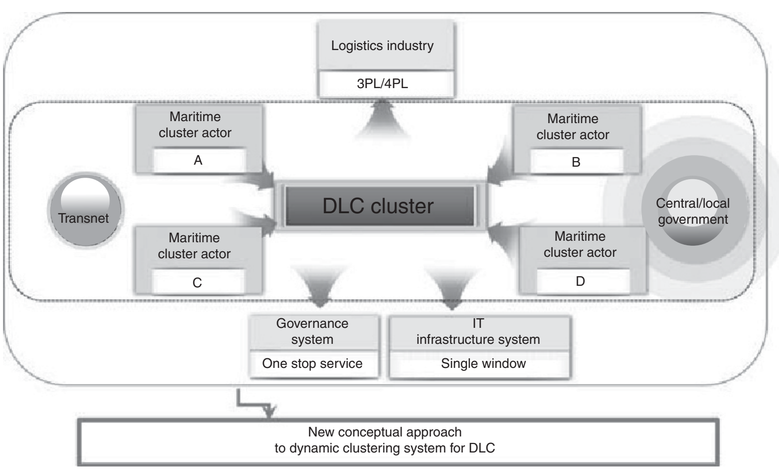

Figure 3.9 A new approach to dynamic clustering development for the logistics industry at a national level
Source: Depicted by the author.

Table 3.8 Vision for an integrated maritime logistics system at global and national level

Overview and status of the maritime transport and logistics industry

Global trend | **Current situation, problems, and challenges**

Vision for "Integrated Maritime Logistics System" at global and national level

1. To integrate a regional economy into the globalized economy: integrated transportation as driving force and enabler
2. To improve the regional trade competitive edge: lowering doing-business costs/increasing quality and efficiency
3. To maximize the impact of integrated logistics on national and regional economies: the logistics industry as growth engine
4. To integrate logistics hubs + sea and airport hubs + free trade zones: generating freight and passengers, including transhipment and transit traffic
5. To accommodate green factors for logistics and transport: green growth + sustainable growth
6. To secure the national economy from natural disaster and terrorist attack: contingency plans and resilience strategies
7. To establish two-core and one-center with FTZ (Dubai model*) or distribution logistics center: value-added and job creation
8. To apply fusion technology (IT+BT+NT) to the logistics industry: e-logistics and e-transportation platform formation
9. To build up manpower for the logistics industry: training course and manpower exchange program
10. To develop efficient governance systems for the logistics industry (e.g., single window system): role of central government as an enabler to integrate private and public sector stakeholders

Note: *The Logistics City of Dubai has developed a "Free Trade Zone Pathway" connecting the Free Trade Zone of Dubai Logistics City and the adjacent Free Zone of the Jebel Ali seaport as a single customs-bonded area.
Source: The author, regularly updated between 2009 and 2015.

- to prioritize infrastructure investment to improve the port–rail corridor network including terminals, container depots, and service companies in SSA;
- to establish a DLC in South Africa serving SSA and relaying cargo to South America;
- to develop a feeder service in West and East Africa and a transhipment hub for relaying cargo to and from South America, responding to forecasting containerizable and containerized cargo flow which can be estimated by Lee and Lee's conversion model;

- to maximize China's engagement on the CASA route (interplay between extra-Asian and intra-Asian traffic is required);
- to ensure regional blocs are connected to the CASA route;
- to cooperate with COSCO and its shipping allies to increase service frequency on the CASA route;
- to establish a logistics network including dry ports in SSA;
- to synchronize COSCO's strategy with changes in the multiple gateway port system in South Africa;
- to optimize size of ships deploying on the CASA trading routes with SSS network development for SSA and a relaying service for South America;
- to secure China's own dedicated container berths in Ngqura port in South Africa, as a gateway and transhipment hub for SSA and South America;
- to find dry ports in SSA in connection with inland transport system (corridors) to minimize transportation costs; and
- to develop integrated maritime logistics and transportation system in Africa in collaboration with COSCO's overseas logistics providers.

In September and October 2013, the Chinese President Xi Jinping raised the initiative of jointly building the "Silk Road Economic Belt and the 21st-Century Maritime Silk Road"[9] (referred to as "One Belt and One Road") when he visited Central Asia and Southeast Asia. The One Belt and One Road initiative aims to build up and promote the economic and maritime connectivity of Asia, Europe, and Africa as well as their adjacent seas. This has been accelerated by the Asian Infrastructure Investment Bank (AIIB) which is to be launched under China's leadership in 2016.[10] The "Maritime Silk Road" is "designed to go from China's coast to Europe through the South China Sea and the Indian Ocean in one route, and from China's coast through the South China Sea to the South Pacific in the other" (National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce of the People's Republic of China, 2015, Chapter III. Framework). The China's initiatives and increased engagement will affect the development of container shipping, LDCs, and maritime logistics in association with the CASA route described in this chapter.

Conclusions

Trade liberalization and connectivity developments among regional economic blocs contribute to increasing maritime cargo flows. This assertion has been supported by a series of analyses adopting Lee and Lee's model. The CASA route and port developments in SSA will be accelerated as a consequence of trade liberalization and China's growing engagement in the two continents. The exponential power of *ChinAfrica* (Michele and Beuret, 2008) and *Chindia* (Engardio, 2007) will generate more cargo movements on the CASA trade routes and an increase in the demand for deep sea shipping and international logistics services. Accordingly, opportunities to create COSCO's shipping lines to establish DLCs and SSS networks for transhipment cargoes within the SSA region and relay services between the SSA and South America are envisaged. For a container hub port and DLC in South Africa, for example, Ngqura, China (COSCO and logistics providers) needs not only to develop SSS networks to provide feeder services for East and West Africa, secure integrated inland transportation corridors in association with dry ports, but also to consider strategic options for maritime logistics and relaying services between South Africa and South America.

China's growing engagement in Africa, along with trade liberalization and increasing maritime connectivity among the members of ASEAN, AANZFTA, IBSA, BRICS, RCEP, and TPP, is expected to promote CASA trading routes in conjunction with DLC, SSS, and relay services in SSA and between SSA and South America. Transnet in South Africa has been developing strategies to build a container port hub as a transport node and to capture transhipment cargoes and/or interlining cargoes on this route. Therefore, South Africa is seen as a hub for traffic emanating from and destined for Europe, Asia, South America, and the east and west coasts of Africa.

Notes

1. The name of the CASA route does not imply that China is the origin of the route; it covers Busan Port and Kaohsiung Port, which are connected to the route service, subject to major liners' fleet deployment policies. This concept was suggested at the International Conference on International Trade and Logistics, organized by Institute of Finance and Trade Economics, Chinese Academy of Social Sciences (CASS), Jungseok Research Institute of International Logistics and Trade, Inha University, and Ningbo University, Ningbo, China, 12–13 June 2011 (Lee, 2011).
2. On the GTAP or CGE, see Lee and Lee (2012) and Lee et al. (2012).
3. A portmanteau word that refers to China and India together in general was coined by a member of the Indian Parliament, Jairam Ramesh.
4. For detailed descriptions of the countries/regions and the production sectors in the ECFA case study, see Lee et al. (2011). For IBSA, see Lee and Lee (2012).

5. For quantifiable measures of the hub- and gateway-functions of ports such as "betweenness centrality," "degree centrality," and "clustering coefficients" (see Rodrigue et al., 2014, pp. 23–4). Betweenness centrality means "position on shortest paths over the global network of container flows," and maritime degree counts "number of connections to other ports in the network" (see Fraser et al., 2014, p. 2).
6. For the fifth generation port model, see Lee and Lam (2015).
7. Ngqura Container Terminal (NCT) topped the world terminals in year-to-year volume growth. The Drewry Maritime Research Company confirmed in a 2012 study that NCT's volumes were more than doubled, peaking at 129 percent year on year, thanks to an upsurge in transhipment cargoes.
8. For an empirical case of cross-subsidization in the container port sector, see Lee and Flynn (2011).
9. As of June 2015, 57 countries joined the AIIB. But US and Japan have not joined it. Its authorized capital stock is expected to be USD 100 billion.
10. The official document of his initiatives has been published by National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce of the People's Republic of China in March 2015.

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4
Green Shipping and Ports

Young-Tae Chang

Introduction

Contemporary ports are required to operate their ports more environmentally friendly due to increasing awareness and concerns of their stakeholders arising from global warming and climate change issues. Therefore, more ports are investing in environmental facilities to respond to the needs and concerns of their stakeholders. Many countries, regions, and international organizations have adopted more stringent regulations to address air-polluting gases from ships.

Ships emit a range of gases from their operations at seas and in port areas. The emissions produced by navigation result from the combustion of fuel in internal combustion engines. The principal pollutants from internal combustion arise from two main sources: soot associated with inefficient engine technology emitting carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_X), and particulate matter (PM); and sulfur-rich fuels emitting carbon dioxide (CO_2), sulfur dioxide (SO_2), heavy metals, and PM (EEA, 2009). These pollutants can be divided into local, regional, and global effects. CO_2 is global concern as the dominant greenhouse gas (GHG) due to global warming and climate change issues. NO_X, SO_2, and PM are major concerns in local and regional areas because of their environmental impact, such as acid rain and photochemical smog and more importantly critical damage to human health. Many ports in the world are attempting to transform their activities into greener ones.

International shipping and port communities have addressed common, but differentiated green issues among GHG, noxious gases (SO_X, NO_X, and PM) and maintaining their economic efficiency. As GHG is a global issue, it has been mostly addressed in the International Maritime

Organization (IMO). Similarly, as the noxious gases are regional issues, they have been handled at both global (inside IMO) and regional levels (e.g., EU). Moreover, while the ports and shipping communities have complied with stricter regulations of IMO and regional blocs (e.g., EU) or proactively acted to follow the green rules, there is a considerable concern among shipping and port communities that these compliance activities may have damaged the economic performances of shipping and port sectors. Therefore, numerous companies, particularly in non-complying regions with IMO and EU rules hesitate to follow the rules and the proactive actions to fear that this may damage their competiveness.

Under this context, this chapter addresses the green issues that contemporary ports face. Among various aspects of green issues, recent empirical studies done by the author are explained. More specific issues are

1. how to assess the emissions of GHG in port territory arising from international shipping;
2. how to assess and reduce noxious gases such as SO_X, NO_X, and PM from the ships; and
3. how much pollution abatement costs (PACs) may have incurred while complying with stringent IMO emission regulations.

Greenhouse gases

GHG have been major concerns in the world since the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and its action plan, the Kyoto Protocol in 1997, respectively. Environmental concerns and ensuing regulations started in northern European countries during 1970s, particularly initiated by Scandinavian countries and Germany. Their major concerns were to protect people and environment in their local areas from pollutions, mostly focusing on air pollutions from vehicles traffic. The protocol delegated the duty and solution of assessing, reducing, and monitoring GHG from international shipping to the IMO when it was adopted. Since then, IMO, regional economic blocs, for example, EU and numerous developed countries have endeavored to address this issue.

IMO has been discussing various ways to reduce GHG since the authority of handling GHG in shipping was delegated to IMO by UNFCCC in 1997. The discussion meetings have been called upon inside one of its prime committees, Marine Environment Protection

Committee (MEPC), which hosts its regular meetings twice a year. Over the times, MEPC explored three measures to reduce GHG from international shipping: Technical Measure (TM), Operational Measure (OM), and Market-Based Measure (MBM). The first two measures are to control technical standard and introduce more energy/GHG efficient operational methods, respectively, whereas the MBM is to reduce GHG throughout market mechanism, particularly either carbon taxation or emission trading scheme. In other words, TM intends to strengthen the design standard of vessels from ship yards in the manner that future ships will emit much less GHG. To this end, IMO adopted Energy Efficiency Design Index (EEDI) to measure the energy efficiency of new vessels. Similarly IMO also adopted Ship Energy Efficiency Management Plan (SEEMP) for existing ships. After such a long discussion, IMO eventually reached its epoch-making protracted agreement in July 2011, at MEPC's 62 annual meeting by adopting EEDI for new vessels and SEEMP for existing vessels. Consequently, MEPC adopted TM and OM as mandatory, but MBM is still pending due to fragmented opinions among member countries. While the measures have not seemed to reach any agreement in IMO for a long time, EU adopted its own regional regulations to reduce GHG and some advanced countries followed this practice as well.

GHG can be emitted during navigation at high seas and also entering ports. While the emissions at high seas are beyond the control of sovereign countries' jurisdictions, the emissions at ports are within their territories and therefore, they can enforce their reduction plans and polices. To this end, it is critical to understand how to assess the emissions at the ports in terms of vessels types, stage of vessel movements, and characteristics of vessels. This section aims to address this issue by referring to the author's recent research (Chang et al., 2013).

Methodology and data

GHG emissions by individual vessels should be tracked at every stage of their movement from the moment of their port entry to their departure. Capturing GHG emissions across these stages and based on various vessel characteristics requires us to first estimate how much fuel a vessel consumes during its movement as the two are highly correlated. Fuel consumption by the main engine follows the cubic law of the design and operational speed. Corbett et al. (2009) and Chang and Wang (2012) apply this method to estimate GHG emissions. We adapt this to the availability of data from the port of Incheon (POI) as the approach provides for the most proper and relevant methodology in estimating fuel consumptions of vessels based on characteristics of main engines and auxiliary engines by navigating distance. The approach basically captures fuel consumptions of the engines between location points in a leg. The fuel consumption by a vessel at each stage of its port movement is denoted as:

$$F_{ijk} = [MF_k \bullet (\frac{s_{1k}}{s_{0k}})^3 + AF_k] \bullet \frac{d_{ij}}{24 s_{1k}} \tag{4.1}$$

where F_{ijk}: the amount of fuel consumed by vessel k moving from point i to j; MF_k: daily fuel consumption by the main engine; AF_k: daily fuel consumption by the auxiliary engine; s_{1k}: the vessel's operating speed (nm/hour); and s_{0k}: the vessel's design speed (nm/hour); d_{ij}: the distance from i to j.

CO_2 emissions are estimated based on fuel combustion. Although the type of fuel used by vessels can vary, it is generally accepted that marine bunker fuel (residual marine oil), a widely used type of fuel, contains 86.4 percent of carbon per unit weight. In addition, the ratio of CO_2 to carbon is known to be 44/12. Therefore, CO_2 emissions from fuel combustion can be estimated as follows:

$$CO_2 = (0.8645) \bullet (44/12) \bullet \sum_{i,j,k} F_{ijk} = 3.17 \bullet \sum_{i,j,k} F_{ijk} \tag{4.2}$$

Finally Equation (4.2) is inserted into Equation (4.1) to estimate GHG emissions:

$$CO_2 = 3.17 \bullet \sum_{i,j,k} [MF_k \bullet (\frac{s_{1k}}{s_{0k}})^3 + AF_k] \bullet \frac{d_{ij}}{24 \bullet s_{1k}} \tag{4.3}$$

The data required for estimating GHG emissions based on Equation (4.3) include fuel consumption by the main engine (MF_k) and the auxiliary engine (AF_k) based on the type of vessel and the stage of the vessel's movement, the operating speed (S_{1k}) at each stage of the vessel's movement and the design speed (S_{0k}) by vessel type, and the navigation distance at each stage of vessel movement (d_{ij}).

The data are from the Incheon Port Authority (IPA) database and include 13,829 vessels processed by the POI from January to October 2012. The set includes two navy vessels and 43 vessels with missing data; these vessels are excluded for the final sample of 13,784 vessels. Each vessel has information on the time of its port arrival, arrival point (anchorage area number) and its docking time, assigned berth number, undocking time, departure time, gross tonnage, nationality, vessel type, call sign number, cargo type, and cargo amount.

Results

General cargo vessels make the most frequent use of the POI, followed by tug boats, chemical product tankers, full container vessels, and international car ferries. Their average gross tonnages are 7,399, 171, 4,161, 11,520, and 19,119 tons. The data have no information on the operating speed during a vessel's movement after port entry, and therefore, additional data are obtained from the POI's pilot association, including vessels' operating speeds, navigation distances, and the amount of time spent during each stage of movement. The distance of a vessel's movement is calculated tracking the moving points recorded in the database with the help of the pilot association. Then the fuel consumption is analyzed at each stage of its movement, which requires data on its engine power (kwh), fuel consumption rate (g/kwh), and engine load factor. Data on the fuel consumption rate and the load factor are obtained from Chang and Wang (2012) and Corbett et al. (2009). Engine power is estimated based on European Environment Agency (2009) and Villalba and Gemechu (2011) adapted to the POI context.

Then data on the vessel design speed by vessel type are collected. Based on guidance from major shipbuilding yards in Korea and experts in shipbuilding research institutes, the data on the design speed are collected from Significant Ships (Royal Institution of Naval Architects, 1997–2001). Figure 4.1 shows the results for fuel consumption based on the type of vessel and the stage of the vessel's movement. These show that international car ferries have the highest fuel consumption, followed by full container vessels and car carriers, although car carriers have the highest fuel consumption per vessel, followed by international car ferries and passenger vessels. Based on Equation (4.3), CO_2 emissions by vessel type and movement are estimated (Figure 4.2).

The CO_2 emissions at POI for ten months in 2012 are 370,000 tons; a result clearly different to the findings of studies by the Korea government and research institutions. The Korea Ministry of Land, Transport and Maritime Affairs (2008) and its research arm, the Korea Maritime Institute (KMI) (2009), estimate CO_2 emissions from the POI based on a top-down approach. The KMI approach estimates aggregated fuel consumption of the port based on a survey rather than tracking individual vessels' fuel consumption as this study has conducted. Then the KMI approach simply multiplies the fuel consumption by a conversion factor between fuel consumption and CO_2 and identifies 86,000 tons.

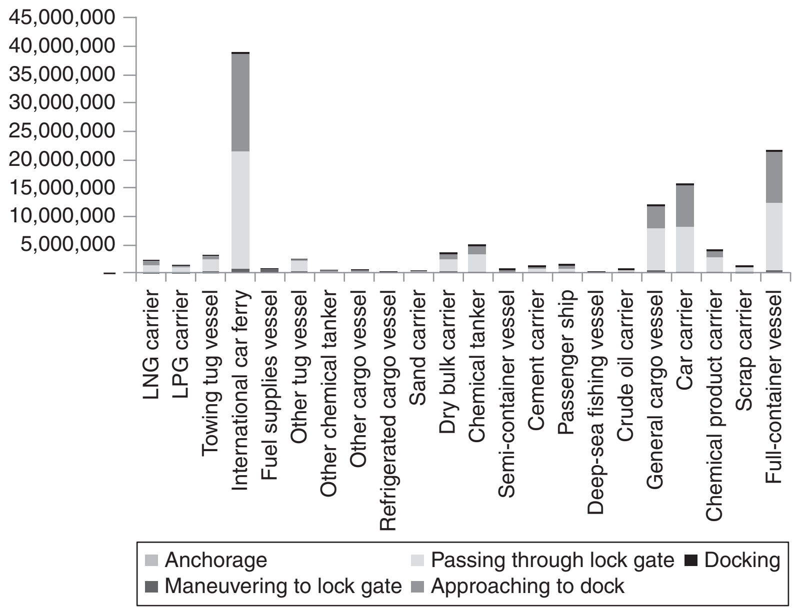

Figure 4.1 Estimation of fuel consumption by ship type and movement (unit: tons)

Our data cover ten months in 2012, but extrapolation of the results to cover a full year show approximately 440,000 tons CO_2; almost five times greater than that estimated by the Korean government and the KMI.

This clearly indicates that the top-down approach taken by the Korean government and the KMI underestimates CO_2 emissions for the POI because this methodology cannot capture individual vessels' characteristics and movement within the POI territory. In addition, it can be seen from Figure 4.2 that vessels passing through lock gates emit 210,000 tons of CO_2. Maneuvering to the dock after lock gates accounts for 140,000 tons. Therefore, these two activities account for 96 percent of the POI's CO_2 emissions. By contrast maneuvering to lock gates after port entry produces only 11,000 tons. The docking process for cargo handling accounts for a negligible portion of CO_2 emissions (2,400 tons of emissions). This is somewhat surprising in that numerous ports have attempted to install alternative maritime power (land-based electricity) to reduce GHG emissions during the docking process.

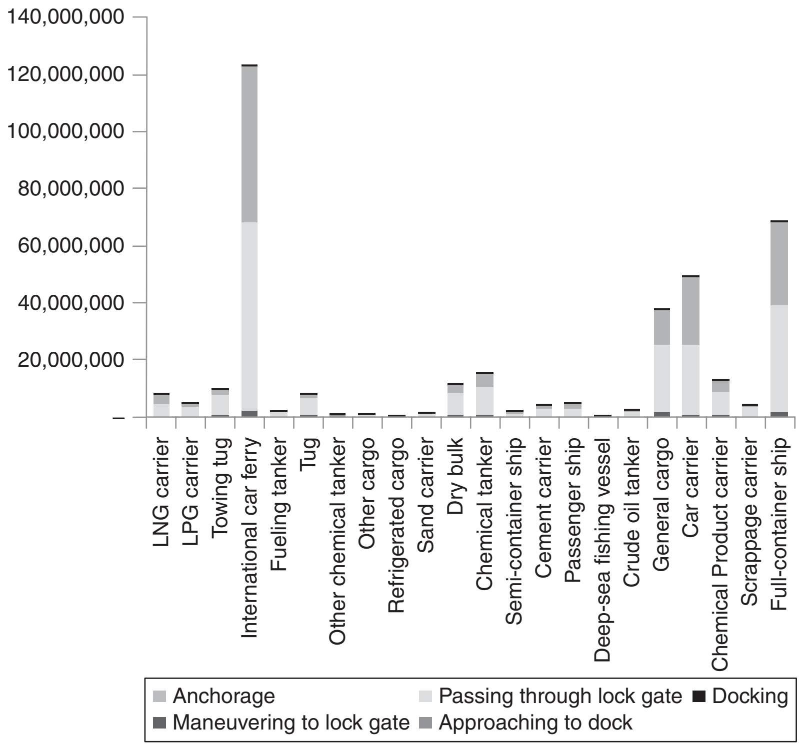

Figure 4.2 Estimation of CO_2 emissions (kg) by ship type and movement

This study presents some important implications for policy formulations and future research. First of all, policy formulation to reduce GHG in ports should be based on bottom-up approach as the results of this study using the bottom-up approach were different by a magnitude of five compared to the one by top-down approach. International organizations including UNFCCC and IMO recommend to use the top-down approach at the initial stage of assessing GHG emissions or when collecting the bottom-up approach data is infeasible or difficult. Even if this top-down approach can be used in such constrained circumstances, it should be always emphasized that the results by this approach can underestimate the true amount of the GHG emissions. Therefore, the results of the top-down approach should be used only for the initial stage temporarily, but be replaced by the bottom-up approach whenever possible. Moreover, when governments attempt to adopt action plans to reduce GHG emissions, they need to understand the detailed inventory of GHG at ports in terms of types of vessels, movement stages of the vessels, and other characteristics of vessels and port operations. For this purpose as well, the bottom-up approach can provide more useful information and therefore, more effective policy directions. As far as the future research, automatic identification system (AIS) data should be collected for more accurate capturing the vessel movements at ports. Though this study is based on the information provided by pilot association regarding vessel-operating speed and navigation distance for each ship, the information can be still biased due to human errors describing the information based on the pilots' experiences rather than more scientifically recorded data system such as the AIS. Therefore, future research can be directed to use the AIS data and compare the results with those of this study.

Noxious gases: NO_X, SO_X, and PM

IMO adopted Emission Control Areas (ECAs) to regulate SO_2, NO_X, and PM for environmental protection on a local and regional level. Its first designated ECAs are the Baltic Sea and North Sea with respective entry into force on 19 May 2006 and 22 November 2007. IMO's second ECA is the North American ECA including most of the US and Canadian coast with entry into force in 2011. Ships navigating in these ECAs should use marine fuels with a maximum of 1 percent sulfur by weight. The sulfur content limit in the ECAs will be lowered to 0.1 percent on 1 January 2015. In addition, ships navigating in all other international waters have to use marine fuels with a 3.5 percent sulfur content as of 2012 (cut by 1 percent from previous 4.5 percent) and the limit will be lowered to 0.5 percent as of 2020 according to IMO regulations (Madsen and Olsson, 2012).

While noxious gases (NGs) – SO_2, NO_X, and PM – have been more regulated stringently in Europe and North America by designating the ECAs, NGs are not considered a major concern in Asia and other continents because these continents have not designated any ECAs. An assessment of the emissions of NGs by ships to consider the designation of ECA(s) is of paramount importance, particularly in Asia because this region has most of the top ranking ports in the world. Therefore, the maritime traffic intensity is highest. Moreover, the region is most densely populated along the coastlines in the world, and so the impacts of NGs on their environment and coastal residents must be as high as, or higher than, those in Europe and North America.

The author assessed the emissions of NG in the most detailed micro-level using the data of all vessels that used the POI in Korea in 2012 (Chang et al., 2014). The POI is the gateway port to the capital region of Korea including Metropolitan Seoul, Incheon, and Kyounggi Province with a population of 24 million comprising 49 percent of the national population and handles more than 150 million tons of cargo and fast-growing container cargo in recent years amounting to more than 2 million TEUs. The POI plans to expand its container terminals massively in the near future to be on par with its counterpart container ports in China across the Yellow Sea, such as Qingdao, Dalian, and Tianjin. The POI area can be considered as a most likely potential ECA in Korea in the future because of its heavy maritime traffic and densely populated coastal areas. In particular, this section estimates the NG emissions based on the type of vessel and the movement of vessels from port arrival. The geographical scope of this study was 25 nautical miles from the main dock areas of the POI because this distance is the vessel traffic control area of the POI. Furthermore, the emissions at this distance directly affect the coastal residents according to environmental experts. Vessels entering the POI typically pass through two lock gates to approach their assigned berths at the main port due to the 9-meter tidal difference.

Methodology and data

Similar to the GHG estimation, the NG emissions are estimated by individual vessels at every stage of their movement from the moment of port entry to their departure. To capture fuel consumption and corresponding NG emissions across these stages and based on various vessel characteristics, Equation (4.1) is used again.

Once the fuel consumptions are estimated, the NG emissions are estimated using the most detailed methodology developed by the European Energy Agency (EEA, 2009), so-called the Tier 3 approach. Equation (4.4) shows the calculation method using the Tier 3 approach of (EEA, 2009) covering an individual vessel's entire trip to a port area and segmenting the trip movements into cruising, maneuvering, and hoteling.

$$E_{trip,k,p,g,f} = \sum_{m} (F_{g,f,m} \times EF_{p,g,f,m}) \tag{4.4}$$

where,

E_{trip}: emission over a complete trip (ton) of vessel k
$F_{g,f,m}$: amount of fuel consumed by vessel k
EF: emission factor

p: pollutant (NO_X, SO_2, PM)
f: fuel type (bunker fuel oil, marine diesel oil/marine gas oil, gasoline)
g: engine type (slow-, medium-, and high-speed diesel; gas turbine, and steam turbine)
m: different phase of the trip (cruise, hoteling, maneuvering)

The research team used the data set obtained from the IPA and explained in previous section covering up 13,829 vessels processed by the POI from January to October 2012.

To estimate the NG emissions using Equation (4.4), data on the parameter values of the emission factor by the engine type, fuel type, and movement phase were collected from (EEA, 2009). The study also shows the percentage of fuel types used by the different ship category. Using this information, it was assumed that most ships use bunker fuel oil (BFO) except for fishing vessels and tug vessels, which use mostly marine diesel oil (MDO) or marine gas oil (MGO).

Results and discussions

The emissions of SO_2, NO_X, and PM of the individual vessel over the segmented movements were estimated using Equation (4.4). Table 4.1 lists the total amount of each pollutant over the movement. POI emitted 990 tons of SO_2, 1,551 tons of NO_X, and 142 tons of PM in 2012. The amounts of sulfur emissions in this study were somewhat similar to those reported elsewhere (Wang and Corbett, 2007) in terms of the emission-to-fuel consumption rate. The per vessel emission

Table 4.1 Total emissions of SO_2, NO_X, and PM over the vessel movement phase (unit: ton)

	Cruise	Anchorage*	Maneuvering	Approaching to dock	Docking	Total emission	Average per vessel
SO_2	811	0.02	99	40.1	39	990	0.072
%	82.0	0.0	10	4.0	4.0	100	–
NO_X	1,341	0.03	118	43.9	48	1,551	0.112
%	86.5	0.0	7.6	2.8	3.1	100	–
$PM_{2.5/10}$**	109	0.0	21	8.1	5.2	142	0.010
%	76.2	0.0	14	5.7	3.6	100	–

Note: *This phase refers to vessel movement of starting maneuvering from the anchorage to passing through the lock gates.
**$PM_{2.5}$ and PM_{10} have the same emission factors from the study by (EEA, 2009).

was 72 kg of SO_2, 112 kg of NO_X, and 10 kg of PM, whereas 82 percent of SO_2, 87 percent of NO_X, and 76 percent of PM emissions occurred during the cruise phase. The emissions of SO_2, NO_X, and PM were considerable during the maneuvering phase, showing 14 percent, 10 percent, and 20 percent, respectively. A study by the EEA (2009) revealed the same emission factor for both $PM_{2.5}$ and PM_{10} so the same amounts are emitted. Despite the public concern regarding emissions during docking/hoteling phase, the portion of emissions for all pollutants at this phase were insignificant, comprising 4–5 percent of the total emissions compared to the other movement phases. The findings in Table 4.1 can be summarized as follows: SO_2 and NO_X emissions are dominated by the high-speed vessel operation phase. PM is also emitted mostly in a high-speed phase, but they showed considerable amounts of emissions during the low-speed maneuvering phase, being the highest during the slow-speed operation among the three pollutants.

Figures 4.3, 4.4, and 4.5 show which vessels contribute more to the inventory of SO_2, NO_X, and PM and in which vessel movement phase. Regarding the SO_2 emissions in Table 4.1 and Figure 4.3, international car ferries are the highest polluters in both the total amount and per vessel amount. The next highest polluters in the total amount were full container vessels, general cargo vessels, car carriers, and chemical tankers in that order, and the order of the per vessel amount after international car ferries was LNG carrier, passenger ship, car carriers, and full container vessels. The estimation results of SO_2 according to the vessel type and movement suggested that the POI should consider introducing a speed-reduction zone in its future potential ECA to reduce the emissions during the cruise phase, which has been implemented in some countries, for example Ports of Los Angeles and Long Beach in the United States. The results of NO_X and PM also showed a similar pattern to that of SO_2 in terms of the major contributing vessel group to the inventory. International car ferries, full container vessels, and car carriers were the major polluters in both the total amount of NO_X and per vessel amount. The other notable vessel groups are general cargo vessels, tug vessels, and chemical tankers in the total amount and crude oil carrier, dry bulk carriers, and passenger ships in the per vessel amount. Again, international ferries, full container vessels, and car carriers were the major contributors to PM in both the total amount and per vessel amount together with dry bulk carriers. General cargo vessels and chemical tankers are also major polluters in total PM emissions as are crude

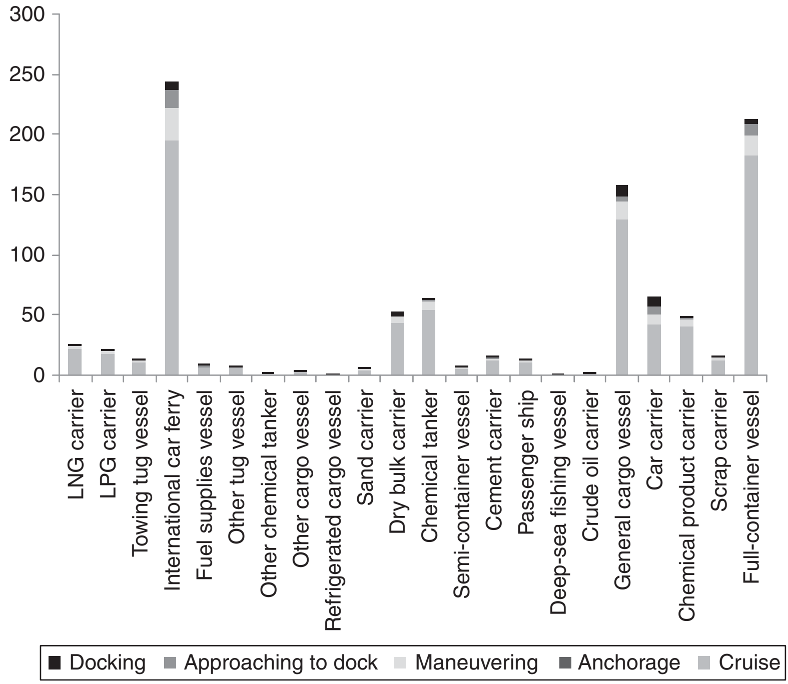

Figure 4.3 Estimation of SO_2 emissions (ton) according to the ship type and movement

oil carriers and passenger ships in per vessel PM emissions. The common phenomenon over the three pollutants is that five groups of vessels, namely international ferries, full container vessels, general cargo vessels, car carriers, and chemical tankers comprise 70–76 percent of their respective total emissions. This suggests that future reduction measures should be focused on these groups of vessels. In addition, all passenger vessels showed high per unit emissions for all three gases, whereas dry-bulk carriers showed high SO_2 and NO_X emissions, crude oil carriers showed high NO_X and PM emissions, and LNG carriers showed SO_2 emissions. As the IPA plans to expand its international ferry and cruise terminal in the near future to accommodate mega-size ships, this will contribute unprecedented amounts of NGs to the inventory due to the high-emission factor of vessels. One of the commonly adopted approaches by advanced economies to reduce the NGs is to designate an ECA in the POI area.

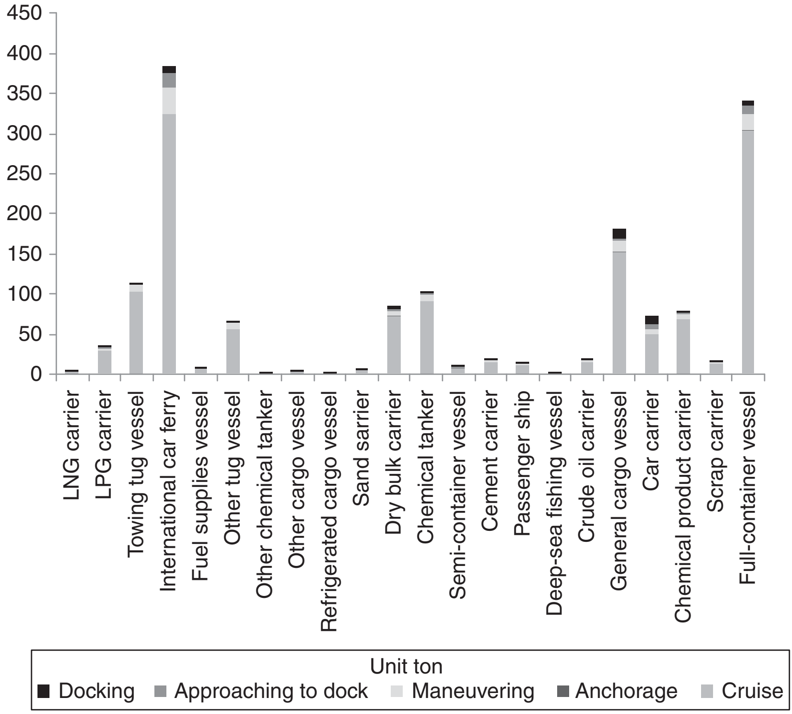

Figure 4.4 Estimation of NO_X emissions according to the ship type and movement

The chapter examined how much the emissions can be reduced in a future ECA of the POI with three scenarios:

1. if a speed reduction is implemented with a 12 mile speed limit within the 25 mile zone similar to the Los Angeles and Long Beach case;
2. reducing the sulfur contents with two options of 1 percent; and
3. reducing the contents to 0.1 percent.

The 1 percent sulfur limit in marine fuel is the current rule in the ECAs but the 0.1 percent rule will be imposed from 2015. Table 4.2 lists the results. The speed reduction zone can reduce the NG emission by one third. More reductions can be realized in NO_X. When the sulfur content limit is enforced in the ECA, the 1 percent current rule is expected to reduce the emissions by approximately 70 percent and 0.1 percent

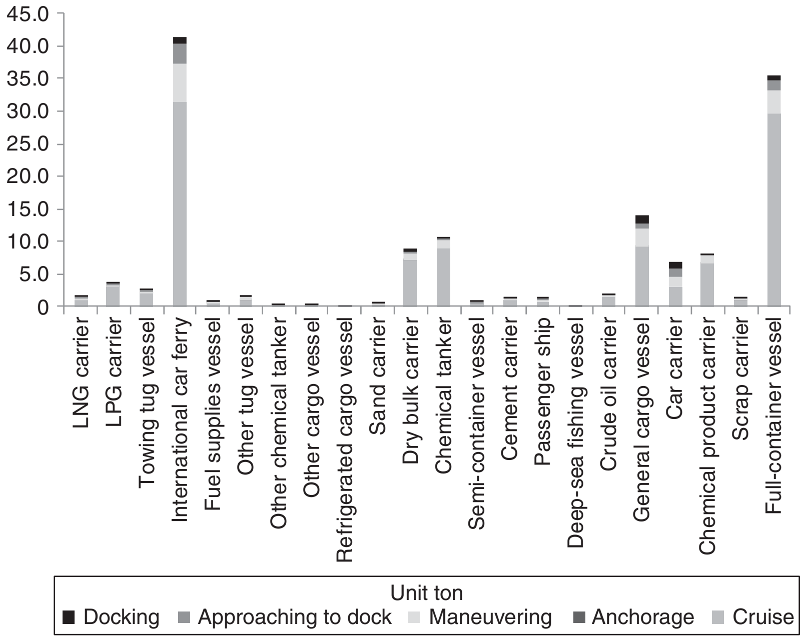

Figure 4.5 Estimation of PM emissions according to the ship type and movement

rule is expected to reduce the emissions remarkably by 93 percent. This chapter could not estimate the results of NO_X and PM reduction using lower sulfur fuel because this approach was based on the Tier 3 approach of the EEA (2009), which does not provide estimates of NO_X and PM when using lower sulfur fuels in the Tier 3 approach.

Table 4.2 Reduction of NG emissions in a future ECA with various measures (unit: ton)

	Current	**RSZ***	**RSZ****	**ECA (1.0%)+**	**ECA (1.0%)**	**ECA (0.1%)+**	**ECA (0.1%)**
SO_2	990	668	32.47%	404	59.18%	68	93.16%
NO_X	1,551	1,021	34.14%	–	–	–	–
PM	142	97	31.67%	–	–	–	–

Notes: *Reduced Speed Zone (RSZ) with 12 knots speed limit is enforced within 25 nautical mile zone.
**Reduction percentage with RSZ system.
+1 percent or 0.1 percent sulfur content regulation is enforced in an ECA.

The message from the findings is clear. If POI plans to reduce the NG emissions, the best option will be to designate POI as a new ECA. However, as the designation of ECA is not a local decision, but rather country or regional decision as in existing ones such as North Sea, Baltic Sea, and North American ones, this is unlikely to happen by the sole decision of POI. Instead, POI can adopt speed-reducing policy in its territory as this policy can reduce the emissions almost by one third. In addition, POI should monitor major polluting vessels more closely. The five groups of vessels, namely international ferries, full container vessels, general cargo vessels, car carriers, and chemical tankers contributed 70–76 percent of the total emissions. In view of ongoing developments of ferry and cruise terminals, and container terminals at POI, it is clear that the emission level at POI will be aggravated in the future when the newly developed terminals are in full operation. Addressing the trade-off issue between further development of commercial activities at POI through the new terminals construction and sharply increasing NG emissions arising therefrom should be an important agenda for POI. One plausible solution to these problems can be introduction of more clean fuel ships, for example, LNG bunkering ships together with the speed reduction policy. It is reported that Korean government explores the possibility of switching vessels fuels from currently dominant high sulfur oils to LNG by building LNG providing facilities at major seaports including Incheon, however they are unsure if this change can be economically justifiable. To examine this issue, they should assess inventory of NG, possible reduction of NG by adopting the policy and their respective benefits to society attributable to improved health benefits. This task requires us to build an integrating model to connect the emissions from vessels as in this study, dispersions and concentration of the emissions, impact of the concentrated emissions on human population in the areas affected by the emissions and finally the monetizing the human impacts in social costs and benefits. This way, the socials benefits and costs can be compared to derive optimal policy. This is beyond the scope of this chapter, but needs to be studied in the future. To this end, collecting AIS-based data again will be more useful similar to the case of estimating GHG described previously.

Pollution abatement costs of EU ECA

Ships entering ports in ECA areas must burn fuels with much lower sulfur levels and run engines that are cleaner and more efficient than what is allowed in non-ECA areas to comply with the ECA regulations. ECAs have been adopted by IMO only in EU sea areas (Baltic Sea and North Sea) and North America (the United States and Canada). The rest of world seems either unaware of its importance or aware, but concerned with its potential economic impact. For instance, Hong Kong has attempted to push Chinese government to apply for ECA in Pearl River Delta area, but actual attempts have been protracted thus far (Wang and Feng, 2014). It is reasonable to assume that ECA ports have suffered considerable financial losses since the implementation of ECA rules due to the system's stringent regulations. This section measures the PAC at ports in currently designated ECAs. Specifically, it measures how many foregone cargoes and passengers may have been incurred at the ports due to the ECA regulations. Environmental directional distance is derived using data envelopment analysis. National panel data are collected on input variables (including capital, labor, and fuels) as well as on the good output variable (port throughput in passenger and cargo) and bad output variables (SO_2 and NO_X) of the ports that have implemented the ECA regulations.

Methodology

This section builds on the environmental directional distance functions developed by Färe et al. (2007a) by changing their models from additive ones into multiplicative ones. Some fundamental concepts must be explained before we proceed to abatement cost calculation. First, we define the producers' inputs as $x = (x_1, x_2, \ldots, x_N) \in R_+^N$ and the good outputs as $y = (y_1, y_2, \ldots, y_M) \in R_+^M$. Bad outputs $b = (b_1, b_2, \ldots, b_J) \in R_+^J$ are generated through production. Environmental production technology is expressed as $P(x) = \{(y, b) : x \text{ } can \text{ } produce \text{ } (y, b)\}$, where $x \in R_+^N$. Thus, each producer can produce y given the fixed level of x, but the production process also generates the undesirable by-product b. Färe et al. (1989) proposed two axioms to characterize bad outputs: null-jointness and weak disposability. Null-jointness is the relationship that, if $(y, 0) \in P(x)$, then $y = 0$, implying that no amount of output can be produced without discharging bad outputs. Weak disposability means that, if $(y, 0) \in P(x)$, then $(\theta y, \theta b) \in P(x)$ for $\theta \in [0, 1]$, implying that pollution abatement activities should be accompanied by the contraction of output levels.

On this basis, Färe et al. (2007b) explain that PACs can be calculated through the environmental directional distance. We start with the environmental directional distance function model, in which regulation is imposed on every producer:

$$
\begin{aligned}
& D_o(X_o, Y_o, b_o; g_y, g_b) = \max \beta_o \\
& s.t. \sum_{k=1}^{K} \lambda_k y_{km} \geq y_{om} + \beta_o g_{ym},\ m = 1, 2, \ldots, M \\
& \sum_{k=1}^{K} \lambda_k b_{kj} = b_{oj} - \beta_o g_{bj},\ j = 1, 2, \ldots, J \\
& \sum_{k=1}^{K} \lambda_k x_{kn} \leq x_{on},\ n = 1, 2, \ldots, N \\
& \gamma_k \geq 0,\ k = 1, 2, \ldots K
\end{aligned}
\tag{4.5}
$$

Here, X_o, Y_o, and b_o denote the inputs, outputs, and bad outputs respectively for the oth producer. The left-hand sides of the constraints represent the ideal points on the production frontier that the oth producer should benchmark to improve efficiency. The g_y and g_b variables are the direction vectors of the improvements needed to reach the frontier, while β_o denotes the inefficiency of the oth producer, indicating how much the oth producer can expand the good outputs and contract the bad simultaneously given current input levels. Note that the weak disposability axiom is incorporated in the second constraint: if we fix β_o and lower b_{oj} by $\theta \in [0, 1]$, $\sum_{k=1}^{K} \lambda_k y_{km}$ also declines by θ, thereby limiting the potential good output expansion of the oth producer. The second constraint plays a crucial role in reflecting regulation, for the producer cannot produce good outputs limitlessly, without considering the environmental impacts.

Next, the environmental directional distance function without regulation is formulated as

$$
\begin{aligned}
& DU_o(X_o, Y_o, b_o; g_y, g_b) = \max \beta_o \\
& s.t. \sum_{k=1}^{K} \lambda_k y_{km} \geq y_{om} + \beta_o g_{ym},\ m = 1, 2, \ldots, M \\
& \sum_{k=1}^{K} \lambda_k b_{kj} \geq b_{oj} - \beta_o g_{bj},\ j = 1, 2, \ldots, J \\
& \sum_{k=1}^{K} \lambda_k x_{kn} \leq x_{on},\ n = 1, 2, \ldots, N \\
& \gamma_k \geq 0,\ k = 1, 2, \ldots K
\end{aligned}
\tag{4.6}
$$

The overall structure is similar to that in model (4.5). In the second constraint, however, producers are allowed to freely dispose bad outputs while expanding good ones. It is thus reasonable to expect that each producer will make decisions based solely on the maximum good output attainable given fixed input levels rather than on the environmental impacts. Färe et al. (2007a) use their additive model by setting $g_y = 1$ and $g_b = 1$ to allow a straightforward interpretation. In their model, β_o is interpreted as the exact number of good outputs that are expandable and of bad outputs that are reducible. However, the additive model suffers from bias arising from different scales of input and output values, as pointed out in Färe et al. (2007a). To eliminate this scale bias, we adopt a multiplicative model by setting $g_y = y$ and $g_b = b$, as the scale or unit of each good and bad output is different. Then, the resultant β_o is interpreted as the maximum proportion by which all good outputs are expandable and all bad outputs are reducible simultaneously relative to the current level (y, b).

Data collection and results

Our variable selection is based on data availability, theoretical necessity, and ECA representations. We had planned to use data on relevant input and output variables concerning individual ports in the EU's ECAs, but data availability constraints made this impossible. We therefore assess PACs at the country level. Though assessing PAC by country does not allow detailed analyses of individual ports, doing so is still valid because Europe's ECAs are implemented based on regional seas, and implementation has thus been homogeneous across the entire region. Seven variables are used in our study: fuel consumption in the port areas, employees in the port sector, the amount of maritime port investment in inputs, passenger and cargo throughput for outputs, and NO_X and SO_X emissions in the port areas for bad outputs. Fuel consumption is a key input in maritime transportation. Employees and port investments are included to reflect labor and capital utilization. Passenger and cargo throughput are major outputs representing ports' efficacy, and NO_X and SO_X are added to measure the environmental performance of each nation.

The UNFCCC report (UNFCCC, 2013) was used to obtain fuel consumption and NO_X and SO_X emission data. The report's data offer fuel consumption and emission data for international navigation; however, these are based on entire shipping journeys from departure to arrival, thus covering fuel consumption not only within the ECAs but also beyond. To estimate fuel consumption strictly within the ECAs, we reviewed the relevant literature and reports. The most useful source was Tzannatos (2010), which calculated the 2008 in-port maritime fuel consumption in Greek waters. Using this source, we calculate the ratio of in-port consumption along with the UNFCCC's consumption data for Greece, arriving at around 0.66; thus, 66 percent of fuel in international navigation was consumed in Greek coastal areas. It is assumed that all other countries in the EU ECA areas covered in the UNFCCC report have the same portion of coastal fuel consumption relative to the total for international navigation. Using this ratio, the international navigation fuel consumption of each country in the UNFCC report is estimated. Domestic shipping emission data were also collected from the European Environmental Agency database (http://www.eea.europa.eu/). Fuel consumption from domestic navigation is estimated by multiplying the domestic NO_X/international NO_X ratio by international fuel consumption. Here, SO_X is not necessarily highly correlated with the amount of fuel consumption. For example, ships can reduce their SO_X emissions by changing fuel types while maintaining their fuel consumption rates. Although NO_X emissions also depend on fuel type, there is a stronger correlation between fuel consumption rates and NO_X emissions.

The number of employees is estimated as follows. First, employment data for coastal areas are estimated using information about populations in coastal areas and employment rate data in the Eurostat database (http://ec.europa.eu/eurostat). Then the proportion of port employment relative to overall coastal employment is estimated using several reports on ECA ports. Employment data covering Belgian ports in 2011 (National Bank of Belgium, 2013), UK ports in 2010 (UK Department for Transport, 2013), and Danish ports in 2009 (Institute of Transport and Maritime Management Antwerp, 2010) were collected. Port employment is then divided by coastal employment. The port sector accounts for an average of 0.8 percent of overall coastal employment. This ratio is used to estimate the port employment of other nations. Finally, passenger and cargo throughput data are collected from the Eurostat database.

As mentioned, the PAC results are estimated by country over the six years between 2006 and 2011. Germany and France are the major contributors of the total passenger PACs. Their loss of passenger output ranges from 59 to 74 percent over the six years because of the environmental regulations. Cargo losses are much higher, with an overall range of 85 to 103 percent.

Figure 4.6 shows the total PAC/output ratios. It shows a remarkable increase in PAC between 2006 and 2007, likely attributable to the expansion of the ECA area to the North Sea region in July 2007: the

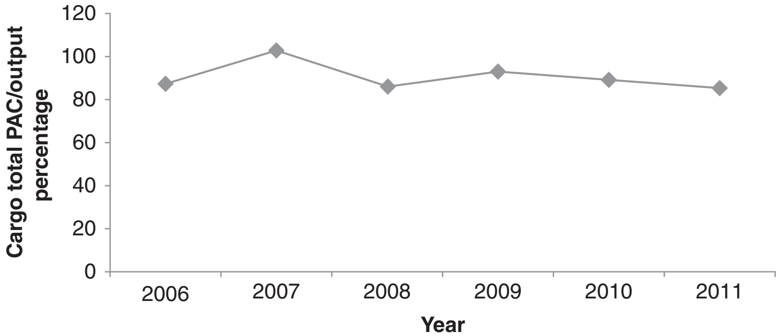

Figure 4.6 Cargo total PAC/output percentage

opportunity cost of implementing the ECAs pollution abatement activities must have increased under the stricter environmental regulation. Interpreting the change in PAC during 2007 and 2008 is complicated because the economic recession may have affected the PAC levels. The strong surge in 2008 and 2009 is attributable to the recession, with the empirical implication that economic recessions significantly increase the opportunity cost of environmental regulations. From 2009 to 2010, the ratio decreases partly attributable to each country's adaptation to the environmental regulation. Interpreting the 2010 and 2011 results is also complicated because two opposite ECA effect and national adaptation trends seem to be intertwined. Output still shows a recovery pattern, as it heads toward pre-recession levels. However, ECA regulations became stricter in 2010, lowering the allowable sulfur fuel content from 1.5 to 1.0 percent.

Figure 4.7 shows the mean technical inefficiency scores for the unregulated and regulated cases. The scores are the ratios of PACs to observed outputs expressed on averages. As expected, the 2006 and 2007 periods show a huge productivity decrease in the unregulated case. The increased productivity during 2007 and 2008 is intuitively unconvincing; one possible explanation is that the average scores may have been strongly affected by outliers. For instance, Lithuania significantly increased its productivity by 39 percent during that period; the country's relatively low output levels may indicate that it was in an increasing returns-to-scale state in 2007 and 2008. This result suggests that regulation can be easily overridden by output expansion through relatively small increases in investments. Productivity decreases from 2008 to 2009 because of the economic recession and the ECA. The increased

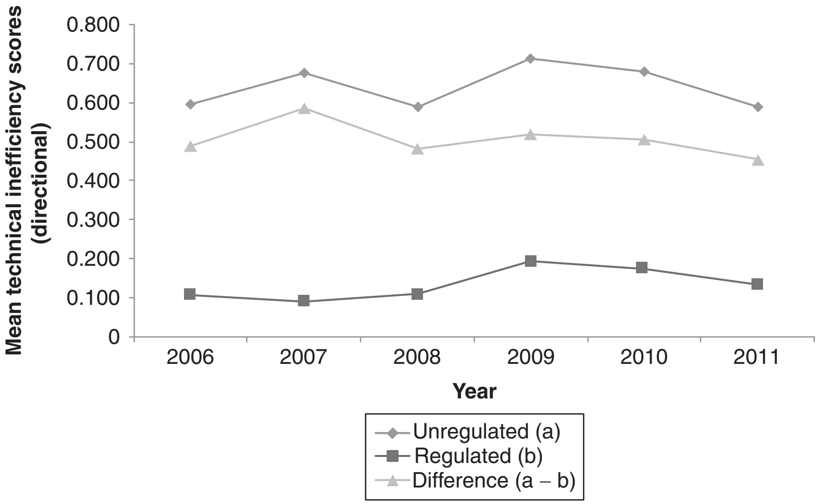

Figure 4.7 Mean technical inefficiency score

productivity from 2009 to 2010 can be attributed to the economic recovery. During 2010 and 2011, the effect of the economic recovery appears to be far stronger than that of the stricter regulations.

Ports forced to comply with the ECA regulations must suffer from increased financial losses, and thus higher PAC values, due to the stricter environmental regulations. Our empirical results do not always show this pattern over the six-year study period, as some port activities must have been affected by both the economic recession and the recovery. In addition, after the stricter regulations were implemented, the maritime sectors no doubt learned how to adapt themselves and enhance their businesses (through the "adaptation effect"). The PAC estimates seem to show a mixture of all these effects. The 2006–2007 period is the only one in which the net effects of the ECA on PACs can be observed. In other periods, net effects are difficult to measure because of the combined effects of the ECA regulations, the economic recession and recovery, and the ports' adaptation. Segregating each effect amid the mixed results should be done in future research.

Conclusion

Ports face unprecedented challenges arising from growing environmental concerns of various stakeholders. Among the various issues, this chapter first described assessing and reducing GHGs and NGs taking POI as a case. Moreover, port PACs borne by the vanguard EU ports were estimated in terms of how much cargoes and passengers may have foregone by complying with EU's strict ECA regulations.

One of important, but less researched topics is estimating human impacts by the GHG and NG arising from international shipping and port activities. This research will need more integrated framework from traffic source, its corresponding emissions through dispersions and concentration by geomorphological climate factors to impacts on human population and monetizing the impacts in socioeconomic measurements.

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5

Applying Game Theoretic Models to Port Policies

Koichiro Tezuka and Masahiro Ishii

Introduction

There has been a recent increase in the number of papers focusing on port competition. Port competition and port competitiveness are recognized as two of the main port policy problems. There are several approaches to analyzing port competition. One approach defines a port's competiveness and uses performance measurements to examine each port. A second approach is to construct theoretical models that provide certain implications that are subsequently applied to real port policy or to port competition situations. This chapter focuses on the latter approach, particularly game theoretic models.

The chapter primarily aims to examine the applicability of game theoretic models to port competition or to port policy. To address this, we first identify the types of problems that are analyzed through a literature review. Then, we provide a Japanese port policy case as an example. We consider how to apply the game theoretic model results to real inter-port competition situations and we report on our interpretations.

This chapter is organized as follows. First, we briefly outline the port competition concepts and define inter-port competition. Second, we provide a background to using game theory in port policies and then conduct a literature review on studies that use game theory – both cooperative and non-cooperative games – to treat port competition. We classify the studies on non-cooperative games into related issues from a model building perspective. Then, we partly apply the model results to inter-port competition relevant to Japanese port policy. Lastly, we summarize our research.

Port competition definition

Several studies provide a similar port competition definition to Notteboom and Yap (2012) who review container port competition and competitiveness. They state that "Port competition is not a well-defined concept, partly because of its complex nature. Hence, the nature and characteristics of competition depend among other things upon the type of port involved (e.g., gateway port, local port, transhipment port), and commodity (e.g., containers and liquid bulk)" (Notteboom and Yap, 2012, p. 550). The authors refer to main two papers, Heaver (1995) and Van de Voorde and Winkelmans (2002), while defining port competition.

Heaver (1995) comprehensively examines the issue of port policy. He discusses increasing port competition and points out three significant implications for port policy:

1. the most important element in the port industry is the terminal, treatment of the topic as one of "ports" may have some unintended adverse consequences;
2. the heightened competitiveness among terminals calls into question traditional public policies based on the monopoly power of ports; and
3. the focus of performance on the terminal raises new questions about the strategies of port authorities in terms of their ability to provide added value services based on the economies of scale or scope.

(Heaver, 1995, p. 127)

These implications are important from the point of defining port competition clearly. Heaver further discusses port organizations and their related factors, such as the risk of excess capacity and the risk of monopoly power. He also suggests that there should be two levels to port policy decisions: governmental (national) port policy and port management. He considers that the port industry should be (and is) moving in the direction of harmonized policies at the governmental decision level.

When defining container port competition, Notteboom and Yap (2012) follow Van de Voorde and Winkelmans (2002) and point out three levels. The first level is "intra-port" competition, representing competition between the container terminals in the same port. The second level is "inter-port" competition, meaning that a set of terminals in the same port competes with another set of terminals within the same

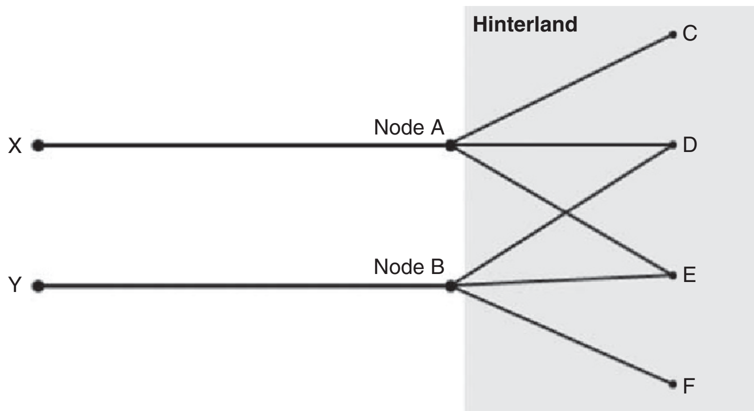


Figure 5.1 Port competition illustration

port area. The third level is inter-port competition. This is similar to "inter-port" competition but differs in that the ports in quite different regions compete.

Figure 5.1 shows an example of the three levels of port competition through a node and link illustration. The A and B nodes represent ports that are an assembly of container terminals in the same region. Nodes C, D, E, and F represent the final point of demand, in other words the "destination". Nodes X and Y are labeled as the "origin". For convenience, the shaded area to the right of nodes A and B is referred to as the hinterland, and the links AC, AD, AE, and AF are called "hinterland access".

In the case of intra-port competition (first level), the competition occurs within the A or B nodes. Multiple terminal operators exist in each node and compete with each other. In the case of "inter-port" competition (second level), two ports compete to attract cargoes for the overlapping final points of demand D and E. In contrast, in inter-port competition (third level), the final points – such as C and F – are contained. They are not overlapped. Note that the origins (nodes X and Y) may not be relevant in this definition.

In this chapter, the term "port competition" is used in reference to the "inter-port" competition identified by Van de Voorde and Winkelmans (2002) and Notteboom and Yap (2012). The difference between the "inter-port" (second level) and inter-port (third level) competition is whether they include the final points of demand that are not overlapped. While the third level of inter-port competition based only on trading volume (such as TEU), in the second level of "inter-port" competition, each port struggles for the same demand. With respect to this definition, it is necessary to set the overlapping hinterland range or the final point of demand. As Notteboom and Yap (2012) point out, the range has increased because intermodal technology and organization improvements now prompt the shipping lines and shippers to frequently review their service schedules, traffic routings, and assets. Therefore, there is intense "inter-port" competition to attract cargoes for the final points of demand and for (mostly) the same customers.

Note that this definition assumes that each port is a substitute. However, Heaver's (1995) harmonization view shows that in some cases each port is complementary. In such cases, it is important to analyze how to promote port cooperation and harmonization from the logistics process/global supply chain perspective rather than from a port competitiveness perspective. This port cooperation and coordination view (rather than competition) is frequently considered through applying cooperative games to port policy. In contrast, non-cooperative games are often used to investigate port competition. The literature review outlines the types of problems that are investigated in studies on game theoretic models for port competition.

Game theoretic model literature review: Background

Global economic growth expands international trade and leads to an increased need for speed in business operations. There are numerous examples of business dealings where consumer goods must be delivered in a specified time period, and there is a focus on supply chain management and intermodal transportation networks to meet these requirements. Container shipping line networks generally have a central role in an international logistics system, and ports connect the maritime and inland networks, thereby leading to increasing demands for efficient and high-quality port services.

Because freight transportation is derived from demand, intuitively the geographical location of a port is included in the port selection criteria. This provides an inherent opportunity for a port that is located in close proximity to an economic center such as a major metropolitan or production area. The costs and time associated with the land transportation distance between the port and the container cargo origin are both crucial for efficient and competitive logistics. There is a consequent focus on the capacity of the transport network connecting the port and its hinterland. This is related to hinterland congestion. Shipping lines and freight forwarders are concerned with both port service levels and costs, because these factors directly affect their corporate performances and indirectly cause the loss of market share and opportunities. Such services and costs are closely related to, for example, port charges, port capacity, and the terminal facility. Additionally, public policies are not negligible and include port tariffs and government investments in ports for expanding port capacities. A port's objective depends on its ownership structure, a further significant factor. Moreover, other key factors such as the international political environment and changes in the social environment may have an impact. Hence, a range of factors – some of which mutually affect each other – exert a complicated influence on port competition.

Consequently, there is considerable interest in port competition including from researchers, port authorities, shipping lines, and other stakeholders, and there are many articles that investigate the factors determining port competition (e.g., Chang et al., 2008; De Langen, 2007; Malchow and Kanafani, 2004; Nir et al., 2003; Slack, 1985; Talley, 2009; Tongzon, 2009; Tongzon and Sawant, 2007; Wiegmans et al., 2008; Yeo et al., 2010; 2011). Chang and Lee (2007) classify approximately 70 studies according to the five major issues in port competition and the most popular methodologies; this classification can be extended to include the above-mentioned articles.

When seeking the key port competition factors, we see that the existing empirical analyses are valid and feasible. In other words, statistical models are adequate tools for exploring the significant port competition factors. However, they do not explain why and how port competition is influenced by the factors: a structural model is needed for this. It is very difficult to take account of multiple factors or variables at the same time. In such a model, it is almost impossible to derive an analytical solution in an explicit form; however, numerical example solutions may be possible. Therefore structural models generally focus on a restricted number of factors.

Non-cooperative and cooperative game models are regarded as efficient methods to investigate the competition among ports. We introduce some previous studies that investigate port competition with game theoretic models later.

Additionally, game theory is applied to explore competition in the shipping industry. Recent interesting papers based on non-cooperative game theory include Alvarez-SanJaime et al. (2013) and Wang et al. (2014), and Song and Panayides (2002) apply a cooperative game.

Alvarez-SanJaime et al. (2013) theoretically and empirically investigate two types of horizontal integration between seaborne companies. They use a model that proposes competition for freight transport between a long-haul truck service and two shipping lines. Wang et al. (2014) analyze the effect of ship capacity scale economics in a liner shipping container market with three non-cooperative game models: a strategic form, a Stackelberg game, and a deterrence game. Song and Panayides (2002) apply a transferable utility game to investigate the relationship between strategic shipping alliances and shipping demand fluctuations.

Game theoretic model studies

This subsection presents three port competition research themes. First, we outline the articles that develop non-cooperative game models and that apply these to analyze the issues related with port competition. The second theme is empirical analysis using a non-cooperative game. Finally, we highlight the papers that investigate competition and cooperation among ports.

To the best of our knowledge, De Borger et al. (2008) were the first to construct a comprehensive model to investigate the interaction among port competition; the port and hinterland road network congestion; and the port and road network capacity investments decided by the government. This article is central to the study of the economics of port competition, and it had a strong influence on the evolution of port competition studies. We review De Borger et al. (2008) in detail and then provide an overview of the subsequent related studies, highlighting any differences, including Van Reeven (2010), De Borger and De Bruyne (2011), Bae et al. (2013), Ishii et al. (2013), Kaselimi et al. (2011), Luo et al. (2012), Wan and Zhang (2013), Czerny et al. (2014), and Zhuang et al. (2014).

De Borger et al. (2008) assume two logistic chains: route A and route B. Each chain consists of a port and its local transport line. The cargoes are transported from an overseas origin through either route A or route B to the destination for consumption. The overall demand for both ports (i.e., for the route) is given by a demand function. There is also a demand for each local transport line from the local traffic that is expressed by a further demand function. A transport cost arises for each cargo that is the combined total of the port charge, the port congestion cost, the local transport congestion cost, and the local road toll. Each port's congestion cost depends on its capacity and its use demand. Similarly, each local transport congestion cost depends on the capacity of its transport line and the total demand from the corresponding port service and local traffic. It is assumed that the demand for each port and each local transport line is determined as follows:

- The transport costs for routes A and B are equal.
- For the local transport line in route A, when the local transport congestion cost is substituted into the corresponding demand function, then the value is equal to the local traffic demand.
- For the local transport line in route B, the required condition is similar to A.

Under these settings, De Borger et al. (2008) consider a two-stage non-cooperative game.

In the first stage, the government decides on the port capacity in addition to the local transport investment needed to maximize social welfare functions. Each port then chooses a port charge that maximizes its profit in the second stage. It is natural to apply backward induction to solve this problem. The model by De Borger et al. (2008) is very general, and it could be difficult to show explicitly the existence of Nash equilibria in the port competition sub game. Therefore, the analyses are mainly based on the first-order conditions of the objective functions and a numerical example, and they yield important policy implications. The hinterland congestion is internalized by the port charge to some extent. The capacity investments work in the opposite direction, that is, the port capacity expansion decreases the charges for both ports while also inducing additional congestion in the corresponding local transport line. However, the investment in the local transport line increases both the charge and the congestion of the corresponding port. In a case where the government has a right to decide the port charge, then the profit-maximizing port might choose a lower price than the government. There is a particular incentive in the regions where the port charges are affected by a regulating authority to expand the port capacity.

Focusing on port user costs and hinterland accessibility, Van Reeven (2010) examines the effect of the port's organizational structure – vertically integrated and vertically separated ports – on inter- and intra-port competition. To address this issue, he adopts a modified horizontal product differentiation model, descended from Hotelling (1929), to express the port service demand. In his model, two ports are located at either end of a line segment, and homogenous consumers are distributed uniformly on the bounded line. Each port consists of a port authority and service providers, and both ports compete for inbound cargoes. The accessibility from an arrival/departure point to the ports is expressed in common with Hotelling (1929) and De Borger et al. (2008), but congestion is not considered. Then, the competition between both ports is described by a two-stage game. First, each port authority decides whether to vertically integrate or to vertically separate its port. Second, all participants determine the port dues, the service fees paid to the service providers, and the port capacities. Van Reeven shows that the Nash equilibrium organizational form is a vertically separated port in which the port industry receives the highest profit and where the highest price (the sum of the port dues and the service fees) is charged to the port users.

De Borger and De Bruyne (2011) develop a leader–follower game to examine the effect of vertical integration between the terminal operators in a port and the trucking companies in the hinterland on port access charges and road congestion tolls. They assume that the homogeneous cargoes that are shipped from overseas countries are transported through a port and further to the final destination for consumption and that the players are a government, the terminal operators, and the trucking firms. At the first stage, the government makes a decision on the port charges and the hinterland congestion tolls to maximize a social welfare function. Then, each one of the terminal operators and the trucking firms chooses a price to maximize their respective profits at the second stage. De Borger and De Bruyne's model compares logistics chain integration and separation. The equilibrium implies that logistics chain integration leads to an increase in the optimal port access charges and in the revenue of the government, but does not affect the optimal congestion tolls. When the firms in the logistics chain (such as shippers) have some market power, then the optimal port access charges work like a subsidy for both the integrated and the separated cases. Their study does not consider either port competition or congestion.

Bae et al. (2013) investigate the strategic behavior among a finite number of shipping lines and duopolistic transhipment (T/S) ports with a non-cooperative two-stage game. The first stage is a Bertrand competition among the ports that maximizes their profits by choosing the port prices. In the second stage, each shipping line decides the proportion of the T/S calls to both ports to maximize their profit function that depends on the port prices and the port congestion. Therefore, each stage expresses the competition among the industry peers. Additionally, the competition between the ports and the shipping lines is embedded by the leader–follower relationship, and the model is modified to examine the effect of port collusion. These elements are not considered in De Borger et al. (2008). Bae et al. then reveal the interaction between the port charge, the port capacity, and congestion. However, they do not consider port capacity investment.

Generally, port competition emerges in the long term rather than in the short term, and there is uncertainty in the economic environment surrounding the ports during that period. Yeo et al. (2013) construct a fuzzy evidential reasoning method in which the shipping lines select the ports under an uncertain environment. In recognition of the considerable fluctuations in the global economy, they include the demand for port services in the uncertain variables (i.e., the ports face risks generated by demand uncertainty). In fact, the empirical analysis by Rodriguez-Alvarez et al. (2011) indicates that demand uncertainty incurs extra costs for three port terminals operating in the Las Palmas Port Authority zone in Spain. Nevertheless, it is meaningful to incorporate demand uncertainty into analytical models. For example, Balvers and Szerb (1996) build an extended Hotelling (1929) model with demand uncertainty and show the effect of risk attitude on the equilibrium.

Ishii et al. (2013) construct a non-cooperative game model to explain inter-port competition under demand uncertainty and sequential capacity investment. Their model includes two competing ports. For each port, the port capacity expansion plan is expressed by a non-decreasing step function. Both functions jump one after the other; that is, both ports will alternately extend their capacities. Both the jump points and the jump sizes are pre-determined; that is, the capacity investment levels and timings are given exogenously. At each jump point of the functions or at any time that the capacity changes, both ports reconsider their strategies (i.e., their port charges). A fluctuating linear demand function is employed, where the slope is constant and the intercept is a continuous time positive-valued stochastic process. Therefore, the demand function stochastically moves in parallel and the shipments are transported continuously in time. Similar to De Borger et al. (2008), the numbers of shipments transported to the ports depend on both the port charges and the congestion costs. Then, they assume that each port chooses a port charge to maximize the expectation of the sum of the discounted profits over the time interval between the capacity investments.

In the game by Ishii et al. (2013), the uniqueness of the Nash equilibrium is presented and it is explicitly derived. The Nash equilibrium strategy implies that the port charge is an increasing function of the slope of the demand function and the length of the time interval, as well as a decreasing function of the enlarged capacity. Ishii et al. investigate the competition between the ports of Busan in South Korea and Kobe in Japan. Although they abstract the capacity investment competition away, they consider the demand fluctuation during a time period, and they explicitly derive the equilibrium strategy. This makes it easier to apply their results to statistical analysis and to simulations that incorporate economic changes than those of De Borger et al. (2008).

Kaselimi et al. (2011) employ a model in which homogenous consumers are distributed uniformly on a unit length line and a port is located on either extreme. Each port has a port authority and a finite number of terminal operators that are profit maximizers. The cost of transporting cargo from a consumer to one port is expressed by Hotelling's (1929) model. Both ports compete for the cargoes that the consumers send or receive. Kaselimi et al. (2011) solve a non-cooperative game such that the port authorities choose the port dues, and the terminal operators simultaneously select the capacities and the service fees. Similar to Van Reeven (2010), they do not consider port or hinterland congestion. Their paper focuses on the effect of dedicated terminals on port competition. They give three numerical examples to analyze the impact of the introduction of fully dedicated terminals on service fees, port dues, terminal capacity and port authority, and multi-user terminal profits.

Luo et al. (2012) develop a two-stage game model to study the pricing and capacity investment decisions of two heterogeneous ports – a dominating or existing port and a new one – under an increasing demand condition. Each port decides its capacity in the first stage. Both ports subsequently compete on price, assuming that their services are differentiated. Then, the equilibrium implies the relation between the capacity expansion and the prices and leads to a strategy by which the dominating port prevents the rise of the new port. They apply the model to explain the transition and evolution of container port competition in Hong Kong and the Pearl River Delta region in Southern China. The study differs from De Borger et al. (2008) in several notable aspects. It uses linear demand functions for the differentiated products to express port user preferences that implicitly reflect congestion. Each port's cost function depends on both port demand and port capacity. Some conditions are imposed in the first partial derivatives of the cost function to incorporate the relation between port capacity and congestion such that capacity expansion can decrease the marginal cost in congestion and can increase the marginal cost when congestion eases. Further, an exogenous or fixed-size capacity expansion is implemented if the profit increment is larger than the investment cost. This simplification facilitates an in-depth analysis.

Wan and Zhang (2013) focus on the interaction between port competition and the transportation chain. Their model is closely related to De Borger et al. (2008) and their setting is essentially a network encompassing a market and two ports, in which each port is directly connected to the market through its own road. They adopt a two-stage game to examine the effect of road capacity expansion and toll policies on port charges, throughput, and profit. Road capacity investment is determined at the first stage and the ports choose the port throughput (quantity) at the second stage (i.e., the second stage is a Cournot competition); this is where they differ most from De Borger et al. (2008). The derived Nash equilibrium implies that both a road capacity investment and a toll increase in one road increase the respective port's charges and profits and decrease those of the rival port. Additionally, Wan and Zhang examine a discriminative toll policy.

Czerny et al. (2014) compare private ports with public ports in a two-stage game. They assume the following spatial structure: two countries have a port each, there is a domestic demand for the transport service, and the carriers in a third region will use each port for shipping. The consumers in the third region are distributed on the unit line and choose the port by totaling the transportation costs and the port charges, as in Hotelling (1929). Compared with Van Reeven (2010), they extend the game by introducing the domestic markets to the model. At the first stage of the game, each government selects the port operator to maximize the national welfare. If privatization is chosen, then the private operator decides the port charge to maximize its revenue. Otherwise, the public port operator chooses the port charge such that the national welfare is maximized. It is certain that an implication related with this issue can be deduced from the results of De Borger et al. (2008); however, their model does not explicitly embed a framework to investigate it. Czerny et al. (2014) unveil the conditions that the port is privatized in the equilibrium and find the effect of the private port operation.

In the model by Zhuang et al. (2014), two ports face container cargo and bulk cargo demand in a region and the difference between the ports is reflected by the linear demand functions for the differentiated product. The ports choose the container and bulk cargo traffic volumes to maximize their profits. If a port decides to specialize in the container or the bulk service, then the fixed cost of the other service (therefore also the total cost) is assumed to be zero. In contrast to De Borger et al.

(2008), both port capacity investment and congestion are implicitly rather than explicitly incorporated into the model. Zhuang et al. (2014) solve both a Stackelberg leadership game and a strategic game: games that depict different port competition types. The former game investigates the competition between a developed and a new port, and the latter game examines the competition between similar sized ports. Based on the equilibria they deduce that port competition without proper coordination – such as government intervention – leads to excessive capacity investments even if there is an insufficient demand.

There are less common empirical studies that investigate various issues in port competition using a game theoretic model including Lam and Yap (2006), Anderson et al. (2008), and Wan et al. (2013). Lam and Yap (2006) modify a Cournot model and integrate it with the framework presented by Porter (1998) to analyze the competition between container terminal operators in the Singapore and Malaysian ports of Port Klang and Tanjung Pelepas from 1998 to 2002. Their empirical results show that the cost advantages of Port Klang and Tanjung Pelepas lead to increases in the market shares of those ports. Anderson et al. (2008) apply a strategic game to analyze the effect of port development on competition, particularly between South Korea's Busan port and China's Shanghai port in the T/S market. In the game, both ports have two strategies: whether to invest in facilities or not. Anderson et al. (2008) estimate the demand response to an investment affecting the port charges or the turnaround time to obtain the payoff value for every possible pair of strategies. Based on the calibrated payoffs, they examine four investment games, assess Shanghai's investment strategy and deduce Busan's reasonable responses. Based on De Borger et al. (2008) and Wan and Zhang (2013), Wan et al. (2013) empirically examine the relationship between road congestion and container throughput in American container ports. They use multiple linear regression models in their analysis in which the dependent variable is the truck-related container throughput for each port, and the independent variables include the road capacities in the port surrounds, rivalry, the amount of US international trade, the population in the catchment area of each port, and the road congestion delays. Their statistical analysis shows that an increment in the road congestion around a port reduces the container throughput of that port while increasing the rival port's throughput.

The articles discussed above primarily focus on port behavior that improves the competitiveness to secure a stronger position in the region. Then, it is natural to assume that ports select strategies to maximize their profits. Such studies based on non-cooperative game models certainly illuminate critical port competition issues; however, there is insufficient analysis on the cooperation mechanisms adopted by adjacent ports. As the global economy grows, there is a concomitant development of new ports and existing ports extend their capacities, particularly in Asia. This gradually reduces the competitive advantage of the dominant ports and increases the importance of cooperative strategies in the port industry in response to the fluctuating business environment. This situation prompted studies investigating related issues such as Juhel (2000), Song (2002, 2003), Li and Oh (2010), and Saeed and Larsen (2010). Although some studies do not treat game theoretic models directly, they are closely related to them.

Juhel (2000) is the earliest identified study that introduces port cooperation. Song (2002) analyses the competition between container ports in Hong Kong and South China with respect to the trade patterns, the trade volumes, and the organizational structures, and he rationalizes the cooperation among the ports. Song (2003) proposes a conceptual framework for port "co-opetition" and applies it to a container port case study in Hong Kong and South China: the word co-opetition is a composite of competition and cooperation and is diffused by Brandenburger and Nalebuff (1996). Li and Oh (2010) summarize the theoretical background of port competition and cooperation and empirically investigate the relationship between China's Shanghai and Ningbo-Zhoushan ports. They deduce some cooperation implications.

The papers overviewed above are based on the game theory concept; however, they only use descriptive methods to explain the cooperation between ports and do not apply mathematical or game theoretic models to the investigations. Saeed and Larsen (2010) develop a two-stage game to analyze the competition between container terminals in the Port of Karachi in Pakistan. The first stage is a transferable utility game, in which coalitions among the terminals are determined. In the second Bertrand competition stage, the terminals that decided to join the coalition in the first stage compete with the non-member terminals. Numerical examples based on this game show the effects of the coalitions on the equilibrium port charges.

Literature review summary and key application factors

Thus far, we have provided an overview of the articles that investigate port competition and various related topics based on game theoretic models or concepts that have a central focus on De Borger et al.'s (2008) model. Their model is general and it examines the effects of port and hinterland congestion on port competition and derives the associated implications for a port's organizational structure.

Other related studies closely investigate specific issues using modified models. Van Reeven (2010), De Borger and De Bruyne (2011), Kaselimi et al. (2011), Czerny et al. (2014), and Zhuang et al. (2014) focus on port structure-related issues. Ishii et al. (2013), Luo et al. (2012), and Wan and Zhang (2013) highlight the impact of transport capacity. Bae et al. (2013) focus on the interaction between ports and shipping lines.

There are structural models that explore the effect of key factors on port competition; however, there is an insufficient empirical analysis to verify the validity, robustness, and effectiveness of the models. Lam and Yap (2006), Anderson et al. (2008), and Wan et al. (2013) contribute to this research field. Generally, both the construction of structural models and the empirical researches based on such models are indispensable for economic analysis. When a structural model is constructed, it is difficult to avoid the researchers' subjective view in the selection of the related factors or variables. Therefore, the results, which are usually stated as a theorem or proposition, show only the relationship among the selected factors. That is, the factors or variables that are not selected do not affect the results. Hence, empirical analysis is necessary to test the structural model, the theorems, and the propositions in statistical procedures. Such a process reveals the major factors and the proper structure. In the current context, there are some barriers to the development of empirical port economics studies including a lack of, and low accessibility to, the necessary data. An improvement of the data environment is expected.

The literature review in this section has revealed the key factors for applying a game theoretic model to port policy, including port competition, port capacity and hinterland congestion, and governance structure. Next, we consider the points when we construct a game theoretic model and apply it to real port policies.

Some implications from applying game theoretic models to port policies

Many studies apply game theoretic models to real cases. Some models can be directly applied to real port competition situations while others must be modified as we can see in the settings of De Borger et al. (2008) as an example. They construct a comprehensive model to investigate the interaction among port competition, the port and hinterland road

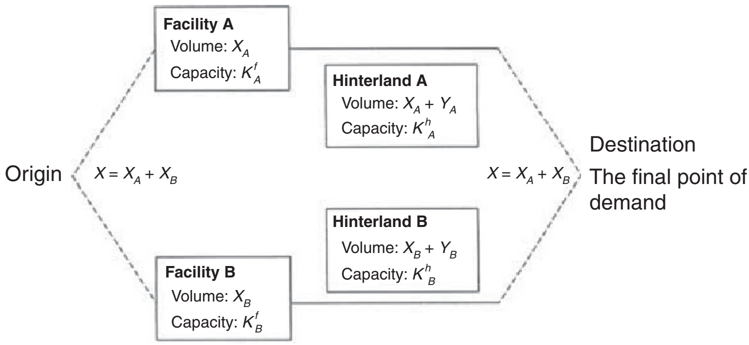


Figure 5.2 Port competition settings in De Borger et al.'s (2008) model
Source: De Borger et al. (2008).

network congestion, and the port and road network capacity investments decided by the government. The settings are general and can be modified for applying to real port policies. Their port competition settings correspond to the "inter-port" competition as defined by Van de Voorde and Winkelmans (2002) which has two port nodes (A and B), two hinterland links (hinterland access) A and B and a single final point of demand. Notably, this study expresses European port competition such as between Rotterdam (the Netherlands), Antwerp (Belgium), and Le Havre (France). The basic port competition conditions seem to differ in the East Asian region. If that is the case, it should be confirmed. Indeed, we note several elements in relation to these settings (Figure 5.2).

Capacity constraint and congestion

We first focus on congestion that stems from capacity constraints. As mentioned, De Borger et al. (2008) set the following situation where congestion is caused by both the port itself and the hinterland. Figure 5.2 shows a situation where two ports compete under their hinterland capacity constraints: because of the existence of congestion, neither port can enjoy economies of scale. In other words, the capacity constraint prevents the ports from severely competing under increasing return to scale. However, in the context of port competition in East Asia (with rapidly developing ports such as Busan and Shanghai), the region seems to have excessive or sufficient capacity and congestion is irrelevant. Rather, to enjoy economies of scale, each port attracts a large amount of cargo by setting low prices (port charges), and severe price competition – known as Bertrand competition – can occur. If economies of scale exists under Bertrand competition, then the marginal cost in equilibrium is below the average cost. To support the severe competition, each government tends to support its ports. In the context of microeconomics, congestion under capacity constraints is a major problem. However, it is difficult to apply the congested situation of De Borger et al. (2008) directly to the "inter-port" competition in the East Asian region because such congestion does not exist.

Final point of demand

Second, it is necessary to consider how to define (or to interpret) the hinterland and the final point of demand. From Figure 5.2, both ports compete to get T/S cargoes for transport to the final point of demand. Note that the word "hinterland" sometimes encompasses both hinterland access and the final point of demand; however, in this case they are separate. As in Van de Voorde and Winkelmans (2002), the situation given in Figure 5.1 reflects the "inter-port" competition where the final demand is overlapping. If we apply these settings to the real port competition such as the East Asian region, then it is important to interpret where the point of final demand is. In the context of ports such as Busan and Kobe, the final point of demand seems to be ambiguous, which means that the competition is not "inter-port" competition as explained above.

Vertical supply chain process

Third, the relationship between port competition and the logistics or supply chain processes should be also considered. De Borger et al. (2008) divide the port logistics process into port handing, hinterland and the final point of demand. Regarding port logistics, Van De Voorde and Vanelslander (2009) separate the functions of maritime transportation into three: pure maritime transportation, cargo handling in ports and hinterland transportation. From the practical point of view, it is important to smooth the vertical supply chain process. As Pettit and Beresford (2009) point out, the role of ports in the supply chain has drastically changed. Ports have been increasingly integrated in the supply chain since the 1960s, and there is a recent focus on the integration of ports with global logistics services. When applying the game theoretic models to port competition, it is important to take this type of vertical integration into account. In this case, the port operator, the freight forwarder, and the shipper are regarded as the players.

Confirmation of assumptions and conditions to obtain policy implications

The game theoretical models including one proposed by De Borger et al. (2008) are simplified to some extent. It is thus necessary to confirm the assumptions and conditions behind the models when the results are used to suggest policy implications about port competition. Regarding this, we raise the following points:

Existence of various decision makers

First, most of the game theoretic models implicitly assume that the various decisions about port policy are made by a single entity including decisions on, among others, price and investment. The cost of import/export, the port term, and the terminal handling all correspond to the port charges. It is sometimes assumed that there are two ports – called port A and port B – and that they set their own port charges. In this case, the port charges tend to include a range of port-related prices such as port dues, tonnage dues, warfage, pilotage, tug hire, line handling, and terminal handling charges. However, these charges are not set by the single entity but by various entities such as central government, local governments (or port management bodies), port authority, harbor transport providers, and terminal operators. In short, while an economic model tends to assume a single decision maker, in reality there are a variety of entities that determine the port charges. Therefore, when we apply a game theoretic model results, it is necessary to confirm who decides the port charges. Compared with other settings, the decision-making structure of a port is more complex (Table 5.1).

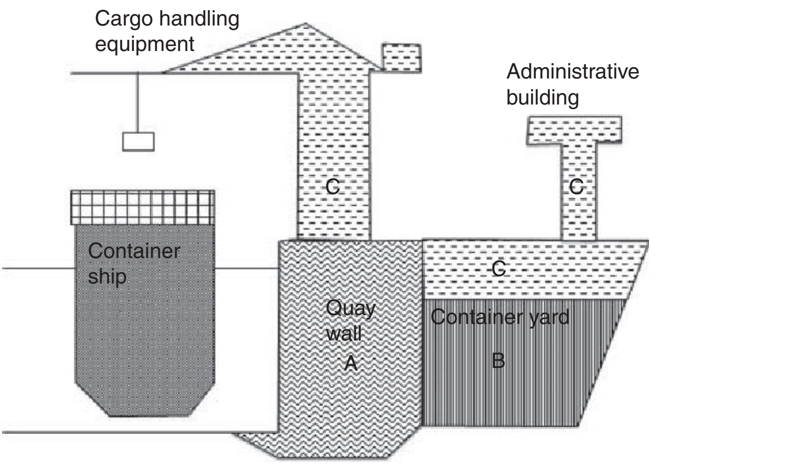
There are three aspects in a port and terminal operation: ownership, tenants, and cargo handling. The first aspect is ownership of the various container assets and Table 5.1 shows the situation in Japan as an example. Most of the quay walls in container terminals in Japan are owned and maintained by the public sector (i.e., the central government (CG), the local governments as port management body (PM), and public corporations (PC)). There are two main parts in the container terminal: the container yard (substructure) and the superstructure. Most of the container yard tends to be also owned by public bodies; however, the superstructures are partly owned by private entities such as a mega-terminal operator or the operating company. The second aspect is tenants. Normally, the tenants (a private company such as a shipping company) borrow and use the quay walls and the wharfs (from a public

Table 5.1 Ownership and operation for container terminals in Japan

	Public-own and public-operate			Public-build and private-operate		
	Public operation	Public corporation*	Hybrid	Super Core Port policy	International Strategic Port policy	
					Public wharf	High-grade container terminal**
A: Wharf	CG or PM	PC	CG or PM	CG	CG or PM	CG
B: Container yard (substructure)	PM	PC	PM	PM	PM	CG
C: Superstructure	PM	PC	PC	MO	PPOC	PPOC
User (quay wall)	SC	Tenant (SC or PHTP)	SC	MO	PPOC	PPOC
User (wharf)	PHTP	Tenant (SC or PHTP)	Tenant (SC or PHTP)	MO	PPOC	PPOC
Applied or Intended ports	Most public (local) ports	Berths owned by the corporations (Tokyo, Yokohama, Nagoya, Osaka, Kobe)	Yokohama MC1 Kobe PC 13,18 Osaka C10 Nagoya T2	Osaka C12 Kobe PC18 Nagoya TS1 etc.	Keihin (Tokyo and Yokohama) and Hanshin (Osaka and Kobe)	Keihin and Hanshin

CG: central government; PM: port management body (local governmental authority); PC: public cooperation; PPOC: private port operating company; MO: mega operator (private company); SC: shipping company; PHTP: port and harbor transport provider.
*Recently, these public corporations are "commercialized"; they converted joint stock companies, but their shares are mainly owned by the local governments.
**The terminal that depth is below 16 meters.
Source: Japan Harbor and Port Association (2013), *Statistical Summary of Harbors and Ports in Japan* (in Japanese).

Table 5.1 (Continued)



body); this corresponds to private–public cooperation. The third aspect is cargo handling. The port and harbor transport providers (PHTP) use the container terminals where the dockworkers operate. Additionally, there are sometimes "landlord" container terminals, where the government owns the wharfs and the private entity owns and operates the other parts of the container terminal. The above structure shows that the owners, the tenants, and the users of the port/container terminal are not three-in-one but are different players in the port/terminal operation. Therefore, when we apply the model results to an actual situation, it is necessary for us to confirm the validity of the assumption about the existence of a single decision maker in the port/terminal operation.

Public and private operator objective functions

The second point we would like to make is how to set the objective function. De Borger et al. (2008) and the other related papers focus on the difference between public and private operations. It is often assumed that the objective differs between public and private operations. In a private operation or in the case of privatization, profit maximization tends to be the assumed objective. In contrast, the objective of the public body (the government) is assumed to be the maximization of social welfare.

In the case of perfect privatization or private operation, it is simple and appropriate to assume profit maximization where the profit represents the total revenue minus the total cost. However, there are different social welfare function formulations as the government's objective; these depend on the relevant situation. In the papers such as De Borger et al. (2008) and Czerny et al. (2014), the social welfare function consists of port profit (producer surplus) and consumer surplus.

Roughly, a profit maximization setting has less trading volume in equilibrium than that of a social welfare function. While the price is equal to the marginal cost in the case of social welfare maximization, the price tends to be above the marginal cost under a private operation with imperfect competition. Therefore, in the model settings, the public entity prefers to having greater trading volumes than those of the private entity to enhance the total surplus. Some studies evaluate the overall levels of social welfare and compare the case of privatization with that of public ownership.

To apply the model settings to a real situation, it is necessary to consider whether the relevant objective functions are matched. For example, regarding the profit maximization objective, the recently privatized terminal operating companies in Japan do not seek profit solely; it seems as if they also pursue social welfare objectives under budget constraints. Overall, to apply the model results to a real situation, it is necessary to verify whether the employed objective functions are well suited to the real context.

Identify the final decision maker

In relation to the above points, it is necessary to confirm who the final decision maker is. If multiple parties are involved in the decision making on port charges and if they have the same or similar objectives, then the final decision maker is irrelevant. However, it is relevant if they have conflicting objectives and it is important to identify the final decision maker and to confirm their objectives particularly in the context of public or private ownership and operation.

There can be some ambiguity in relation to the final decision maker. There are cases where a port is owned and operated by a private company, yet the final decision maker seems to be the central or local government because of severe regulations. If the private body does not have discretion over decisions such as the determination of port charges and investment because of severe governmental regulation, then it can be interpreted that the final decision maker is the government and further that it appears as if the government sets the port charges. In this case, the objective is not necessarily profit maximization but social welfare maximization. This point suggests that it is important to confirm the real port governance structure when we apply the model results to a real situation.

In the case of port policies in Japan, it can be difficult to identify the final decision maker and/or their objectives because of a complicated governance structure. The decision process is neither simple nor clear.

Recent Japanese "inter-port" competition policies

We reviewed various theoretical game model studies. This section considers the practical applications of those game theoretical models to port competition policies in Japan as an example, considering the key factors identified in the literature review. We briefly introduce two recent major Japanese container port policies that aim to attract container T/S. Japanese ports seem to have lost their competitiveness in the past 30 years and the Containerization International Yearbook rankings illustrate this fall. Their global ranking positions for certain Japanese ports in 2012 compared with (1980) are: Kobe 52(4), Yokohama 43(13), and Tokyo 23(18). The total trading volume in the East Asian region has rapidly grown in the last decade along with the development of the Chinese economy, and some ports in the area – such as Busan – have enhanced their capacities through new construction. Ishii et al. (2013) imply that the Japanese government responded inappropriately slowly to this changing market, resulting in declining global ranking of Japanese container ports. Notably, in the last decade the port congestion arising from a port capacity shortage seems not necessarily relevant; however, the severe price/port charge competition arising from excessive port capacity is.

Briefly, the major Japanese ports are lagging behind the other major Asian ports in terms of cost and service competitiveness. Therefore, Japan's major container ports are less attractive to (and thereby cannot capture) T/S cargoes bound for European and American ports. To strengthen the "port competitiveness" that attracts T/S container cargoes, the Japanese government introduced two "selection and concentration" policies for Japanese container ports: the Super Core Port policy followed by the International Strategic Container Port (ISCP) policy.

Super Core Port policy

The Super Core Port policy intended that the Japanese mega terminal operators would attain the same high standard as PSA International that manages Singapore port, and it aimed to strengthen the port competitiveness for selected ports in Japan. Kobe and Osaka ports (to be jointly referred to as the Hanshin port) were first selected as a

"Super Core Port" by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) in July 2004, followed by Keihin Port (including Tokyo and Yokohama ports), Ise port (including Nagoya port) in 2007. According to the Port and Urban Projects Bureau in the city of Kobe, the aim of the Super Core Port policy was to strengthen the international competitiveness of Japanese ports by reducing costs, expediting the transaction process, and improving service. Following the policy, the Bureau not only undertook to develop container terminals in Kobe (Hanshin) port, but they also announced interest-free loans for the maintenance of cargo-handling machinery and intended to offer a discounted port rates incentive to foreign container liners calling in at more than one port in Osaka Bay after 2007. However, this policy did not work well, and there were difficulties in establishing a competitive new Japanese mega terminal operator. The Super Core Port policy was replaced by a new policy, that is, the ISCP policy.

International Strategic Container Ports policy

The ISCP policy, introduced in 2009, aims

1. to form the selected ports into ISCP that provide as high a level of service as the other major East Asian ports;
2. to make the selected ports domestic hub ports by 2015;
3. to decrease the overall rate of the T/S cargoes that use the other East Asian major ports – such as Busan – by 2015; and
4. to make the selected ports into international East Asian hub ports by 2020.

The Japanese national government and MLITT selected two ports as ISCP: Hanshin Port (incorporating Osaka and Kobe ports) and Keihin Port (incorporating Yokohama, Kawasaki, and Tokyo ports). To achieve its targets described above, the Japanese national government supports these two ports through subsidies, interest-free loans, and tax exemptions. Further, the "Private Port Operating Company" (PPOC) scheme was newly introduced to allow the selected ports to enjoy private sector advantages.

Background to the Japanese port competitiveness policies

In short, the Japanese national government tried to address two things through its policies. First, by selecting the major Japanese container ports the government seemed to be seeking economies of scale and scope. Second, they intended to enhance efficiency by introducing new organizational schemes such as a mega terminal operator or a private port operating company. This would allow Japan to face the port price competition in the East Asian region.

The literature review reveals that a port charge (price) is one of the main factors that affect port competitiveness. Table 5.2 shows the export/import procedure costs by Asian country (cost per 20 foot container) in contrast with those in the United States in 2012. Compared with most other Asian countries, the "Ports and Terminal Handling" (which can be related to port charges) cost in Japan is high, a weakness for enhancing its port competitiveness. Consequently, the government introduced policies for decreasing port charges. The policies aimed at improving the status of Japanese container ports in the East Asian region. In fact, Ishii et al. (2013) investigate Busan and Kobe ports from port charges and port capacity perspectives. Their results show that Kobe's port charges remained higher than those in Busan even in the capacity investment period. If Kobe port had wanted to improve its port competitiveness relative to Busan port, it should have timely decreased its port charges; however, it encountered regulatory difficulties.

In addition to the price and capacity investment problems, Japan has a complicated organizational relationship between the national and the local governments in respect to port policies. Even though the national government generally invests in and owns the quay walls in wharfs, it does not have enough power to directly manage port policy, even in the largest ports (such as Keihin or Hansin). This means that investments related to port infrastructure are made slowly. However, the local government (such as Kobe-Osaka city or Tokyo metropolitan district) or related entities that operate and manage the ports (port management body, PM) have constructed their own ports, and there are now approximately 100 container ports in Japan. This implies that Japan has an "overcapacity problem" (Terada, 2002). The Japanese national government attempted to implement the "selection and concentration" method discussed above. However, many local authorities already owned and operated their own container ports/terminal and each local port tried to carry out their preferable port policy: some local ports prefer to act as feeder ports for other international ports – such as Busan – rather than for the selected domestic ports. Table 5.3 shows that local ports in Japan – such as Hiroshima and Moji – use Busan as a T/S port. This is reasonable strategy for local Japanese ports from a total cost perspective.

Table 5.2 Export/import procedure cost by Asian country

Nature of procedures	Japan	Korea	China	Hong Kong	Taiwan	Singapore	Malaysia	Thailand	Vietnam	Philippines	United States
Documents Preparation	100	50	245	90	175	116	85	175	160	105	230
Customs clearance and technical control	85	15	80	0	100	50	60	50	100	85	60
Ports and terminal handling	250	100	140	265	180	150	120	160	150	225	400
Inland transportation and handling	445	500	95	220	200	140	170	200	200	170	400
Total	880	665	580	575	655	456	435	585	610	585	1,090
Documents Preparation	140	65	260	100	240	99	75	125	130	90	205
Customs clearance and technical control	135	30	80	0	100	50	60	255	95	185	90
Ports and terminal handling	250	100	140	265	180	150	120	160	175	200	420
Inland transportation and handling	445	500	135	200	200	140	165	210	200	185	600
Total	970	695	615	565	720	439	420	750	600	660	1,315

Source: World Bank (2013).

Table 5.3 Transhipment container cargo volume from Japanese ports via Busan to the United States

Cargo origin	Hakata	Osaka	Kobe	Hiroshima	Moji	
Actual TEU	17,239	5,729	3,640	3,518	2,586	
Cargo origin	Yokohama	Hiroshima	Niigata	Tokuyama	Tokyo	Total
Actual TEU	2,103	2,100	2,093	2,021	1,411	53,957

Source: Watanabe (2012).

This is one example of the difficulty in enhancing the status of Japanese container ports. Briefly, the Japanese port governance structure is complicated, and it takes a long time for the central government to implement and come into effect the policies that enhance port competitiveness.

Interpretations arising from the Japanese port policy

Lastly, we briefly see the applications of the key factors to port policies in Japan. The points raised should be considered from a practical perspective. First, regarding congestion and capacity constraints, as repeatedly noted, under-capacity seems not a problem in East Asian port competition. Rather, severe price competition occurs because of over-capacity. In this case, the mark-up in port charges is also irrelevant. However, when examining the hinterland (or more strictly speaking, hinterland access), then congestion can be relevant; particularly the roads that connect the ports/terminal and are congested in the peak periods, and the final point of demand. Then, to enhance social welfare, it may be necessary to implement initiatives to decrease the negative externality costs. Second, with respect to the final point of demand, it seems difficult to specify where the final demand is. In other words, if we focus on the "inter-port" competition (the second level of port competition), then the specification is very important although it is irrelevant to consider that when we focus on inter-port competition (the third level of competition). We showed that the Japanese government tried to enhance their ports' competitiveness from the point of "inter-port" competition, yet the final points of demand in the context of East Asian port competition are ambiguous. Third, regarding the governance structure, it is not necessarily clear who the final decision maker in Japanese ports is. While most container ports in Japan are owned and operated by local government, the central government tries to support these ports through grants or regulations. Additionally, recently privatized companies do not necessarily have the discretion to determine the port charges. Therefore, we need to confirm and set the appropriateness of the objectives in the context of Japanese port competition policy. The appropriateness of the assumption that a single port entity is simply a private profit maximizer should also be considered. If the assumption does not hold in some cases, then a hybrid objective type – such as the weighted average of profit maximization and social welfare maximization – might be employed.

Conclusion

This chapter aimed to discuss the application of game theoretic models to port competition and port policy. To address this, we considered the following points: First, we confirmed the definition of port competition. It is first to make clear about the definitions of three types of port competitions according to the previous studies – for example, Van de Voorde and Winkelmans (2002) and Notteboom and Yap (2012). Second, an outline of the main articles is provided, in which non-cooperative game models are developed to apply for the analysis of port competition and the related topics. Here, De Borger et al.'s (2008) is the first research that investigates a general competition between ports using a two-stage game model. Their paper stimulated a series of papers that modify the models to depict more specific situations surrounding competitive ports. Therefore, the paper of De Borger et al. (2008) is put at the heart of the review for this chapter, and the subsequent related studies are overviewed, including Van Reeven (2010), De Borger and De Bruyne (2011), Bae et al. (2013), Ishii et al. (2013), Kaselimi et al. (2011), Luo et al. (2012), Wan and Zhang (2013), Czerny et al. (2014), and Zhuang et al. (2014). Our literature review unveils the relationships and interactions among factors and variables associated with port competition. Then, we explained the gaps between the models described above and actual competition from the view point of economic structure, in particular, congestion, hinterland, and vertical supply chain.

Lastly, we briefly outlined recent port policies in Japan: Super Core Port policy and ISCP policy. These policies were introduced to improve the competitiveness of ports in Japan. Third, we focused on the ownership and operation structures of a port to verify the assumptions of the game theoretic models, or to evaluate the robustness. Finally, taking these points into consideration, we applied the game theoretic models for examining port policies in Japan form the point of "inter-port" competition in East Asian region.

Some issues remains for our future study. First, it is required to construct more applicable model. By considering existing studies based on game theoretical models, we need to build the model that can deal with the more realistic situation. Second, to explore the applicability of models to port competition, data collection and empirical analysis should be also needed. One example is to calculate the port charges and analyse the port competition by using them. The other example is to estimate capacity for each port and examine whether "over-capacity" or "congestion" problems arise, especially in the East Asian region. By addressing them, we could obtain more detailed and practical implications, which are consequently expected to contribute to studying port policies from the game theoretical viewpoint.

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6

Toward Robust Management of Maritime Risk and Security

Zaili Yang, Jin Wang, and Adolf K.Y. Ng

Introduction

Maritime security is defined as

> the advancement and protection of a nation's interests, at home and abroad, through the active management of risks and opportunities in and from the maritime domain, in order to strengthen and extend the nation's prosperity, security and resilience and to help shape a stable world.
>
> (HM Government, 2014, p. 9)

Maritime security risks include

- terrorism affecting a nation and its maritime interests, including attacks against cargo or passenger ships;
- disruption to vital maritime trade routes as a result of war, criminality, piracy or changes in international norms;
- attack on a nation's maritime infrastructure or shipping;
- transportation of illegal items by sea, including weapons of mass destruction, controlled drugs and arms; and
- smuggling and human trafficking.

In the post-9/11 era, anti-terrorism challenges have been seen from air transport, through shipping to whole container supply chains for rationalizing the use of limited security resources to avoid the risks of terrorists attacking ships. It becomes more worrisome given the possibility that terrorists can have the increasing pirate activities, notably in Somali waters and the West African coastline, and possibility of terrorists to collaboration between collaborate with pirates and/or adapt their ability of hijacking ships to attack other maritime infrastructure/assets such as ports. Maritime security issues have been clearly pushed to the forefront of the international agenda consecutively in the past decade, attracting active endeavor to improve security records through a culmination of a number of initiatives, research developments, regulations, and innovations. However, these advances are often presented in a form of piecemeal. Also, the existence of international standards might not be good enough to achieve the objectives of maritime security (Ng and Gujar, 2008), given that such standards are sometimes too vague to implement a security assessment process effectively (Ng and Yang, 2014). As a result, there is a strong need to develop an integrated framework to accommodate them in a systemic manner for realizing cost-effective maritime security policymaking.

This chapter aims to propose a new conceptual methodology of maritime security, namely Maritime Security Assessment (MSA) in which risks are addressed in a comprehensive and cost-effective manner. The MSA is expected to contribute to providing a paradigm shift in maritime security assessment and management and to advancing the state of the art to a point where robust quantitative security assessment is feasible. Different with the analysis of piracy attacks, terrorist threats are however inherently difficult to quantify due to lack of critical mass in historical accident data and tend to be expressed in vague or qualitative terms. To tackle the above research challenges, in this chapter, following a review of historical maritime security related data and the new development of maritime security regulations, a conceptual MSA methodology is generated by incorporating formal safety assessment (FSA) into the shipping and port security context. Advanced risk modeling and decision-making approaches are then outlined to support the MSA framework. Finally, recommendations on further exploitation of advances in technology are suggested with respect to risk-based security policymaking, particularly in situations where conventional risk analysis methods cannot be appropriately applied due to a high level of uncertainty in failure data.

Overview of piracy attacks

In light of the high increase of attacks off the coast of Somalia between 2007 and 2011 and the emerging of the West Africa piracy phenomenon together with the flaring up of piracy incidents in Southeast Asia, in particular the Malacca Strait and the waters off Indonesia and the

Philippines, the shipping industry and international organizations are disparate for solutions to the menace of piracy.

For example, to address maritime piracy activities in Somali waters, the United Nations Political Office for Somalia (UNPOS) is engaged in implementing the National Security and Stabilization Plan through active engagement with the Somali Transitional Federal Government. The United Nations Office for Drugs and Crime (UNODC) focuses on developing fair and efficient trials for the pirates, as well as assisting States in the prosecution and imprisonment of pirates in the region (Pristrom et al., 2014).

An important reference for the development of such solutions is the analysis of piracy attacks in history. Figure 6.1 shows all cases of piracy and armed robbery which have been brought to the attention of the International Maritime Organisation (IMO) from 1 January 2007 to 30 August 2012. From Figure 6.1 it can be seen that the highest occurrences of piracy incidents are the waters off the East African coast. During the period considered (1 January 2007–30 August 2012), this was by far the most dangerous area for ships to become a piracy victim. However, the likelihood of becoming a victim of a hijacking has decreased from one out of 4,000 ships at the peak of Somali piracy to currently one in 13,000 (GAC Protective Solutions, 2012). This may be due to the introduction of useful initiatives such as the implementation of Best Management Practices (BMP) in maritime operations. Pristrom

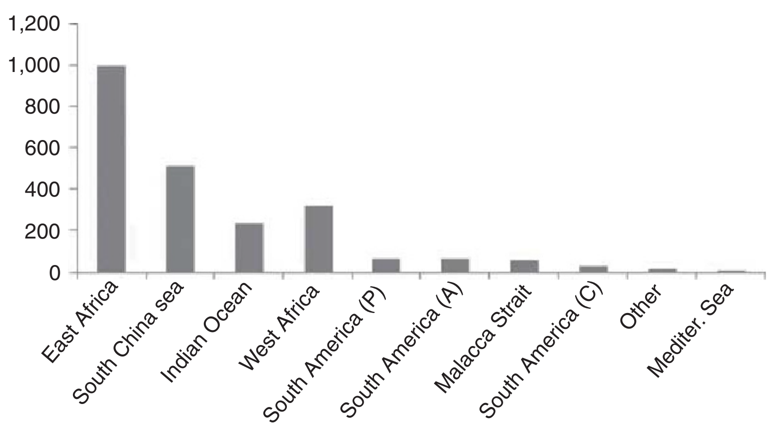

Figure 6.1 All incidents of piracy and armed robbery from 1 January 2007 to 30 August 2012 by geographical areas
Source: IMO GISIS database.

Table 6.1 All incidents of piracy and armed robbery from 1 July 1994 to 30 August 2012

Ship type	Total number	Ship type	Total number
Bulk carrier	1,273	Reefer	88
Tanker	1,016	Ro-ro	72
General cargo ship	926	Car carrier	35
Container ship	858	Passenger ship	33
Chemical tanker	498	Ferry	13
Special purpose	257	Barge	9
unspecified	254	Other	7
Small craft	236	Mobile offshore drilling unit (MODU)	4
Fishing vessel	233		
Gas tanker	146	Warship	3
Total	4,636		

Source: IMO GISIS database.

et al. (2014) also analyzed the statistics of incidents with respect to three other piracy hotspot areas: The South China Sea, the Indian Ocean, and West Africa. Apart from a statistical analysis of maritime piracy and robbery incidents/accidents that have happened on different types of ships over the past 20 years, major contributing factors and the most vulnerable vessels were highlighted with a view to developing a sustainable mechanism to suppress piracy and robbery crimes.

Furthermore, in Table 6.1 the ship type that has been mostly attacked is bulk carriers, followed by tankers and general cargo ships. Container ships that are usually fast and have a high freeboard come fourth in this list. Although this is a good indication of ships attacked, it is argued that ships that are drifting or tied up in ports are easier targets for perpetrators, and Table 6.1 may only be a reflection of the proportion of ship types trading the world oceans.

The number of hijackings of a certain ship type might be more appropriate to identify the threat for a ship. It is evident from Table 6.2 that ships with the highest risk of becoming a piracy victim are smaller ships, such as yachts, and fishing vessels. Out of the 1,273 attacks carried out on bulk carriers, 37 ended with the ship being hijacked.

As the intention of pirates is not necessarily to hijack a ship, it is useful to analyze the attacks where pirates managed to board the ship. Figure 6.2 shows the ratio for 3,664 successful boarding between 1 July 1994 and 30 August 2012 against the number of the ships steaming (underway). One should interpret Figures 6.2–6.5 by looking at both the ship type that has the highest ratio of being boarded while steaming

Table 6.2 Worldwide hijackings from 1 July 1994 to 30 August 2012

Ship type	Total no
Fishing vessel	71
Other small craft such as yachts and boats	69
General cargo ship	61
Chemical tanker	40
Tanker	40
Bulk carrier	37
Unspecified	33
Container ship	9
Others	23
Total	383

Source: IMO GISIS database.

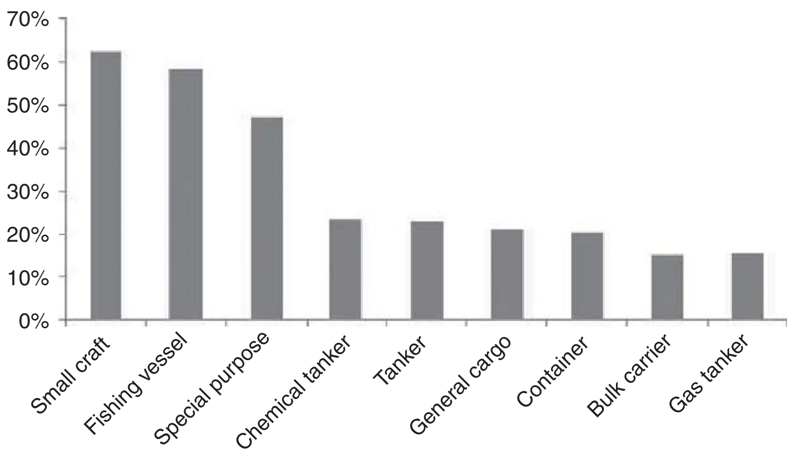

Figure 6.2 Successful boarding while the ship was steaming (attacks (worldwide) from 1 July 1994 to 30 August 2012)
Source: IMO GISIS database.

and the absolute percentage value for each ship category for different geographical areas.

As can be seen from Figure 6.3, the ships with the highest risk of becoming a victim of piracy off the East African coast remains small craft (82 percent). A substantial contrast to the figures for East Africa piracy is constituted by those from South America. The boarding rate

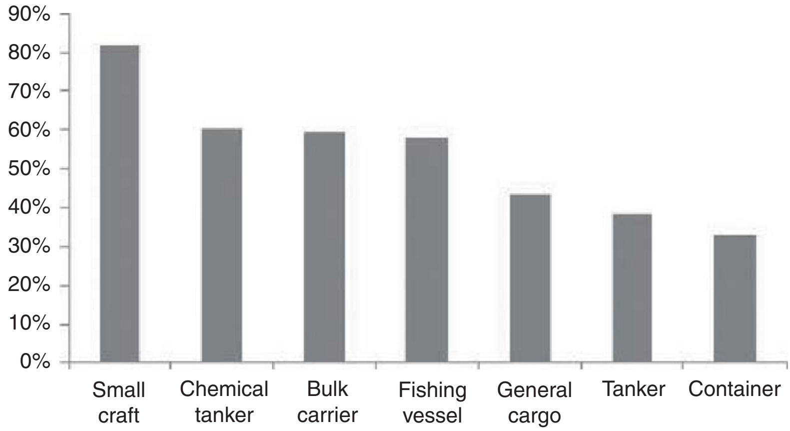

Figure 6.3 East Africa: Successful boarding while the ship was steaming
Source: IMO GISIS database.

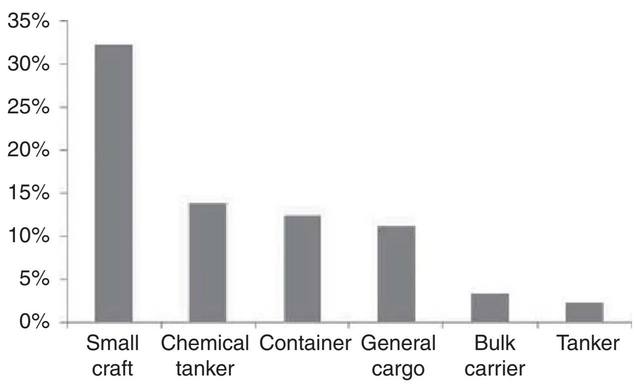

Figure 6.4 South America: Successful boarding while the ship was steaming
Source: IMO GISIS database.

while steaming is significantly lower, as can be seen from Figure 6.4. However, small crafts are still exposed to the greatest threat of becoming a victim of piracy, followed by chemical tankers and container ships. The category "Fishing vessel" is not represented here as there were only few attacks which would distort the statistics.

In West Africa, the statistics are closer to the worldwide average (Figure 6.5) in the sense that the highest threat by ship type and while

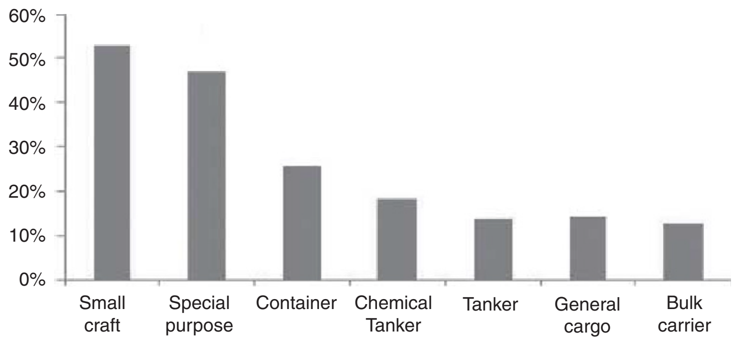

Figure 6.5 West Africa: Successful boarding while the ship was steaming
Source: *IMO* GISIS database.

steaming is for small craft and special purpose ships while the ratio of boarding is well below 20 percent for tankers, general cargo ships, and bulk carriers.

The statistical analysis of ship types for different regions shows that ships with the highest risk of being boarded while steaming do not differ significantly in different geographical areas. Small craft, special purpose ships, and chemical tankers are, in the vast majority of the cases, vessels with a low freeboard and a slow speed and therefore easier to board, irrespective of their geographical locations. Furthermore, the West African waters of the Gulf of Guinea stretching from Liberia in the west to Angola in the south are considered to be much more dangerous for seafarers than any other region. The nations of that region produce 5 million barrels of oil on a daily basis (Saul, 2009), and the ships which are at risk in the Gulf of Guinea are mainly those which are related to the oil industry. Considering the fact that oil production has increased in West Africa over the recent years, the number of attacks on ships directly or indirectly deployed by the oil industry has likewise increased.

The business model of pirates operating in the Gulf of Guinea is very different to that of their East African counterparts who hijack ships for ransom. A substantial proportion of the West African pirates who are usually more violent are based in Nigeria. They attack victim ships that are at anchor or drifting while waiting for cargo or orders to proceed to the port. Hence West African perpetrators do not have to attack while the ship is at full speed. The nature of West African business model has changed from petty theft of crew personal effects and ships stores in and around port areas (UK P&I Club, 2011) into a more sophisticated and violent criminal activity. West African piracy can be grouped into the three main categories: "Armed robbery," "Cargo theft," and "Kidnapping".

While armed robbery is somewhat opportunistic and aimed at ransacking the ship valuables including personal belongings of the crew, it differs from incidents of the same category in other regions of the world as the level of violence applied by the attackers is generally higher. Very often such attacks cause serious harm to the crew including the ship's master. Due to the threat level, the territorial waters of Benin and Nigeria have been formally designated as a piracy high-risk area (HRA) by the International Bargaining Forum (IBF), the body involving the International Transport Workers Federation and maritime employers (Schuler, 2012). Seafarers sailing through the IBF HRA benefit from a higher pay. Similarly, the Joint War Committee (JWC) that comprises underwriting representatives from Lloyds and the International Underwriting Association of London (IUA) has taken action by declaring the waters of the Beninese and Nigerian Exclusive Economic Zones north of Latitude 30N as war, piracy, terrorism, and related perils listed areas (Roberts, 2012). The JWC decision to declare this area as HRA for insurance purposes directly results in higher insurance premiums for the associated shipowners/operators (Pristrom et al., 2014).

New developments in maritime security management

Response to maritime security/piracy

Maritime piracy needs to be distinguished from other clusters within that domain such as maritime terrorism, armed robbery, or theft due to their different motivations (Schneider, 2012). However, the modus operandi of pirates is very different from that of terrorists but both phenomena are constantly evolving and may develop characteristics that make a distinction between them more and more difficult (Pristrom, 2013; Pristrom et al., 2014). While piracy is, to some extent, predictable depending on sea areas (high-risk vs. low-risk areas), weather conditions or the implementation of BMP, maritime terrorism cannot be confidently predicted and is still debated (Schneider, 2012). Whereas pirates seek financial gain from attacks, terrorists pursue a political agenda (as illustrated by the terrorist attack during the Boston Marathon and shootings at the Parliament Hill of Ottawa in April 2013 and October 2014, respectively).

Skiffs and dhows are often used by Somali pirates to carry out their attacks as these types of craft easily blend in with local fishing vessels and are therefore difficult to be identified by merchant ships or patrolling military assets. The tracking of dhows is further complicated by the fact that they do not follow the usual commercial practice of shipping as there are no scheduled services or rarely any cargo documentations such as bill of ladings. In some cases, dhows are used as pirate mother ships to carry out attacks further out at sea (NATO Shipping Centre, 2011). Somali pirates have the advantage of operating in the vast area of the Western Indian Ocean which spreads across 2.5 meter square nautical miles.

The great success in reducing the number of incidents in the HRA is, to a large extent, attributable to the naval forces. Starting from a more restrained role in the early days of Somali piracy, most governments have given them greater backing in apprehending pirates. The reactive role has more and more been replaced by a proactive role to render Pirate Action Groups (PAGs) harmless. The international cooperation mechanism established through the Shared Awareness and Deconfliction (SHADE) process is unique in naval history. The navies have established the IRTC in the Gulf of Aden and maintain the Mercury information sharing platform. The efforts and results are consistent with the argument by Fu et al. (2010) that more government intervention would be required so as to address piracy problem in Somali waters comprehensively. The navies also regularly provide escorts to World Food Programme (WFP) ships providing humanitarian aid to Somalia (Pristrom et al., 2014).

The BMP against Somalia Based Piracy (BIMCO, 2011) are the shipping industry's response to the threat posed by pirates to their ships, crews, and cargoes within the HRA. The contributors to the BMP comprise shipowner associations, special ship type associations such as tanker, passenger, and dry cargo associations as well as the maritime insurance industry, navies, and others. The BMP are to be implemented on board ships by their masters with guidance and support from the ship operator in order to avoid, deter, or delay piracy attacks in the HRA. Failure to do so may result in disputes with maritime insurers who may make provisions in the insurance cover that require adherence to the BMP (Marsh, 2011). The BMP set out three fundamental requirements to protect ships against maritime piracy and robbery attacks:

- Registering of ships with the Maritime Security Center Horn of Africa (MSCHOA);

- Reporting by ships to the United Kingdom Maritime Trade Office in Dubai (UKMTO); and
- Implementing Ship Protection Measures.

Armed response on board merchant ships

The International Association of Ports and Harbours (IAPH) believes that "arming or military training of civilian crews will only escalate violence in pirate encounters. The use of weapons should remain restricted to military staff on internationally agreed missions" (IAPH, 2010). However, the latest estimate on the use of armed guards shows that the likely number of armed transits is 16,500 out of around 55,000 vessels transiting the Indian Ocean (McMahon, 2012). No ship has been hijacked with armed personnel on board (Cameron, 2011; Cook, 2011). This statement is supported by IMO statistics (IMO, 2011a) and has given rise to a fast-growing private maritime security industry which is attempting to fill the gap where the protection of ships has not been sufficiently provided by navies. The terms "privately contracted armed security personnel" (PCASP) and "private maritime security companies" (PMSCs) are synonymous with private businesses and should be clearly distinguished from security provided by States or on behalf of a State. In the absence of any international laws regulating the PCASP/PMSCs, serious concern has been voiced by IMO Member States, as well by shipowners and their associations, about the righteousness of some of those PMSCs that use firearms to protect ships from attacks by pirates. The increase in private armed guards on board ships also puts flag States' Administrations under pressure as shipowners overwhelm them with requests to approve the use of PCASP on board their ships (Fairplay, 2011).

It was agreed by the IMO Member States that the authorization of PCASP and the use of military or other law enforcement officers duly authorized by the government are a matter for flag States in consultation with shipowners, companies, and ship operators and not the IMO (2012). It is the national shipowners' view that private armed guards are a clear second best choice to military personnel (ICS, 2011).

IMO guidelines

The IMO guidance is not intended to endorse or institutionalize the use of PCASP. The IMO, however, has realized that there is a strong need to provide guidance to shipowners, masters, flag states, and port and coastal states as it has become common practice among many shipowners to protect themselves using armed security services. The industry-developed BMP also provide guidance on PCASP (BIMCO, 2011), which in essence coincides with the IMO guidance.

The development of port and coastal state guidance was derived from the need for "[f]lag States, the shipping industry and the PMSCs who provide PCASP to know whether and under what conditions the embarkation and disembarkation of PCASP and/or firearms and security-related equipment for use by PCASP is allowed" (IMO, 2011b). It was one of the conclusions of the Maritime Security Working Group (MSWG) that due to different "legislative regimes among Member States, it was appropriate for only high-level recommendations to be developed at this stage" (IMO, 2011b). Such recommendations do not address all the legal issues that might be associated with the movement of PCASP or of the firearms or equipment intended for use by them.

Maritime security technology and education

For a ship operator's or managing company's emergency services, it is important to have updated and reliable information about the ship's position. Modern satellite-based tracking systems are capable of providing position information on a frequent basis. Automatic Identification System (AIS)'s position data as well as those from the Long Range Identification and Tracking (LRIT) are important for the identification of ships when coming under attack from pirates. Such information is used by navies and law enforcement agencies to find and identify ships that have requested assistance (Pristrom et al., 2014).

In this regard, the use of citadels has been a successful measure in the protection of ships that have been boarded by pirates. A citadel is defined in BMP4 (BIMCO, 2011, p. 38) as "a designated pre-planned area purpose built into the ship where, in the event of imminent boarding by pirates, all crew members will seek protection. It is designed and constructed to resist a determined pirate trying to gain entry for a fixed period of time". The success of such rescue operation depended on the proximity of the ship that had already been boarded by pirates. BMP4 also states that the "citadel approach is lost if any crew member is left outside before it is secured". In addition to the requirement of 100 percent crew assembled safely in the citadel, two more criteria must be met by the ship before a navy intervention can be considered:

1. The crew must have self-contained, independent and reliable two-way external communications in addition to VHF communication.
2. The pirates must be denied access to ship propulsion.

(BIMCO, 2011, p. 38)

Another new innovation that has entered the maritime security market is high security door locking solutions at bulkheads. When installed on tankers they must, in addition to the security requirement, be able to be operated safely in potentially explosive atmospheres (Woodbridge, 2012). The locks would only allow crew members with a valid electronic "permit to work" to access critical parts of the ship such as restricted areas.

The maritime industry is considering making maritime security and defense a new profession. A more universal approach to the security and defense of the maritime industry as a whole should be taken far beyond currently recognized "high risk" regions (Kuhlman, 2012). Such an initiative can be dated back to the promulgation of the International Ship and Port Facility Security (ISPS) Code at the beginning of this century, when it stated that Ship Security Officers (SSO) and Port Facility Security Officers (PFSO) should be appointed at ship and port facilities, respectively. However, little satisfactory progress has been made yet, requiring more efforts from the stakeholders in the field. The IMO Member States have clearly indicated that seafarers should not be armed as they are not security experts. However, further requirements on security-related training for all or some seafarers become only internationally binding if the International Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW) is amended.

An example of a national maritime strategy

The UK published its National Strategy for Maritime Security in May 2014 (HM Government, 2014). The objectives of the Strategy are

- promoting a secure international maritime domain and upholding international maritime norms;
- developing the maritime governance capacity and capabilities of states in areas of strategic maritime importance;
- protecting the United Kingdom, our citizens and our economy by supporting the safety and security of ports and offshore installations and Red Ensign Group (REG)-flagged passenger and cargo ships;
- assuring the security of vital maritime trade and energy transportation routes within the UK Marine Area, regionally and internationally; and
- protecting the resources and population of the United Kingdom and the Overseas Territories from illegal and dangerous activity, including serious organized crime and terrorism.

The Strategy focusing on integration and collaboration has been proposed in the current climate of limited resources. The Strategy consists of the following five elements (HM Government, 2014):

- understanding the maritime domain – gathering intelligence, sharing information, building partnerships, analyzing data, and identifying concerns;
- influencing to help achieve the objectives;
- preventing maritime security concerns from arising or escalating;
- protecting the country's interests by taking action to reduce the vulnerability of the shipping and maritime infrastructure as well as efforts to increase the resilience in the event of an attack; and
- responding whenever appropriate or necessary.

The Strategy can be in short described as UNDERSTAND, INFLUENCE, PREVENT, PROTECT, and RESPOND. Effective delivery of maritime security activity requires clear and robust decision making in government so as to respond to incidents, to seek evidence, and to generate policy. The Strategy sets out a holistic approach to maritime security.

Development of a novel maritime security assessment (MSA) methodology

Maritime security studies are often deemed as a new dimension of enhancing maritime safety. While maritime safety accidents are unintentional, maritime security incidents are intentional. Although both of them may have the same risk outcomes – injuries and property damage, they are quite different in nature, thus leading to significant variations in approaches of analyzing them. For example, threat-based security risks, which are inherently difficult to quantify may tend to be expressed in vague or qualitative terms. It is due to this reason that maritime security research in the literature largely focuses on qualitative analysis for addressing risk mitigation measures without appropriately quantifying risks of the threats. An analysis of 247 maritime security papers published in scholarly journals from 2000 to 2013 on the Web of Science indicates that a majority of them address maritime security effort from political, economic, and cultural aspects, leaving few looking at the quantification of maritime security risks (Yang, 2014). It apparently indicates the existence of a significant research gap, requiring the development of systematic risk analysis methodologies with the support of novel and advanced risk modeling and decision-making techniques.

Incorporating FSA in maritime security studies may provide a feasible solution to the challenge (Yang et al., 2013b). A new MSA methodology is proposed to integrate several studies focusing on maritime security risk quantification and safety management, consisting of

- identification of threats and vulnerabilities (Yang et al., 2013a);
- subjective security risk estimation (Yang et al., 2009b);
- security risk mitigation and protection (Yang et al., 2010);
- security cost–benefit analysis (Yang et al., 2009a);
- dynamic security-economic evaluation (Yeo et al., 2013); and
- security inspection and maintenance (Yang et al., 2014).

Identification of threats and vulnerabilities

Threats and vulnerabilities (TVs) are identified through a pairwise analysis. The criticality of the vulnerabilities varies when facing different threats (attack modes). Vulnerabilities are identified from the multiple levels of assets, infrastructure and systems of a security target. The relevant threats of the identified vulnerability are analyzed and its criticality prioritized with regard to these threats. A risk matrix approach (Pillay and Wang, 2002) can be initially used to screen and distinguish the TVs with high criticality from those with comparatively trivial ones. The matrix portraying risk as the product of Likelihood (L) and consequence (C), is used as the basis for qualitative risk determination. Considerations for the assessment of probability are shown on the horizontal axis, while the ones for the assessment of consequence are shown on the vertical axis. Plotting the intersection of the two considerations on the matrix provides an estimate of the risk. Although numerical grades can be used to define the security risk parameters (i.e., likelihood and consequences) to assist in raw data collection during this process, it may be still difficult for experts, with 100 percent confidence, to provide isolated evaluations of the vulnerabilities with respect to each parameter, particularly in the lack of past experience. Relatively speaking, it may be easier to carry out the comparison for an asset under two different threats or between two assets under the same threat. For example, it is often difficult for an expert to rationally evaluate the consequence of an asset in port being attacked under a newly rising threat. However, there is probably more confidence for him to provide information regarding if the new threat can cause more/less loss compared to an existing one.

An extended Analytic Hierarchy Process (AHP) approach is used to evaluate the vulnerabilities in a pairwise comparison investigation in order to address the above research challenge. If only a limited number of TVs are identified, AHP can be directly used to figure out their relative probabilities and consequences. However, the task of conducting pairwise comparison becomes time consuming when a large number of critical vulnerabilities are identified. A group crossing comparison approach (i.e., extended AHP) is therefore developed to solve the problem. The principal is to use the same evaluation of a common pair of T_iV_j from two sets of TVs (one set for the various vulnerabilities V_m ($j \in m$) under the same threat T_i while the other for the same V_j under different threats T_n ($i \in n$) as a bridge to associate and adjust the values of TVs from the two sets. Suppose that with respect to a criticality parameter, the performance of different vulnerable assets $A_1, A_2, \ldots, A_m$ under one specific threat T_j ($j \in n$) can be compared in Group 1. The performance of a vulnerable asset A_i ($i \in m$) under various threats $T_1, T_2, \ldots, T_n$ can be analyzed in Group 2. Then the performance of A_i under T_j in Groups 1 and 2 can be used as a bridge to connect and normalized all the evaluations in such two groups. For example, if the relative performance of A_i under T_j is evaluated as P^1 in Group 1 and P^2 in Group 2 in terms of the criticality parameter, then the normalization can be carried out via the followings.

- Dividing the performance values, $P^2_{i,1}, P^2_{i,2}, \ldots, P^2_{i,n}$ in Group 2 by (P^2/P^1) to obtain the adjusted performance values, $P^{2'}_{i,1}$, $P^{2'}_{i,2}, \ldots, P^{2'}_{i,n}$ in Group 2, in which $P^{2'}_{i,j} = \frac{P^2_{i,j}}{P^2/P^1}$. This means that $P^{2'}_{i,1}, P^{2'}_{i,2}, \ldots, P^{2'}_{i,n}$ are in line with $P^1_{1,j}, P^1_{2,j}, \ldots, P^1_{m,j}$ in terms of their units (evaluation dimensions).
- Dividing each of $P^{2'}_{i,1}, P^{2'}_{i,2}, \ldots, P^{2'}_{i,n}$ and $P^1_{1,j}, P^1_{2,j}, \ldots, P^1_{m,j}$ by their sum (the sum of all the values in both sets), to obtain the final normalized performance values with respect to the particular parameter, which are symbolized as $P_{h,l}$ ($h = 1, 2, \ldots, m+n-1; l = Wi, Dj, Rk, Dl$).

Similarly, if three or multiple groups are involved, their individual performance values will be first adjusted on a common space and then normalized to realize their sum being equal to one. More technical explanations can be found (Yang et al., 2013a).

Subjective security risk estimation

After the above screening process, the vulnerabilities with high criticality need an in-depth prioritization analysis. Detailed risk parameters are defined using fuzzy logic due to the subjectivity of the input data. The threat-based risk parameters used to define subjective security estimates include those at both the senior and junior levels. The senior parameter is “Security estimate” (SE), the single fuzzy output variable, which can be defuzzified to prioritize the risks. The variable is described linguistically and is determined by some junior parameters. In risk assessment, it is common to express a security level by degrees to which it belongs to such linguistic terms as “Poor,” “Fair,” “Average,” and “Good” that are referred to as security expressions. To analyze the junior parameters, four fundamental risk parameters can be identified and defined as “Will” (W), “Damage capability” (D), “Recovery difficulty” (R), and “Damage probability” (P) (Yang et al., 2009b). W decides the likelihood of a threat-based risk, which directly represents the lengths one goes to in taking a certain action. To estimate W, one may choose to use such linguistic terms as “Very weak,” “Weak,” “Average,” “Strong,” and “Very strong”. The combination of D and R responds to the consequence severity of the threat-based risk. Specifically speaking, D indicates the destructive force/execution of a certain action and R hints the resilience of the system after the occurrence of a failure or disaster. The following linguistic terms can be considered as a reference to be used in subjectively describing the two sister parameters: “Negligible,” “Moderate,” “Critical,” and “Catastrophic” for D and “Easy,” “Average,” “Difficult,” and “Extremely Difficult” for R. P means the probability of the occurrence of consequences and can be defined as the probability that damage consequences happen given the occurrence of the event. One may choose to use such linguistic terms as “Unlikely,” “Average,” “Likely,” and “Definite” to describe it.

The defined senior and junior risk parameters can be modeled by using a fuzzy IF–THEN rule base system for security risk estimates. For example, the following is a fuzzy IF–THEN rule: IF W of a threat is “Very strong” AND D is “Catastrophic” AND R is “Extremely difficult” AND P is “Definite,” THEN SE is “Poor”. Obviously, the IF–THEN rules in this study can have two parts: an antecedent that responds to the fuzzy input and a consequence, which is the result/fuzzy output. In classical fuzzy rule-based systems, such input and output are usually expressed by single linguistic variables with 100 percent certainty and the rules constructed are also always considered as single output cases. However, when observing realistic maritime security situations, the knowledge representation power of the fuzzy rule systems will be severely limited if only single linguistic variables are used to represent uncertain knowledge. Given a combination of input variables, SE may belong to more than one security expression with appropriate belief degrees. For example, a fuzzy rule with certain degrees of belief can be described as: IF W of a threat is “Very strong” AND D is “Catastrophic” AND R is “Extremely difficult" AND P is "Likely," THEN SE is "Poor" with a belief degree of 0.9, "Fair" with a belief degree of 0.1, "Average" with a belief degree of 0, and "Good" with a belief degree of 0. It is noted that all the parameters and the belief degrees of the rules are usually assigned at the knowledge acquisition phrase by multiple experts on the basis of subjective judgments. In order to model general and complex uncertain problems in security assessment, classical fuzzy rule-based systems are extended to assign each rule a degree of belief.

Once a rule-based system is established, it can be used to perform inference for given fuzzy or incomplete observations to obtain the corresponding fuzzy output, which can be used to assess the security level of an identified TV from Step 1. During the estimation process, if all the evaluation of the defined TV with respect to each junior parameter is expressed by a single linguistics variable, then a single IF–THEN rule will be employed for security estimate. Risk input is however sometimes described by multiple linguistics variables with respect to a risk parameter. For example, W of a defined TV may be evaluated as "Very strong" with a belief degree of 0.5 and "Strong" with a belief degree of 0.5. Multiple rules will be hired in this situation, which requires an advanced method capable of synthesizing the rules without losing useful input information. An Evidential Reasoning (ER) approach is well suited to modeling subjective credibility induced by partial evidence. The kernel of this approach is an ER algorithm developed on the basis of the Dempster–Shafer (D-S) theory, which requires modeling the narrowing of the hypothesis set with the requirements of the accumulation of evidence (Yang and Xu, 2002). It is therefore employed to synthesize all the relevant rules for producing security risk assessment.

Risk mitigation and protection

Once an identified TV pair (in Step 1) has been evaluated to have a high security risk/criticality (in Step 2), risk control measures (RCMs) for improving the security level of that TV are developed from both risk mitigation (with respect to D and R) and protection (with focus on W and P) aspects. To investigate the protection-based RCMs, more detailed "higher level" root causes (influencing W and P) are needed. Such causes require to be identified in a hierarchy using a top-down approach, in which the evaluations of the bottom-level attributes can be obtained using either objective data or subjective judgment by experts with confidence. The identification process will entail extensive interaction with security analysts and practical security management operators including questionnaire surveys and interview of marine masters and security officers, and the like. Since this process is essentially dynamic and scenario based, the factors involved in one analysis can significantly differ with another and thus, the development of a unique comprehensive model including all possible factors is not realistic. As an alternative, a "live" database regularly updated through collecting the factors used in real applications with time enables the development of a generic basic model including the most frequently used factors in the past as a reference for the future analysis. For example, willingness of a terrorist to attack an asset in port may be affected by the root causes such as "population in the asset," "mission role of the asset," "ease of access to the asset," "symbolic value of the asset," "distance to the control perimeter," and "recognition of the asset to an unknown person" (Hudson et al., 2002; Yang and Wang, 2009).

Next the evaluations of the bottom-level attributes in the hierarchy need to be synthesized to calculate the value of the upper-level risk parameters and top-level security estimates. Although showing much attractiveness in risk synthesize, ER is arguably not suitable to model the multiple-level quantitative configuration in this step due to its complex calculation process. A new risk reasoning approach is developed to realize the real-time risk synthesize from the bottom-level evaluations to the top-level security estimates (Yang et al., 2008). The belief structure in the rule base developed above can be transformed and represented in the form of conditional probabilities.

Using a Bayesian network (BN) technique, the rule base can be modeled using a five-node converging connection. It includes four parent nodes, NW, ND, NR, and NP (Nodes W, D, R, and P); and one child node NSE (Node SE). Having transferred the rule base into a BN framework, the rule-based risk inference for the security analysis will be simplified as the calculation of the marginal probability of the node NSE. To marginalize SE, the required conditional probability table of NSE, $p(S|W, D, R, P)$, can be obtained by converting the rule base into a conditional probability format. Once the observations are obtained, they can be transformed and expressed by the linguistic variables defined in Step 2 with belief degrees. The transformation can be completed using fuzzy Max–Min mapping operation intending to measure the similarity of two fuzzy sets. The marginal probability of NSE can be calculated using the Bayes' rule (Jensen, 2001).

Multiple cost–benefit attributes analysis

The developed RCMs (in Step 3) bring security benefits of reduced risk from Step 4, increased accountability and less customers' revenue loss together with the corresponding costs such as security equipment investment and longer transportation cycles. Maritime transport systems thus require identifying the "optimal" security RCMs based on multiple cost–benefit attributes in an uncertain environment, in which the attributes are often not presented in a monetary unit as well as not independent to each other. Consequently, a heuristic approach based on techniques such as BNs, entropy, and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) can be developed to deal with both "multiplicity" and "uncertainty" in RCM selection simultaneously (Yang et al., 2009a). For instance, the role of BNs in TOPSIS is explained in a complementary way, in which BNs can avoid their application drawbacks resulting from the single attribute consideration in security risk assessment. Furthermore, given any potential RCMs, all relevant (sometimes conflicting) decision attributes in the form of the nodes in BNs will produce certain associated attribute values expressed as posterior probabilities, which can be used and combined in a traditional TOPSIS framework as a reference to rank the set of RCMs or a group of RCMs called risk control option (RCO). More elements of the model and their relationships are as follows (Ng and Yang, 2014; Yang et al., 2010).

1. Identify risk-based decision problems (objectives) and RCOs (actions/functions)

The first step is concerned with the setting up of clear objectives and functions. The objectives are the targets or goals of a study and the functions are the set of actions that are required in order to achieve the final aim. Obviously, the objectives of dealing with risk-based decision-making problems are to determine the optimal RCO from multiple potential actions or their combinations. Technically, RCOs can be obtained using such methods as the Chain rule (PVA, 1997). Additionally, the objectives are always with respect to particular perspectives. The potential actions are chosen by not only decision makers but also all the stakeholders.

2. Identify decision attributes and constraints and analyze risk factors and their causal relationship with the attributes and constraints

Although with the identification of the objective and perspective, risk-based decision problems can be expressed using the kind of summary prose, they will not be truly well defined until the following is completely identified and developed:

- the set of possible RCOs, which may be identified after appropriate risk analysis;

- the set of decision attributes, which function to distinguish the options;
- the set of constraints, which are usually considered as some realistic conditions and requirements and enter the analysis networks as evidence;
- the set of risk factors, which can connect decision attributes as their media; and
- the set of directed acyclic arrows, which represent the causal relationships between the risk factors, attributes, and constraints.

3. Connect all risk factors and attributes to form qualitative BNs

After identifying all the risk factors and decision attributes, one can start to confirm the relationship between them and construct a qualitative BN to represent their interactive dependencies. The knowledge about the decision problem and intuitive understanding of the various dependencies are then used to construct the causal structure. Here the graphical representation becomes very handy and permits the decision makers to express the fundamental relationships of direct or indirect influence between the decision attributes. The influence relationships expressed in BNs have a feature with causality. The concept of d-separation can be used to ensure that the BN models correspond with a real-world situation.

4. Distribute prior probabilities to model the uncertainties of the decision attributes/criteria

When the qualitative BNs have been built, the prior probabilities to all the nodes of the networks require to be distributed to model the uncertainties of the decision attributes and quantify the BNs.

5. Infer the uncertainties given actions and constraints and obtain the posterior probabilities of the decision attributes

Once the qualitative and quantitative BNs are appropriately constructed, the next task is to analyze the networks to obtain the posterior probabilities of the decision attributes given risk control actions and constraints from a realistic situation. The objective of using BNs in a risk-based decision-making model is to predict and infer the unobservable situations (uncertainties) related to the decision attributes using the posterior probabilities when observable evidence (alternative risk control actions and constraints) is provided. Such posterior probabilities can be obtained using the Bayes' rule and Chain rule (Jensen, 2001) with the assistance of computing software such as Hugin (Andersen et al., 1990).

6. Select the best security RCOs through constructing decision-making alternative matrices based on the posterior probabilities

In the BN-based MADM model, if the uncertainties associated with probabilistic measures are considered, then the overall performance scores can be obtained using a novel function as follows:

$$S_i = \sum_{j=1}^{n} w_j u_{ij} = \sum_{j=1}^{n} w_j \sum_{k_j=1}^{l_j} p_{ijk_j} l_{ijk_j} \tag{6.1}$$

where S_i is the overall or composite score of the ith option; W_j is the normalized weight assigned to the jth attribute; p_{ijk_j} is the probabilistic measure of the k_jth state of the jth attribute given the ith option; l_{ijk_j} is the location measure of such a state; the combination of p_{ijk_j} and l_{ijk_j} is used to represent the utility measure of the ith option on the jth attribute. From above, it can be revealed that the larger the overall score, the more desirable the corresponding ROC is. The best option is therefore identified to have the highest overall score.

Dynamic security–economic evaluation

The selected RCMs (in Step 4) can improve the security levels of maritime transport systems, while these measures can cause increasing shipping costs and time required to import and export goods. Apart from the direct cost incurred for the implementation of the RCMs, possible negative economic effect of tighter security measures on productivity needs to be investigated for supporting rational security policymaking. Ensuring a certain level of regulations can increase shipping efficiency, while an excess of the level may result in the reverse of these gains. From a system security viewpoint, System Dynamic (SD) is used to demonstrate security cost–benefit simulations through the development of visual causal loops among security cost and benefit factors. The model can successfully predict the appropriate security level while maintaining the optimal maritime operation productivity. Figure 6.6 demonstrates the use of SD to model causal relations between security levels and container throughput in port.

The balancing loop and the reinforcing loop are found in a single structure, causal loop diagram (CLD) from the whole SD procedures. The balancing loop illustrates how an enhanced security level negatively impacts container cargo volume while the reinforcing loop models positive impacts between security level and container volume (Yeo et al., 2013). The balancing perspective is that an increase in port security

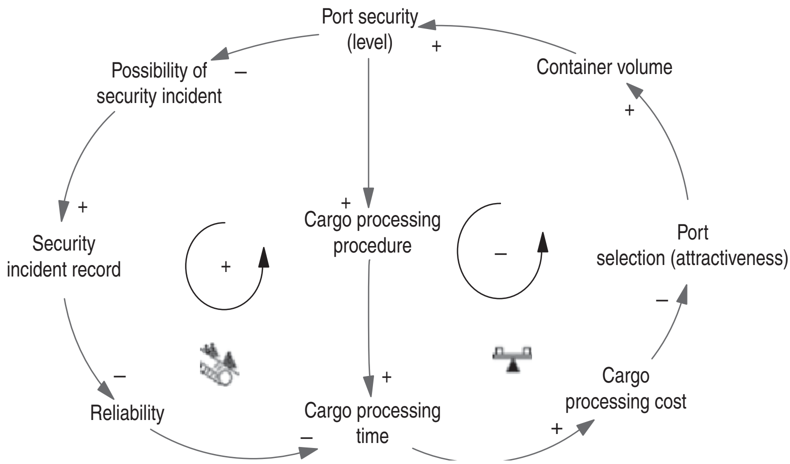

Figure 6.6 Causal loop diagram

levels makes cargo inspection a more complicated process, creating the increase of cargo processing time and cargo processing cost and the reduction of port attractiveness and container volume. From the perspective of reinforcement, when port security is higher, there is lower occurrence likelihood of security incidents, lower incidents records, and higher port reliability. Increased reliability, which leads to higher trust between port and its upstream and downstream partners in a container supply chain (as evidenced by the implementation of C-TPAT), contributes to the reduction of cargo processing time and results in reduction of cargo processing cost. Decreased cost has a positive effect on port selection, thus attracting more container volume. Consequently, from the viewpoint of the above analysis, improving security level and increasing port reliability can attract more containers.

With reference to the above two loops, this model quantitatively analyses how the increase of port security levels leads to an increase or decrease of container volume. SD is utilized to simulate a model using these two axioms and is able to quantitatively determine the effects of port security on container volume from a dynamic perspective. From the viewpoint of maximizing economic growth, it could be worthwhile to assess impacts of port security on container cargo volume in order to give implications to seaport stakeholders and to address an overall port complexity, specifically in terms of security concerns. SD has been used to analyze the relationship between seaport security levels and container volume in this study. Use of SD demonstrates the benefits of simulations. The ripple effects from the escalation of port security would be observed throughout an entire port's productivity. In such a system, any inappropriate negative impact can apparently cause the death spiral of a seaport's competitiveness. One of the findings of this investigation is the configuration of the quantitative impacts of time, cost, reliability, and the level of security on port attractiveness and container volume. While exploring the impacts, this study brings new contributions to the literature including the development of the visual causal loop diagram (CLD) among evaluation factors, the representation of several sub-models, and creation of valuable scenarios analysis.

Security inspection and maintenance

After the implementation of the adopted RCOs (from an economic perspective in Step 5), the overall security level needs to be monitored and used as a benchmark to measure security changes of a maritime transport system in its dynamic operational environment. A maritime security inspection and maintenance model can be established. First, the major generic key security performance indicators (KSPIs) used by designated authorities in maritime security plan are identified. Table 6.3 shows the major KSPIs which designated authorities use in port facility security assessment (PFSA).

Current security practices are reviewed with particular attention to the grades used by five international ports covering four continents (Asia, Europe, North America, and Oceania)[1] when assessing the above KSPIs. A standardized scoring sheet template based on the grades is produced. KSPIs interaction and impacts onto the security estimate of port facilities are configured. Consequently, all the KSPI grades at the lowest level can be transformed and presented by the top level KSPI grades (Good, Average, Fair, Poor). Finally, the interaction and impacts are synthesized to measure the changes of security levels using the ER approach in a quantitative way. Cost-effective RCOs can be employed to maintain the security level, at which an optimal productivity with acceptable security risks can be achieved.

The significance of the newly proposed MSA methodology lies in that it presents a scientific framework capable of realizing quantitative security risk analysis under uncertainty to aid decision making and rationalizing maritime security management under economic constraints. The ISPS code was developed to quickly respond to the terrorist attacks on the United States on 11 September 2001. Due to the rapid turnaround time, the development was characterized by the need to create an imperfect product rather than having nothing at all (Mitropoulos, 2004). For

Table 6.3 The partial hierarchy of KSPIs

Code	Key Security Performance Indicators (KSPIs)
S	Port facility security level
S-P1	Access control
S-P1–I1	Identify and prevent unauthorized substances introduced into ship/port facility and its restricted areas
S-P1–I2	Identify and prevent unauthorized entry to ship/restricted areas of port facility and its restricted areas
S-P1–I3	Control activities within the restricted areas
S-P1–I4	Clearly identify the restricted areas within port facility
S-P1–I5	Identification of port personnel, transport workers, and visitors
...	...
S-P6	Ship–port interface
S-P6–I1	Respond to security threats/breaches of security of port facility or ship–port interface
S-P6–I2	Maintain critical operations of port facility or ship–port interface
S-P6–I3	Interface with ship security initiatives
S-P6–I4	Facilitate shore leave for ship personnel
S-P6–I5	Facilitate access of visitors to ship, including their identities

Note: S – security level; P – parameter level; I – indicator level.
Source: Yang et al. (2014).

example, the ISPS code regulates the ship security assessment that must be performed by ship owners and operators. However the depth of ship security assessment suggested by the Code is very limited in comparison to, for example, the depth demanded by probabilistic risk assessments for ship safety (Liwang et al., 2013). Similarly, the process of ship security risk analysis by other international organizations such as International Association of Classification Society (IACS), and to some extent NATO, is mostly described in regulations and guidelines as a best practice, thus arguably lack of traditional scientific background and risk to be subjective (Liwang et al., 2013). The MSA methodology together with its supporting models in this chapter, has initiated a pioneering work to explore possibilities and perform quantified and more thorough maritime risk analysis than what is described in the ISPS code and the relevant regulations and guidelines by other international bodies in a systematic way. Furthermore, MSA assists in examining and evaluating the extent to which the more detailed quantitative analysis increase maritime security management. The methodology incorporating the FSA concept will also facilitate the transfer of the benefits of FSA in maritime safety in the context of maritime security and provides

1. a consistent regime with ship and port security aspects considered in an integrated way;
2. cost-effectiveness whereby any investment is targeted to where it will achieve the greatest benefit;
3. a proactive approach, enabling security threats that have not yet given rise to accidents to be properly considered;
4. confidence that any regulatory requirements are in proportion to the level of security risks; and
5. a rational basis for addressing new threat-based risks posed by ever-changing technology.

Conclusion

It is well recognized that collaboration between industrial organizations and academic institutions would be of mutual benefit. As mentioned earlier, it is far from easy to obtain reliable information on terrorist attacks. Unsurprisingly, such a deficiency implies that policymakers and practitioners often struggle to find the appropriate approach and strategies to deal with the problem, not helped by further uncertainties (often) under budgetary constraints. Hence, the industry is desperate for knowledge and innovative tools, ideas, and solutions in dealing with the maritime security that is fast becoming serious challenges on ships and other components of the maritime sector. Nevertheless, individual researchers found it incredibly difficult to get access to the key and/or appropriate personnel for data and information collection, especially outside the regions where they are located. The major barriers include (but not limited to) diversified local cultures, and thus the trickiness in finding right channels to get in touch with the right people. There is no doubt that the best ways to tackle these barriers are two folds. One is the development of novel advanced approaches capable of reducing uncertainties in data which is either currently available or relatively easier to collect, while the other is the creation of an innovative partnership comprised of researchers, policymakers, industrial practitioners, interest groups, industrial alliances, and other maritime/port stakeholders which are concerned on this topic. As the only expedient way to make any critical breakthrough against such an obstacle, we must actively motivate relevant individuals and organizations from different corners around the world to join this partnership and actuate them to actively involve in the decision-making process, intellectual leadership, and the creation and dissemination of knowledge relevant to this topic. Indeed, an industrial organization can benefit from the knowledge developed by an academic team and ensure that state-of-the-art technologies are used for improving its operations. Also, an academic team can benefit from collaboration with an industrial organization to identify possible research needs and also to ensure the research strikes a balance between novelty and applicability. It is widely accepted that any newly developed risk and security assessment methodology should preferably be introduced into a commercially stable environment in order that the application has the chance to become established to prove feasible; otherwise it is more likely that its full potential will not be realized.

Recommended further studies may be the development of a number of security modeling and decision support tools to support the implementation of framework of UNDERSTAND, INFLUENCE, PREVENT, PROTECT, and RESPOND. Such tools have to be flexible in a sense that they can be used in situations where there is a high level of uncertainty in data and there are multiple conflicting factors for making a rational decision.

Note

1. Due to confidentiality agreements and security concerns of port operators, we cannot review the details of the ports under investigation. Given the highly sensitive nature of security data and information, we believe that being able to convince five ports from four continents in providing relevant data for our analysis is quite an achievement by itself. Indeed, such generosity from the port operators reflects their strong interests in the assessment model that we introduce in this study.

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7

Choice of Financing and Governance Structures in Transport Industry: Theory and Practice

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Introduction

The purpose of this work is to develop a descriptive theory of corporate finance and corporate governance for the world transport industry. More specifically, we examine the economic, institutional, and industrial factors behind a transportation company's choice of different financing mechanisms and governance structures (collectively called "financing methods"). This combined treatment of corporate finance and corporate governance is in line with Williamson (1988), who argues that "the supply of a good or service and its governance need to be examined simultaneously". This is a step further than the traditional approach in corporate finance, which tends to limit its investigation of a firm's choice of financial structure (i.e., debt vs. equity) in aggregate, with no follow-on inquiry into the resultant governance structure at an individual firm or industry level. The value of the level of aggregation and abstraction in neo-classical financial theory, along with the simplifying assumptions that are usually made, lies in their potential for clarifying difficult analytic issues, but it also rules out important practical considerations which influence financial system form and functions (Neave, 1991). In this study, we draw on insights from institutional economics (of which transaction cost economics (TCE) is a fast-growing branch)

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and development economics and explain a firm's financing methods within the context of a wider socioeconomic environment and under alternative behavioral assumptions. The result of this analysis is an eclectic theory of transactional factors that help to shape the form and function, as well as their change over time, of the financing methods used in the world transport industry. In combination with insights from traditional finance theory, this has the potential of better explaining the industry's financing patterns as observed in practice.

The first section compares the neo-classical (modern) theory of finance with the TCE approach to corporate finance and corporate governance. This also provides the justification for our industry-specific study of financing behavior. The second section in this chapter reviews some major theories and empirical studies of firms' financing choices. This is followed in the third section by a discussion of the relevance and applicability of these theories to the transport industry. The economic, institutional, and industrial characteristics of the transport industry are then discussed in the fourth section, leading to the formulation of a descriptive theory of corporate finance and corporate governance. Finally, the last section concludes by identifying some implications and directions for future research.

Neo-classical finance theory versus transaction cost economics versus practical observation

In his article that introduced the idea of TCE to corporate finance and corporate governance, Williamson (1988) notes that neo-classical finance theory and TCE are mainly complementary approaches to economic organization; both have helped and will continue to inform our understanding of different forms and functions of organization. Agency theory (AT) (Jensen and Meckling, 1976), a landmark development of finance theory, and TCE both come in different forms, but both are concerned (either directly or by implication) with different types of economic organization and their effects on efficient contracting and control. AT is concerned with the separation of ownership from control, while TCE traces its origins to vertical integration and is subsequently applied to the governance of contractual relations. The key commonalities and differences between the two include[1]:

- Managerial discretion and efficient contracting: Both TCE and AT take exception with the traditional theory of the firm whereby the firm is regarded as a production function to which a profit-maximization objective has been ascribed. Instead, TCE regards the firm as a governance structure and AT considers it a nexus of contracts. Both rely on substantially identical behavioral assumptions, that is, that human agents are subject to bounded rationality (leading to incomplete contracting) and are given to opportunism (moral hazard and agency costs in AT). This is the basis of the efficient-contracting orientation to economic organization that is common to both approaches. AT examines contracting mainly from an ex ante incentive-alignment point of view, while TCE is more concerned with crafting ex post governance structures.

- Basic unit of analysis and agency/transactions costs: The most important difference between TCE and AT lies in the choice of the basic unit of analysis. TCE regards the transaction as the basic unit of analysis, while AT focuses on the individual agent. Both are microanalytic in nature and both imply the study of contracting. Whereas identifying the transaction as the basic unit of analysis leads TCE naturally to an examination of the principal dimensions with respect to which transactions differ, use of the individual agent as the elementary unit of analysis has given rise to no similar follow-on effort in AT. In TCE, asset specificity (including human capital specificity) is one of the key dimensions with respect to which transactions differ, and one resulting refutable implication is the proposition that agents align transactions (which differ in their attributes) with governance structures (the costs and competences of which differ) in a transaction cost economizing way. Assessing the comparative efficacy of alternative governance structures for harmonizing ex post contractual relations is the distinctive focus and contribution of TCE. In AT, the existence of agency costs (monitoring expenditures of the principal, bonding expenditures of the agent and the residual loss), which are assumed evident to prospective transacting parties, means that equity and debt will be priced on the basis of the projected performance of the firm after agency costs have been taken into account. In other words, the entrepreneur will bear (ex ante) the entire wealth effects of these expected costs so long as the market anticipates these effects.
- Debt and equity as financial instruments versus governance structures: TCE's focus on individual transactions and the implied imperative to align transactions with governance structures in a transaction cost minimizing manner leads to the identification of attributes of different transactions and the resulting contractual arrangement that is chosen to match these attributes. Whereas most prior studies of

corporate finance treat debt and equity as merely financial instruments, TCE regards them as different governance structures that are chosen in a discriminating way.

Apart from the influence of AT, modern corporate finance has been revolutionized by the famous Modigliani and Miller (1958) (M&M) capital structure irrelevance propositions. Basically, these propositions state that, under certain assumptions (see discussion below), a firm's value is determined by its real assets/investments and not by the type of instruments used to finance the investments. The key contribution of the M&M propositions is that they provide the basis for rational investment decision making within the firm; and by showing what does not matter; they also show (by implication) what does (Miller, 1988). Since many of the necessary conditions for the M&M capital irrelevance propositions are violated in real life situations, it is important for the financial manager to know what kinds of market imperfections to look for (Brealey and Myers, 2000).

Being practically oriented, this study aims to examine what factors, in a real-life market place, shape or influence the forms and functions of financing that a firm adopts and how these vary across countries (with different socioeconomic and institutional characteristics) and evolve over time. This industry-specific, micro-analytic approach contrasts with that in traditional finance, which tends to abstract from industry- or firm-specific characteristics and country effects by looking into firms' financing decisions in aggregate and under various simplifying assumptions. The value of the latter approach is obvious (one of which being that it is tractable and its inferences probably generalizable), but since the value of a model depends on the use to which it is put, and given our aim to explore the factors influencing the financing of transportation companies in real life (where one or more of the restricting conditions are unlikely to hold), it is only natural that we do not restrict ourselves to the M&M propositions or its counterparts in modern finance. At this juncture, it should be noted that the view that capital structure is literally irrelevant in corporate finance is actually far from what M&M ever actually said about the real world applications of their theoretical propositions (Miller, 1988). In choosing to look to reality to explain the financing decisions of industry firms, we actually follow M&M's own advice to relax their assumptions in the direction of greater realism and relevance in an industry-specific context.

Many authors note the merits of an industry-focused study. In discussing the testing of economic hypotheses using homogeneous groups, Elton and Gruber (1970) show that pooling data for all firms (with distinct characteristics) without controlling for latent variables can destroy the true underlying relationship among variables. The identification of homogeneous groups of firms (which helps to hold constant some latent variables across firms) can form a more meaningful basis for the testing of hypotheses in the field of finance (Elton and Gruber, 1970, p. 587). In their highly acclaimed study of the cost of capital, Miller and Modigliani (1966) use the utility industry as the testing ground for techniques of estimating the cost of capital because "[t]hey permit us to have both a large sample and one in which the component firms are remarkably homogeneous in terms of product, technology, and market conditions" (p. 334).[2]

Neo-classical (modern) financial economics is essentially non-institutional, but institutions matter in ways not hitherto acknowledged or even imagined (Williamson, 1996, p. 192). This is also the stance taken by John Lintner, one of the creators of modern financial theory, who "believed that the institutional setting of the financial markets, including legal and regulatory restrictions as well as elements of business organization and practice, can and does importantly affect financial behaviour and the resulting market outcomes" (Friedman, 1985, p. ix). Rybczynski (1984) also notes that the way an industry is financed must be looked at against the background of the evolution of financial systems and the way the process of economic development has preceded in the past and is preceding at present.

In the sections that follow, we develop a theory of corporate finance and corporate governance in the world transport industry, based on a combination of financial economics, institutional economics, development economics, and observations of current practice. More specifically, we consider the following questions: What is the actual experience of using different financial instruments and governance structures by the transport industry over the last several decades? Are there cross-country or intra-industry differences in the industry's financing methods? How does the product market environment and/or the information environment that firms face influence their corporate financing decisions? How important are institutional factors like government and commercial organization involvement (e.g., subsidies, shipyard finance, taxes) in shaping firms' financing choices? Do specific firms have individually optimal financial structures? Does the entire industry (or a sub-sector thereof) have an optimal aggregate financial structure? If so, what are the determinants?

These are essentially the same questions that Friedman (1985) asked, and it is beyond the scope of this current study to provide concrete answers to any of them, not to mention all of them. Nevertheless, we hope that by asking the right questions, we can come to stimulate sufficient interest among future researchers who, through a series of coordinated studies, may subsequently shed light on these important questions that remain hitherto unanswered.

Review of the literature on corporate finance

It is usually the position in modern finance not only to separate the financing decision from the investment decision, but also to look at the mix of different financing instruments (i.e., the capital structure) as a "fundamentally marketing problem" or as an outgrowth of information asymmetry (Myers and Majluf, 1984). Epitomizing the capital structure argument is the famous Modigliani and Miller (1958) proposition that "financing decisions do not matter in perfect markets" (hereinafter, M&M I).[3] Recognizing the existence of market imperfections in reality (e.g., tax), finance theorists have proposed alternative explanations for the observed discrepancy between the M&M I proposition and real-life practice (e.g., Miller, 1976; 1988; Modigliani, 1982; 1988; Modigliani and Miller, 1963). Nevertheless, such alternative theories still fall short of generating testable hypotheses/predictions consistent with real-life observations, in particular in industry-specific settings. For a comprehensive survey of these theories and related empirical studies, see Franklin and Winton (1995), Swoboda and Zechner (1995), and Maksimovic (1995). All of these authors, in their conclusions, point out that there remain many unresolved issues with regard to the financing decisions of firms. In this section we focus on three "mainstream" theories. The first is the classic Modigliani and Miller (1958) capital structure irrelevance proposition (without tax). The second is the "pecking order theory" proposed by Donaldson (1961) and popularized by Myers and Majluf (1984) and Myers (1984). The third is Williamson's (1988) TCE approach to a combined treatment of corporate finance and corporate governance. The main arguments of these three theories and some representative empirical studies are summarized below, while their relevance and applicability to the transport industry are discussed in a subsequent section. With the exception of Williamson (1988), it should be noted, these theories of corporate financing do not address the issue of the governance structure that follows a particular financing method. This latter aspect of corporate financing is a parallel focus of this chapter.

M&M's capital structure irrelevance propositions

Modigliani and Miller (1958) show that in perfect capital markets (without tax[4]), a firm's value is determined by its real assets, not by the securities it issues and, as a result, capital structure (the firm's mix of different securities) is irrelevant as long as the firm's investment decisions are taken as given. The arbitrage-based proof offered by Modigliani and Miller (1958) (see Brealey and Myers (2000) and Welch (1995) for an example) largely hinges on the presumption that both the levered firm and the unlevered firm generate exactly the same net operating income (agreed by and known to all) and that the capital markets are perfect and well-functioning (with no transaction costs). Given these and other assumptions, it is not difficult to show that the two firms have the same overall market value of debt and equity, no matter how they are packaged. Thus, it may be fair to say that the M&M conclusion resides in its presumptions. The important point in judging the value of a theory, of course, is to see whether its implications or predictions are borne out by real life observations (Friedman, 1953).

It is obvious that in real life, corporate financing behavior is not consistent with M&M's theorem. For example, while M&M predicts that capital structure does not matter in perfect capital markets, there exist clear patterns in the financial structure of specific industries (see Brealey and Myers, 2000; Long and Malitz, 1985). This discrepancy may be due to one or more of M&M's conditions not obtaining in practice, and it is useful to identify which of these conditions are violated in real life. Existing theories may be refined as a result.

In summarizing M&M I, Brealey and Myers (2000) remark:

> We believe that in practice capital structure does matter . . . If you don't fully understand the conditions under which MM's theory holds, you won't fully understand why one capital structure is better than another. The financial manager needs to know what kinds of market imperfection to look for. (p. 474)

The most serious market imperfections are often those created by government. Examples include differential tax treatment (between debt and equity, or on the corporate level vs. the personal income level), government grants/subsidies for some types of strategic investments (e.g., Title XI in the United States and Keihek Zoseon in Korea; see Lee, 1996) and other institutional factors. To understand the reason why transport financing takes on the patterns that we observe, it is undoubtedly important that we take into account not only the financial environment, but also the non-financial environment.

The pecking order theory

Myers (1984) contrasts the static trade-off hypothesis with the pecking order theory of financial structure. The static trade-off hypothesis posits that a firm's optimal financial structure (which varies from firm to firm) is determined by a trade-off of the costs and benefits of borrowing, given that the firm's assets and investment plans are held constant. The benefits of borrowing mainly come from the interest tax shield and the costs from potential financial distress. Firms with safe, tangible assets, and plenty of income to shield ought to have higher debt ratios than unprofitable firms with risky and intangible assets. Although these predictions are broadly consistent with observation, according to Brealey and Myers (1991), the static trade-off theory cannot explain why some of the most successful companies tend to have the least debt.[5] In this respect, the pecking order theory seems to do a better job. The pecking order theory of capital structure states that firms prefer internal finance and adapt target dividend payout ratios to their investment opportunities. When internal funds are insufficient for investments and firms have to use external finance, they will issue the safest securities first, for example debt, convertible bonds and, as a last resort, equity.

Baskin (1989) conducts an empirical test of the pecking order theory. Focusing on 378 large firms from the 1960 Fortune 500 which had data available on Compustat in 1984, he finds that more profitable firms tend to have less (book value) debt, and he interprets this result as consistent with the predictions of the pecking order theory (and contradicting the static theory of optimal capital structure). Needless to say, this result is also consistent with other (perhaps more ad hoc) theories.

While the pecking order theory is consistent with implications of information asymmetries and the AT of Jensen and Meckling (1976) and other well-established facts (e.g., higher costs and more stringent market discipline for the use of public equity), several difficulties present themselves in the testing of the pecking order theory. First, it is difficult to establish a line of demarcation by which the theory is to be accepted or rejected – the choice seems quite arbitrary. It can be quickly accepted or rejected, depending on one's criteria. Second, some of the results of many empirical studies can be shown to be consistent with both the pecking order theory and alternative theories. In short, both the static trade-off theory and the pecking order theory are successful in explaining some observed differences in the capital structures of firms, but are less successful in explaining others (Brealey and Myers, 1991). Therefore, despite the merits of both hypotheses, neither seems to be the whole truth.

The transaction cost economics approach to corporate finance

Williamson's (1988) TCE approach to corporate finance starts by assuming only two forms of finance; projects must be financed entirely by debt or by equity but not both. He also assumes that projects can be arrayed from least to most in terms of their asset specificity, that is, the extent to which the asset in question may be redeployed for alternative purposes without substantial loss of value. Furthermore, it is assumed that debt is a governance structure that works almost entirely out of rules, which imposes on the debtor a number of restrictions: regular debt repayments, conforming to pre-specified liquidity tests, pre-emptive claims of the financier in case of default against the assets financed, etc. Different debt-holders will realize different recovery of value in the degree to which the assets in question are redeployable.

Since the value of a pre-emptive claim declines as the degree of asset specificity deepens, the terms of debt financing will be adjusted adversely against the debtor. Faced with increasingly adverse terms as asset specificity increases, the debtor might have to sacrifice some of the specialized investment features in favor of greater redeployability. But the more adverse financing terms associated with assets of greater specificity may be avoided by inventing a new governance structure (call it equity) to which suppliers of finance would attach more confidence, and this may be achieved by giving the equity providers closer control of the company, for example, through their access to internal information, their decision-making power through members of the board of directors, and residual claims on the firm's earnings and liquidated assets throughout the firm's life. Therefore, equity evolves as a governance structure to reduce the cost of capital for projects that involve limited redeployability (greater specificity) and to preserve value-enhancing investments in specific assets. It can thus be seen that debt and equity are actually governance structures (rather than merely financial instruments representing differential claims on firm value) that are created to match investment/asset characteristics with the costs of organizing such investment activities.

Thus, according to Williamson, a transaction cost minimizing reasoning supports the use of debt or rule-based financing for redeployable assets, while non-redeployable assets are financed by equity or discretion-based financing methods. This clearly has refutable implications as to whether there is a systematic pattern in a firm's financing of projects along the dimensions of asset specificity and degree of uncertainty.[6]

Motivated by the TCE paradigms attributable to Williamson (1979), Klein et al. (1978), and Monteverde and Teece (1982), Palay (1984) studies the factors that lead corporations to adopt particular forms of governance structure in rail freight contracts, including forms of contracts and contractual terms. By cross-classifying rail freight contracts based on their terms and conditions against characteristics of investments (e.g., type and redeployability of equipment, transaction frequency), Palay (1984) provides evidence in support of the basic TCE proposition that, as investment characteristics become more transaction-specific, the associated governance structure becomes increasingly unique to the parties and transactions it supports.

In another application of the TCE to the US airline and airport industry, Langner (1995) examines the relationship between contractual aspects (e.g., contract duration) of slots allocation and transaction-specific characteristics such as asset specificity and the frequency of transacting. His analyses using historical and current practices of transacting in slots in the United States indicate that the governance structures (i.e., contracting arrangements) between airlines and airports are related to specifics of the transacting parties, the frequency of transacting, as well as asset (including human asset) specificity, a finding that is broadly consistent with predictions of the TCE.

It is obvious from the above discussions that the corporate financing theories we reviewed are not strictly opposed. For example, both the static trade-off theory and the TCE suggest that the form of financing is related to characteristics of the asset being financed. Also, both the pecking order theory and the TCE approach predict that equity is the financial instrument of last resort, albeit for different reasons.

As noted in an earlier section, one of the key differences among these theories is the unit of analysis: For TCE, the transaction is the basic unit of analysis and this focus on the transaction naturally leads to an examination of the principal dimensions with respect to which transactions differ. In contrast, the modern finance approach uses the individual agent as the elementary unit of analysis, and this focus on the agent (firm) leads to the study of financial structure choices on the level of the firm (distinct from its activities) but does not give rise to follow-on efforts to investigate the implications of the financing activity on the governance structure adopted (Williamson, 1988). Compared with the modern finance approach, the TCE approach seems able to generate a wider class of testable implications that are not only applicable to corporate finance, but also to other economic organization issues. The wide spectrum of applications of TCE (among them corporate finance and corporate governance), including some empirical studies, is summarized in Williamson (1996), Williamson and Masten (1999), and Shelanski and Klein (1995).

The test of a theory is whether it yields meaningful predictions that are consistent with real life observations. It is not the intention of this study to test the comparative validity of any of the existing theories of corporate financing behavior. Instead, we aim to combine insights from these (and other) theories and develop a descriptive theory of corporate finance in the transport industry context. In the next section, we discuss the relevance and applicability of the pecking order theory and TCE to corporate financing behavior in the world transport industry.

Relevance and applicability of existing corporate financing theories to the transport industry

Some important questions we attempt to answer in the study of financing behavior in the transport industry are: What determines whether a transportation company will choose between private debt (e.g., bank loans) and public debt (e.g., corporate bonds), or between internal equity and external equity, or some hybrid instruments (e.g., leasing)? What is the economic or institutional rationale behind the financing choices observed in practice?

Although there exist no systematic studies of the relative importance of different financing methods in the transport industry, there does exist a body of anecdotal evidence, which suggests that a bank (term) loan is the most favored method of financing transport investments, in particular shipping investments. Stopford (1997), for example, remarks that commercial bank loans (where banks often provide up to 70 percent of the total funds) have been by far the most popular form of finance for ships. He also notes that the type of finance available to the shipping industry has gone through distinct phases and that such changing patterns of financing over time are related to the industry's own character (e.g., the shipping cycle, changes in the financial community's perception of risk and return in shipping, and institutional factors; also see Stokes, 1992; 1996). McConville and Leggate (1999), while concurring with Stopford and others, also note that the issuance of public bonds in the shipping industry (mainly in the United States and Western Europe) has been quite limited in number (34 as of 1999, as compared to over 300 public equity issues) and has been quite recent (with 70 percent only in issue since late 1997). Thus, the comparative popularity of public equity over public debt seems to contradict the prediction of the pecking order theory – but see below for an explanation of the predominance of private (bank) debt over all other financing methods, a phenomenon that somewhat reverses this conclusion.[7] Elsewhere, Cullinane and Gong (2002) provide evidence that, at least as far as the Chinese Mainland is concerned, evolutions in the country's economic and financial systems are responsible for the increasingly popular use of public equity for financing transport investments in China, a nation that had previously relied primarily on state financing. No attempt, however, has been made in any existing study of transport finance to offer any economic rationale for the observed financing patterns, their variations among countries, and their changes over time. This is an area to which this current study aims to make an original contribution.

Among the three theories outlined above, it appears that only the pecking order theory and TCE are able to generate empirically testable predictions and hypotheses regarding the questions raised earlier. Brealey and Myers (2000), for example, suggest the following testable hypotheses in the case of the pecking order theory:

- Firms prefer internal finance to external finance.
- If external finance is required, firms issue the safest security first. That is, they start with debt, then possibly hybrid securities such as convertible bonds, and then equity as a last resort.

Because equity ranks both on the top of the list (via retained earnings) and at the bottom, the pecking order theory does not presume a preference of debt over equity or vice versa (Brealey and Myers, 2000). As to the main reasons why firms prefer internal finance to external finance, Donaldson (1961), Myers (1984), and Brealey and Myers (1991) point to managers' reluctance to face the glare of publicity (in a stock issue), the restrictions imposed by lenders (in a bank loan) and the high issue cost of raising public equity. However, the pecking order theory does not tell us whether and why public debt or private debt will be used as a first priority.[8] The pecking order theory, moreover, does not suggest what forms of governance structure (e.g., contract terms) will be adopted in various financing activities (for example, when debt is used). Similarly, the pecking order hypothesis cannot explain why financing methods in the same industry may differ across countries and vary over time.

In comparison with the modern finance approach, under the New Institutional Economics[9] (NIE, of which TCE is a part), the transaction is made the unit of analysis and the critical dimensions along which transactions differ are identified, including frequency of occurrence, uncertainty, and asset specificity (Williamson, 1996, p. 105). Since these factors vary from transaction to transaction, from firm to firm, as well as over time, it predicts no ex ante optimal capital structure or financing choice that is applicable to every firm or that remains unchanged over time. Instead, the NIE/TCE approach to economic organization leads to predictions of financing choice only at a transactional level; it also gives rise to predictions about the governance structure (e.g., contractual arrangements) most likely to be used when a particular financing choice is indeed made. The NIE/TCE approach is also more eclectic, since it studies the financing choice behavior of firms within a wider framework of the economic development (including the financial system) and transactional attributes (e.g., characteristics of the industry and the firm, including both the financier/lender and the fund-seeker/borrower).

Therefore, judging from the range of implications/predictions that the theory encompasses and their conformance with observations, it seems that the NIE/TCE approach is more relevant to our investigation. In the section that follows, we propose a descriptive theory of financing behavior in the transport industry based mainly on the NIE and drawing on insights from financial economics, development economics, and practical observations. This culminates in the formulation of a testable proposition to be empirically examined in future studies.

Corporate finance and corporate governance in the transport industry: A descriptive theory

To construct a theory of the choice of financing methods (as in any economic theory of choice), one has to start with the question of classification (Fama and Miller, 1972, p. 4). Following the general economic theory of choice, we divide the many separate factors bearing on any choice into two classes: The first class is the “opportunity set” or the “constraint set” and, the second, the decision maker’s “tastes” or preferences. In financial economics, the first class of factors influencing a firm’s choice of financing is usually taken as given (exogenously determined), and the subject’s preferences/expectations are often assumed homogeneous. While this is in line with the traditional approach in positive economics, it overlooks an inherently crucial determinant of financing choice behavior as observed in reality, that is the circumstantial factors (e.g., the opportunity set of available financing choices) to which firms are subjected at various times. Financial economics is essentially non-institutional, but institutions matter in ways not hitherto acknowledged or even imagined (Williamson, 1996). According to Williamson (1993), a contractual approach to the study of economic organization informs the analysis of corporate finance and corporate governance quite generally, and cross-country studies need to be informed by significant legal (political and institutional) differences. Once the wider economic environment is taken into account, the evolutionary nature of the financing and governance mechanism is also predictable since financial markets/systems themselves change over time (Rybczynski, 1984; also see Taggart, 1985 for US evidence).

The second class of factors, that of decision maker's (fundraising firm's) preferences (idiosyncrasies), is also given greater attention in this study than in the finance literature. Modern financial theory is built on the assumptions of no (or inconsequential) transaction costs and well-specified (perfect) information conditions. This category of theory further assumes that financial agents have the same well-specified probability distributions (without showing how such are determined) and formulate and solve complex decision problems precisely and costlessly, even in the face of uncertainty and market imperfections. Given such hyper-rationality, agents are supposed to clearly understand the relations between alternative decisions and the impact of their decisions on their respective wealth positions. Therefore, the behavior of these agents will all be rational, utility maximizing, and predictable. Investors, on the other hand, are also assumed rational, utility-maximizing agents, and can see through any massaging of financial information. Hence, capital structure does not matter; neither do dividends.

In reality, the choice of an optimal capital structure for a given firm is a subjective decision. Agents (entrepreneurs, investors, and bureaucrats alike) have bounded rationality (Simon, 1957), and there are expensive information costs, transaction costs, cost of financial distress, and agency costs involved in decision making. These are the inevitable consequence of, and are exacerbated by, the existence of uncertainty/risks. Given such limitations, neo-classical financial theory is better at explaining well-established practices, but is poor in explaining creative or exploratory aspects of finance, the dynamics of technological changes, or the evolution of sophisticated financial systems from primitive ones. The reason is that financial system change largely occurs under uncertainty rather than objectively specified risk, and many of the interesting features of uncertainty are assumed away when decision problems are formulated in a manner conducive to neoclassical investigation (Neave, 1991). In comparison, the NIE/TCE is well suited for the purpose of investigating choice behavior under complex situations, since it takes into account current practices and other real-life imperfections in developing a theory to explain financial system organization and change.

In making a recommendation to implement research on cross-country studies from a TCE perspective, Williamson (1993) proposes that country studies can usefully benefit from taking measures on, and making comparisons and assessments with respect to, some features of the institutional environment and institutions of governance. One of these features is the analysis of assets: "An inventory of human and physical assets with reference to their industry- and firm-specific qualities is needed to evaluate economic organization" (Williamson, 1993, p. 53).

The TCE imperative: Align financing structure capability/costs with transaction requirements

According to TCE, a financing mechanism is matched with a particular transaction on the basis of cost-effectiveness, capability, and the transaction's particular requirements. With regard to demand for (supply of) financing, this theory predicts that firms seeking funds (financiers) will choose between available alternative financing and governance mechanisms on the basis of perceived overall costs and benefits. Each choice is made on a transaction-by-transaction basis, aligning each transaction's requirements with governance capabilities and costs (hence many different kinds of alignments will coexist in any financial system at any given time; see Neave, 1991). Different sets of finance and governance structures are selected according to the agents' goals, the way they attempt to achieve these goals, the information conditions under which they act, and the costs and technologies of transacting (Neave, 1991).

When the transaction is made the basic unit of analysis, the most important dimension of which is asset specificity, TCE predicts that finance and governance structures will vary from transaction to transaction, even for the same firm. More specifically, projects for which physical asset specificity (redeployability) is low to moderate ought to be financed by debt (and correspondingly, contractual terms suitable for the given asset specificity are used). As asset specificity becomes greater, however, the costs (including interest payments, financial distress costs, and covenant restrictions) of debt financing increases relative to the benefits, and now equity should be used instead. The influence of asset type or specificity on transport financing is well reflected in Macquarie Corporate Finance Limited (2000, p. 41):

> Leasing is perhaps the most common form of finance in the aviation sector with virtually all of the world's airlines undertaking some form of lease financing . . . The rail sector has traditionally not used leasing as a means of finance because it has been dominated by government-owned organizations (private sector lease financing has been unable to match government's cost of funds) and because of the specialized and often non-standardized nature of the equipment. As the sector becomes more open to private operators through privatization and competition policy, a greater usage of leasing seems likely.

In the context of transport financing, the NIE/TCE theory also implies that financing and governance mechanisms (the form of financing and the accompanying contractual arrangements) are simultaneously determined on a transaction-by-transaction basis, in accordance with the principle of aligning the transaction's requirements and costs with the available instrument and its capability. Having expounded on the influence of asset specificity on financing choice, in the text that follows, we attempt to interpret the observed patterns of corporate finance and corporate governance in the transport industry in the light of the NIE/TCE. For convenience of exposition, we will mainly use the example of the ocean transport or shipping industry.

Interaction between fundraising firm and financier with constraints on financing alternatives and differential costs/benefits

For the firm seeking finance, the first factor that bears on the financing choice is likely to be the opportunity set that is faced, since the financing schemes or instruments available at any time are constrained by the state of economic (including financial market) development (see International Finance Corporation, 1996; World Bank, 1997). It was, for example, impossible for a Chinese shipping company or airline to issue public equity or public debt in the domestic stock market before 1990 since no such market existed![10] But as China tried to reform itself toward a market-like economy (e.g., by establishing two domestic stock exchanges and allowing large firms to be listed overseas), new financing opportunities (most notably, publicly traded securities) were created, and as a result, the financing of companies also evolved.

In a similar vein, under any given economic condition, the available financing options are largely shaped by factors relating to the type of assets/investments being financed. For example, whether the asset has a liquid second-hand market, the fund-seeker's credit worthiness and business track record, and the like (see Grammenos and Xilas, 1996).

As documented by Stopford (1997) and Grammenos and Xilas (1996), the shipping industry has persistently relied on commercial bank loans for the majority of their funding needs.[11] The predominant use of private debt versus other financing methods may be explained as follows. First, the equity base of shipping companies has been seriously eroded in the past due to high risk-taking activities and poor product market conditions, which resulted in a lack of internal funds (Grammenos and Marcoulis, 1996). Second, relative to other financing schemes, bank loans provide a quick and convenient source of financing, since the secretive and volatile nature of shipping does not favor public fundraising due to the secretive nature of the business and the information disclosure requirements (see McConville and Leggate, 1999; Stokes, 1996). The recent experience of Golden Ocean (which went into severe financial distress after a public bond issue in the United States) spoke eloquently of the "joint ignorance" that exists between shipowners, finance arrangers and public capital providers, and the dire consequences that follow.

Another, yet related, explanation is somewhat less obvious: shipowners actually find it attractive to use bank loans. On the one hand, compared with the typically much higher cost of public equity at around 15–20 percent, a bank loan is a much lower cost method of financing, with interest rates at around 1 percent above LIBOR (the London Interbank Offered Rate) or less for the average borrower. On the other hand, by "playing" (as in "asset plays" – the asset being the vessel for which there exists a liquid second-hand market) with money that comes mostly from banks, particularly during times when banks were less prudent, the borrowing ship owner actually has much to gain in a bullish market, but not as much to lose in a bearish market downturn. In effect, the borrower has acquired an option: If the shipping market is good, a handsome return is made (net of debt repayment), since vessel prices are extremely volatile and may rise or drop dramatically within a relatively short span of time.[12] If the freight market turns out bad and vessel prices drop with it, the most that is lost is the ship owner's portion (usually about 30 percent) of the investment in the ship. In other words, the ship owner may default on debt repayment, leaving the residual value of the ship at the risk and disposal of the bank. The one-company-one-ship ownership structure typical in the shipping industry alleviates to some extent the potential impact of failure in one transaction on the borrower's other businesses or reputation. On the other hand, while individual financiers usually remember the lessons they have learned, at any point in time a financial system has a certain proportion of inexperienced agents. This continuing fresh supply of inexperience means that some of the lessons of the past must be learned repeatedly (Neave, 1991, p. 22). This is indeed well manifested in bank shipping finance: banks are known to have unusually short memories and have been blamed for supplying the industry with easy finance in the past (with some banks sometimes providing up to 100 percent financing) and for fuelling oversupply, which leads to subsequent market downturns and bad debts. The value/role of the option acquired by ship owners in bank financing warrants a separate study in its own right (but see Uttmark, 2002 for a practitioner's view on this).

From the perspective of the financier, on the other hand, he also has to consider a number of transaction-specific factors. If the transaction is a common financing activity involving predictable risks, then standard forms of rule-based financing and contracts may be used. If, however, the transaction is highly irregular and involves large ex ante uncertainty, then a financing/governance structure must be chosen which is relatively flexible and which allows for sufficient ex post adjustments (in contract terms and conditions, etc.). Consider a request from an old customer for (say) a 70 percent ten-year-term loan for a new general purpose dry bulk carrier. In this case, other than predicting the preference of debt over equity, our theory suggests that standard (rule-based) loan arrangements are likely to be used, with the financier usually demanding standard terms and conditions such as charter parties from first-class charterers, the market interest rate, a first-preferred mortgage and collateral securities, and standard-type covenants.

Next, consider a second case, in which a relatively new (but equally creditworthy) client requests (say) a 70 percent funding for a new tailor-made LPG carrier for which only a five-year charterparty has been secured. Assume further that the fund-seeker does not insist on any specific type of financing (i.e., he/she is indifferent between debt and equity, whether private or public). Based on the transactional circumstances, our theory will predict that private debt (preferably with a fund supplier with experience in the industry) will be preferred to public debt or public equity. The reason is, not only is the business track record of the new ship owner unknown to the lender, but levels of asset specificity and investment uncertainty are both very high. Equity financiers will have to be given a very high rate of return to entice them into the transaction, and even if this happens, the restrictions on the company's financial and operating conditions are likely to be demanding. In contrast, debt financing is more likely to work, if certain conditions can be worked out between the transacting parties in private. These conditions, other than rate of return and/or fee charges, may include the provision of details about the firm's strategic, financing, and operating aspects; timely and regular provision of the firm's inside information; and more importantly, with flexible contingencies (favorable to the financier) built into the loan contract and allowing for frequent ex post adjustments.[13] These are likely to increase the overall transaction costs of the deal, but the funds-hungry firm may have to accept it (happily) because the costs under alternative equity financing schemes are probably even higher, given the asset type and investment risks. The ultimate choice of financing or governance structure will depend on the interaction of various transaction-specific factors, including the perceived trade-off between costs (including disclosure costs) and benefits of the available financing/governance structures, the experience/utility function of the financial intermediary, the maturity, sophistication and efficiency of the financial system, and the like (Neave, 1991).

Country effects and the influence of institutional factors

Not only do financing/governance structures differ systematically across industries (as characterized by the similarity of investment assets and opportunities) and over time (as a result of the evolution of the wider socioeconomic environment), but there also appears to be country-specific characteristics in the financing of the same industry at any given time, a result that is attributable to different institutional features in different countries. Booth et al. (2001) analyze capital structure choices of firms in ten developing countries and provide evidence that these decisions are affected by the same variables as in developed countries. However, there are persistent differences across countries, indicating that although some of the insights from modern finance theory are portable across countries, much remains to be done to understand the impact of different institutional features on capital structure choices.

In the air transport sector, local or central government funding has essentially financed airports in most parts of the world. Even though this system will no longer be able to cope with the large investments required to upgrade the world's airports, various institutional barriers exist in many countries that deny airports access to other funding sources. In the United States, for instance, public airports have access to tax-free debt through the revenue bonds, making debt relatively cheap, even though it may be limited in available volume (Doganis, 1992). In some other countries, the institutional structure of the airports makes it difficult or even impossible for the use of private finance unless institutional changes in the legal framework of airport ownership or tax regulation are implemented first. Such changes are always difficult and slow to bring about (Doganis, 1992). Until such barriers are cleared, the financing pattern in the sector is shaped mainly by institutional, political, and economic factors. The immediate effect of institutional changes on financing behavior is evidenced in the public listing of two of China's major airlines, China Eastern Airline and China Southern Airline, in both local and overseas stock exchanges after the regulatory barriers were removed in the early 1990s. The changes in these airlines' financing choices is a direct result of the country's economic reforms, under which some formerly state-owned enterprises are allowed to seek public listing.[14]

Applications of the TCE-based approach to other forms of economic organization

Williamson (1988) shows that the general TCE asset-based approach may be applied to examine the economic rationale for a variety of other forms of economic phenomena, including leasing and leveraged buy-outs. The common theme is that they can all be traced back to the same TCE imperative, which is to align transactions (which differ in their attributes) with governance structures (the costs and competencies of which differ) in a discriminating (mainly, transaction cost economizing) way.

The TCE justification for leasing as a governance structure is as follows. Assume that standby access to an asset on wheels is required and that market procurement of the services supplied by this asset is believed to be defective.[15] If the assets in question are durable, general-purpose assets, and they are resistant to user abuse (and/or the costs of inspection and attributing abuse are low), then leasing may evolve as a natural response.

This may be explained as follows. First, let k be an index of asset specificity and let $D(k)$ and $E(k)$ represent the cost of debt and equity capital, respectively. It is easy to show that, at very low asset specificity, the cost of debt $D(0)$, is necessarily lower than the cost of equity, $E(0)$, since the former is a relatively simple, rule-governed relation whereas the latter is a much more complex governance relation involving higher setup costs and intensive monitoring/politicking. As asset specificity deepens, the costs of both debt and equity finance increase, but debt financing rises more rapidly (i.e., $D' > E'$). This is because a rule-governed regime will sometimes force liquidation or otherwise cause the firm to compromise value-enhancing decisions that a more adaptable regime, of which equity governance is one, could implement. Let $\bar{k}$ be the value of k for which $E(k) = D(k)$. Then the optimal choice of all-or-none finance is to use debt for all projects for which $k < \bar{k}$ and equity finance for all $k > \bar{k}$.

Next, based on the impossibility of "selective intervention" (mainly because of managerial discretion/agency costs), Williamson (1988) shows that an intermediate form of governance (called "dequity," which combines the strengths of discretion-based equity and those of rule-based debt) cannot dominate both debt and equity over the full range of k. This intermediate form of governance (δ) has the following properties: $D(0) < \delta(0) < E(0)$; and $D' > \delta' > E' > 0$.

General-purpose assets (e.g., ships, airplanes, railroad cars, trucks) satisfy the condition $k = 0$. Moreover, since measurement problems are assumed negligible, there is no need to combine owner and user for user-cost reasons. Since an outside owner that is specialized in this type of equipment (or that has a competitive advantage in handling this type of equipment) can repossess and productively redeploy these assets more effectively than could a more specialized debt-holder, leasing is arguably the form of finance that has the least overall costs for this type of asset.

It is interesting to compare the above analysis with those contained in the previous section on the 'TCE Imperative', in particular with Macquarie Corporate Finance Limited's (2000) explanation of the popular use of leasing for standardized transport assets and with the empirical results of Palay (1984). It is also useful to contrast TCE's approach to leasing with that in corporate finance. Brealey and Myers (2000) summarize "sensible" reasons for leasing as follows:

- Short-term leases are convenient (e.g., renting a car for a week on holiday; obtaining an operating lease on equipment for a year or two)
- Cancellation options are valuable
- Maintenance is provided (in the case of a full-service lease)
- Standardization leads to low administration and transaction costs
- Tax benefits (e.g., depreciation allowances for lessor; tax deductible and/or low lease payments)

It can be seen that both corporate finance and TCE provide similar (and complementary) justifications for the use of a lease for standardized equipment. While corporate finance places more emphasis on "valuation effects" (e.g., tax benefits and the value of flexibility), TCE enjoys the advantage of being a consistent, unified, transaction cost minimizing approach. Thus, combining insights from both modern finance and transaction cost economics/institutional economics add to our understanding of economic organization.

It is possible to extend the above analysis not only to project finance (e.g., toll roads) and bareboat chartering (a practice similar to a financial lease), but also to mergers and acquisitions (M&As) and alliances. While M&As (as well as leveraged buyouts) have been treated by Williamson and others using TCE reasoning, alliances have not yet been subjected to similar analyses, at least in a transport industry context. Panayides and Gong (2002) review consolidation, mergers, and acquisitions in the shipping industry. One of the questions they raise is, why do some shipping companies prefer M&A to alliances? It is our conjecture that this may be because a full M&A is regarded as a governance structure through which the intended benefits (e.g., wider market coverage, operating and financial synergies) of the strategic move can be realized at lower overall costs (e.g., cost of coordination, which is higher in an alliance). Future studies may be able to shed more light on this.

In summary, corporate finance and governance is obviously influenced by the wider economic and institutional environment, the costs, and competences of different financing/governance structures, as well other transactional circumstances such as asset specificity and the informational condition. While the implications of the theory proposed herein need to be systematically tested, it is comforting to see that the predictions of our theory are broadly consistent with observed practice in the industry, and this is not just because we have developed the theory on the basis of the observations themselves. In fact, it is in the evaluation of the usefulness of the theory that lies the key difference between the TCE approach and the neo-classical finance approach to economic organization. A descriptive theory of the type put forward here, owing to its focus on an individual transaction as the basic unit of analysis, may be said to suffer from being too much tied to a transaction or a class of transactional circumstances, leading to a lack of generalizability. But this latter criticism is clearly unjustified, since, as Williamson (1988) and others show, the transaction economics approach actually applies to a wide class of economic organization problems not limited to corporate finance. In contrast, sweeping statements about financing behavior at the aggregate level that are results of studies which abstract from real life complexities are probably less likely to offer similar insights (obvious as they sometimes are) that are consistent with real life practices. The usual caveat is thus in order: the trade-off between eclecticism and wide generalizability may depend on the intended use to which the theory is put.

We believe that more systematic evidence to be provided in future research will be able to extend greater support for our proposition, which may be summarized as follows: The corporate finance and corporate governance structure in the transport industry is jointly determined in a total cost minimizing way by transactional characteristics such as asset specificity and product market characteristics, and by the interaction between the entity seeking finance and the financier, under the constraint of available financing alternatives (themselves a function of the wider socioeconomic system).

Conclusion and directions for future research

Modern finance theories, which are non-institutional in nature, suggest that capital structure is irrelevant or that there exists a pecking order according to which corporate financing choices are made. While the pecking order theory is able to generate predictions that are broadly consistent with some observed corporate financing practices, it appears incapable of providing non-ambiguous justification for many categories of financing behavior observed in general industry and in the world transport industry in particular. There is strong evidence to suggest that in real life, there exist wider economic, institutional, and industry-specific factors that exert an important influence on the way an industry is financed. There are also clear cross-sectional patterns in the financing methods in different sub-sectors of the transport industry, and such patterns are related to asset specificity, industry characteristics and other institutional as well as non-institutional factors.

In this chapter, we have proposed an eclectic approach to corporate finance and corporate governance in the world transport industry by combining insights from neo-classical financial economics, the NIE (of which TCE is a fast-growing branch) and development economics. Although such a micro-analytic approach may be criticized as being too narrow or industry-specific, the synergy thus created generates an analysis that is more consistent with real-life observations than can be achieved by relying on any single paradigm. Given the dearth of studies in the transport industry that systematically explore the economic and institutional rationale behind observed financing practices, it behoves future researchers to conduct a series of coordinated research studies along the lines of the descriptive theory we have proposed herein. Other than providing empirical evidence on the past and current use of different financing methods in the industry, future research on transport financing may also examine the comparative cost-effectiveness and capability of different types of financing and governance structures (e.g., public debt or equity vs. private debt or equity). Regarding these governance structures as more than financial (e.g., risk management) instruments may lead us to examine shipping pools, alliances, and hybrid financing schemes (e.g., leasing, bareboat chartering) through a unified, TCE-based approach of economic organization. Outcomes of such analyses may be of interest not only to academic researchers and industry practitioners; it may also inform governments in the formulation of economically efficient and effective policies that are geared toward building a strong transport infrastructure. From another perspective, the results from such focused studies may also contribute to the refining of existing finance and economic theories.

Notes

1. This discussion about TCE draws heavily from Williamson (1988).
2. Myers (1984) noted in footnote 3 that Miller and Modigliani's (1966) use of the electric utilities industry enables them to side-step the issue of controlling for other variables (such as a tax-saving incentive for using debt, since the utilities can pass these costs to customers) in their study of capital structure. This is yet another example of the advantages of adopting an industry-focused approach (needless to say, such advantages depend on the purpose of the investigation), although the M&M study has sometimes been criticized for its focus on a single industry.
3. This proposition is in fact the reason why investment and financing decisions can be completely separated (Brealey and Myers 1991, p. 397). It is now generally recognized that financing decisions are in fact related to the investment decisions and in turn to the product market environment (see Long and Malitz, 1985; Maksimovic, 1990; Spence, 1985).
4. When there is tax, M&M's proposition I as "corrected" in their 1963 paper suggests that firms should borrow as much as they can, without, of course, overlooking the potential cost of financial distress. Miller (1976) provides a treatment of capital structure under differential tax rates. See Brealey and Myers (2000) for a summary of these two papers.
5. But even this may be consistent with the static trade-off hypothesis: Profitable firms might find that the financial benefits that can be derived from the use of debt are out-weighed by the attendant costs (of information disclosure, restrictive covenants, etc.). In addition, no theory can be expected to be entirely consistent with all observations. The choice of alternative theories may have to be arbitrary to some extent and depend upon the purpose of the investigation. We prefer to trade off "simplicity" for "fruitfulness" in our choice among alternative theories, since taking account of a wider spectrum of economic (including industry) factors results in more precise predictions.

The disadvantage is that the conclusions may not be generalized to other industries or circumstances.

6. Evidence of companies aligning financing requirements with the costs of different financing instruments on a transaction-by-transaction basis has important implications for capital budgeting. For, if the cost of each project is different, then across-the-board use of the company's weighted average cost of capital (WACC) would be unwarranted.
7. Gong, Firth, and Cullinane (2001) report that about 800 transportation companies have had their shares listed on major stock exchanges worldwide as of December 2000. Although the size of each of public equity and public debt is unknown, the former is believed to be far greater than the latter.
8. But see Subrahmanyam and Titman (1999) for a treatment of the linkages between stock price efficiency, the choice between private and public financing, and the development of capital markets. Among others, they find that the advantage of public financing is high if costly information is diverse and cheap to acquire. The effects of an information disclosure cost differential between different forms of financing on the choice of financing sources are also discussed in Yosha (1995).
9. See Coase (2000) for a definition of the New Institutional Economics.
10. In the words of a pundit, a choice is a choice only if there is a choice.
11. The Chinese shipping companies are probably one of the rare exceptions. Until the early 1990s, Chinese shipping companies had been funded primarily (if not solely) out of the state budget. A similar case seemed to have applied in the Former Soviet Union (see Chrzanowski, 1975).
12. Many shipowners have admitted on various occasions that they make much more money from "buy-low-sell-high" investment strategies ("asset plays") than from carrying cargoes.
13. Leland and Pyle (1977) show that financial intermediation can be viewed as a natural response to asymmetric information, since these intermediaries enjoy economies of scale in acquiring and processing private information for certain classes of assets for which information is not publicly available or not credible, a situation that is quite true of the infamously secretive shipping industry.
14. For more international evidence, see Zhang (1998), Ohta (1999), and Hayashi et al. (1998).
15. We believe that information asymmetries and moral hazard are particularly important reasons for making the market mode inefficient. Specifically, insofar as the shipping industry is concerned, the secretive and risk-laden nature of the business, combined with the lack of credible public (financial) information about the industry firms, makes it very expensive to use public funds.

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8

Private Finance in Port Investment: The South Pacific Islands

Francesca Romana Medda and Simone Caschili

Introduction

Maritime ports and investments to target their expansion are often deemed by governments not only as an important enhancement of their national assets but also as a means of establishing a gateway to the global shipping network. In the last two decades, ports have grown rapidly to become increasingly specialized, highly capital-intensive, and able to carry out a wide range of value-added activities. The recent financial crisis and the consequent restricted availability to credit highlights a major long-term challenge for port investment, which is how to attract the private sector in the financing of port developments in order to maintain and increase market share while achieving profit margins. Foreign direct investment (FDI) in ports is generally very successful, and effective strategies, particularly in developing countries, where international terminal operators (ITOs) in Africa and South Asia are responsible for over 75 percent of privately handled containers and cargo (Drewry, 2010), are proof positive of this success. But, as observed by UNCTAD (2011), although an attractive option, FDIs are not always simple to implement.

One of the main difficulties of FDIs is that the flow of private investment, as with ITOs, is often decided on the basis of available information and data. This relevant information not only describes the features of the ports, such as possible market size, emergence of inland trade, and transhipment capability, but may also set the tone for the economic and policy environment of the host country to include policy stability, regulatory transparency, support for the investment, and

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so forth. However, it is important to stress that, in lagging regions, especially those of the South Pacific Islands (SPICs), this information is often unreliable and disputable due to ineffective data collection practices, corruption aimed to inflate or deflate the significance of data, and underinvestment by administrative agencies. The countries in the SPICs which have attracted main FDIs are the Solomon Islands and Fiji, and this is particularly important when we focus on the private investment in main infrastructures (ports) in the SPICs.

Nonetheless, a combination of perceived and actual robust information can undeniably provide investors with a financial picture of the level of financial attractiveness of a port when considering potential investment. Against this background, in this study our objective is to estimate the Port Attractiveness Index for the SPICs in order to identify possible policy recommendations to foster private financial intervention for port development. We will use the Port Attractiveness Index (Caschili and Medda, 2015) as a potential financial benefit parameter, χ. Port Attractiveness is defined as "the combination of the productive capacity of a port and its level of international competitiveness which provides direct and indirect economic and financial benefits".

We argue that a port generates freight traffic by means of its interconnectedness with inland trade routes and with other regional and international ports. Thus, in order to be attractive and competitive, ports need to be integrated vertically; in other words, they have to secure and provide access to maritime and landside chain operations. They also need to be integrated horizontally, that is, the ports must be specialized but with a wide geographical market share. The implication here is that the reputation of the port assumes a significant role in order in reducing financial exposure in the investment. A port must therefore be equipped with effective facilities; it must provide reliable services at the lowest price; and it needs to have an efficient productivity level. These characteristics comprise the reputation of a port as an intricate network of operators, investors, and maritime brokers (Caschili and Medda, 2015).

In light of the above observations, we structure the analysis in this chapter as follows. We first describe the SPICs' economic features in maritime trade based on the type of data collected and briefly set out the limitations due to the scant availability of data. We then describe the methodology we have applied to identify the Port Attractiveness Index for the SPICs. In the third section, we examine and discuss our results, and we conclude the chapter by proposing a number of policy recommendations toward the promotion of trade development and economic growth in the South Pacific region.

The South Pacific Islands: A maritime perspective

In the SPICs, merchandise trade represents one of the main economic activities. Many of the small countries rely heavily on trading goods and raw materials. One important example is seen in the case of Papua New Guinea (PNG) and Fiji where merchandise trade plays a pivotal role in the local economies that are highly dependent on external trade (World Bank, 2012). The Samoan Islands also depend on merchandise trade, although their share of exports decreased markedly between 2008 and 2010 due to the economic downturn. Moreover, Samoa has relatively good indicators for trade. When compared with the other countries in the SPICs, Samoa requires only 22 days to export goods and 28 days to import goods (Table 8.1). This puts the country top in the table in terms of effective trade operations in the SPICs.

We next review the context of the SPICs region by comparing the attractiveness of the local economies using data on FDI (Figure 8.1). FDIs are the net inflows of investment for acquiring a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, and other long- and short-term capital, as shown in the balance of payments. Figure 8.1 shows total net, that is, net FDI of the reporting economy from foreign sources, minus net FDI of the reporting economy to the rest of the world. Data are in current US dollars.

We can observe from Figure 8.1 that in recent years, Fiji and the Solomon Islands have successfully attracted net positive investment inflows. In particular, they have forged long-term business collaborations with New Zealand and Australia, which has propelled the level of investments in the SPICs countries and boosted the economic growth.

Table 8.1 Main merchandise trade indicators

Indicator	Samoa	Kiribati	Palau	PNG	Tonga
Trading across borders (rank)	58	77	96	134	63
Documents to export (number)	5	6	5	7	6
Time to export (days)	22	20	26	23	22
Cost to export (USD per container)	490	870	720	1,149	505
Documents to import (number)	6	6	9	9	6
Time to import (days)	28	21	31	32	25
Cost to import (USD per container)	575	870	680	1,250	490

Source: World Bank (2012).

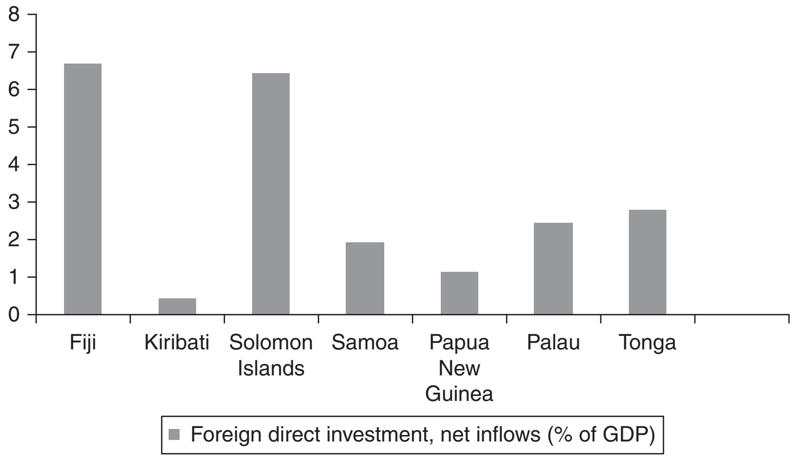

Figure 8.1 Foreign direct investments (% of GDP)
Source: World Bank data set (2012).

Due to the lack of comprehensive data sets for the region under consideration, however, the data have been drawn from different sources and merged together to produce a satisfactory and robust data set. Figure 8.2 depicts the geo-referred visualization of the 35 ports under examination.

We have collected information on 35 container ports in 25 countries in the region: 12 belong to major Pacific Rim countries and 23 are within the SPICs. The collection has been performed such that we have selected any container port in the SPICs that connects to the international container network. For modeling purposes, we have chosen one port for each Pacific Rim country that has trade relationships with SPICs. In Table 8.2, we have shown the list of container ports in our case study.

The state-of-play shipping network is studied using data we have collected to verify our overall aim of private investment facilitation in the SPICs maritime system. Maritime shipping is the dominant mode of transport for international trade for the SPICs and is the main focus of the model. We have reconstructed with the collected data the container trade shipping network within SPICs and between SPICs and major Pacific Rim countries.

As reported in Table 8.3 for each port (or at the national level), we include the following information: throughput, maximum draft, Logistics Performance Index (efficiency of customs) (LPI), country Internet

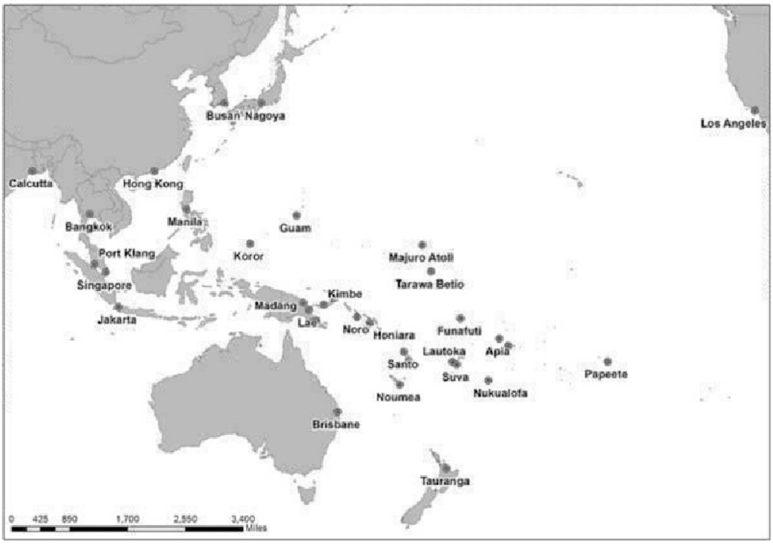

Figure 8.2 Visualization of the geographic location of the container ports considered in the study

users, Liner Shipping Connectivity Index (LSCI), and ease of doing business.

Most of the selected variables in Table 8.3 have a high variance since our data set comprises international hubs (i.e., Hong Kong, Singapore, Busan) as well as underdeveloped ports in the SPICs. In the data set we also introduce the GDP variable in order to characterize the national economy of the country where the port is situated. The variables GDP, ease of doing business, and percentage of Internet users, respectively, allow us to acquire overall information on the economic and financial dynamism in the study countries. As expected, SPIC countries all have very low GDP, and new business activity has a relatively high difficulty in getting started. Although the SPICs are better positioned than some of the strong emergent economies (i.e., India, China, and Indonesia), a less rosy picture appears when we consider the percentage of people with Internet access. With the exception of the more dynamic examples of PNG and the Solomon Islands, most of the SPICs have low to medium values of Internet usage. When we focus on the maritime activity, as expected, ports in the SPICs show low traffic volumes (Figure 8.3) and poor port characteristics (Figure 8.4). In Figure 8.3, we visualize throughput, and Figure 8.4

Table 8.2 Container ports and countries examined in our case study

Country	List of ports (three-digit code)
American Samoa (S)	Apia (APW), Pago Pago (PPG)
Australia (R)	Brisbane (BNE)
China (R)	Hong Kong (HKG)
Fiji (S)	Lautoka (LTA), Suva (SUV)
Guam (S)	Port of Guam (GUM)
Indonesia (R)	Jakarta (JKT)
India (R)	Calcutta (CCU)
Japan (R)	Nagoya (NGO)
Kiribati (S)	Tarawa Betio (TRW)
South Korea (R)	Busan (BNU)
Majuro Atoll (S)	Majuro Atoll (MAJ)
New Caledonia (S)	Noumea (NOU)
Malaysia (R)	Port Kelang (PKL)
New Zealand (R)	Tauranga (TRG)
Philippines (R)	Manila (MNL)
Palau (S)	Koror (KOR)
PNG (S)	Kimbe (KIM), Lae (LAE), Madang (MAG), Oro Bay (ORO), Port Moresby (PMB), Rabaul (RAB)
French Polynesia (S)	Papeete (PPT)
Singapore (R)	Singapore (SIN)
Solomon Islands (S)	Honiara (HIR), Noro (NOR)
Thailand (R)	Bangkok (BKK)
Tonga (S)	Nukualofa (TBU)
Tuvalu (S)	Funafuti (FUN)
United States (R)	Los Angeles (LAX)
Vanuatu (S)	Port Vila (VLI), Santo (GBS)

Note: (S) SPIC; (R) Pacific Rim country.

shows the maximum vessel draft allowed for ports in our SPICs case study.

We use vessel maximum draft as a proxy for ports' technical characteristics. It is noteworthy that, although ports in the SPICs are on average poorly equipped, some ports (i.e., in PNG, Fiji, and Majuro Atoll) can accommodate fairly large vessels. In the next section we describe the methodology which underpins the estimation of the Port Attractiveness Index.

Port attractiveness: Methodology

Caschili and Medda (2015) define port attractiveness as the combination of the productive capacity of a port and its level of international

Table 8.3 Relevant statistics of port variables

	N	Min	Max	Mean	Std. Dev.	Variance	Skewness	Kurtosis
Throughput	29	2000	280,000,000	3,446,542	6,997,488	490,000,000,000,000	2.59	6.41
Maximum draft	35	6.4	22	11.68	3.56	12.64	1.25	2.24
Efficiency of customs (LPI)	22	1.95	4.02	2.7	0.7185	0.5162	0.46	–1.42
Internet users	35	2	83.7	29.01	28.57	816.19	0.86	–0.82
LSCI	31	2.9	143.6	27.0	35.6527	1271.2	1.82	2.61
Ease of doing business	27	1	133	72.11	45.08	2032.54	–0.47	–1.39

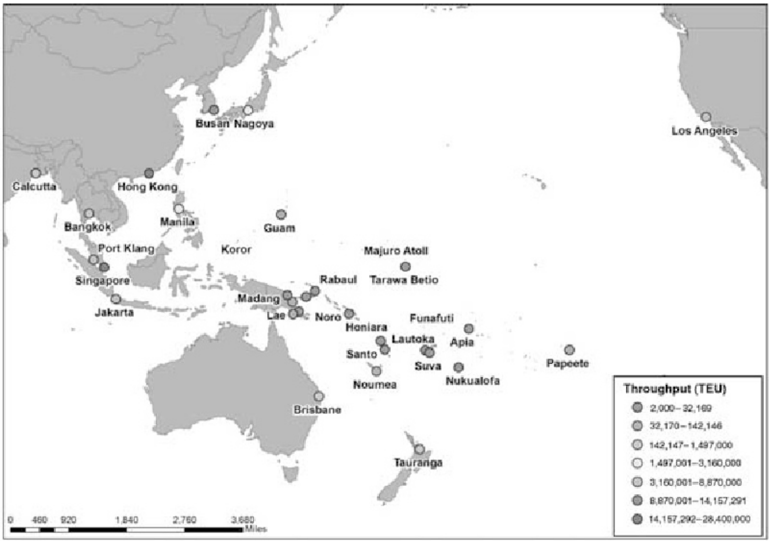

Figure 8.3 Geo-referred visualization of port throughput

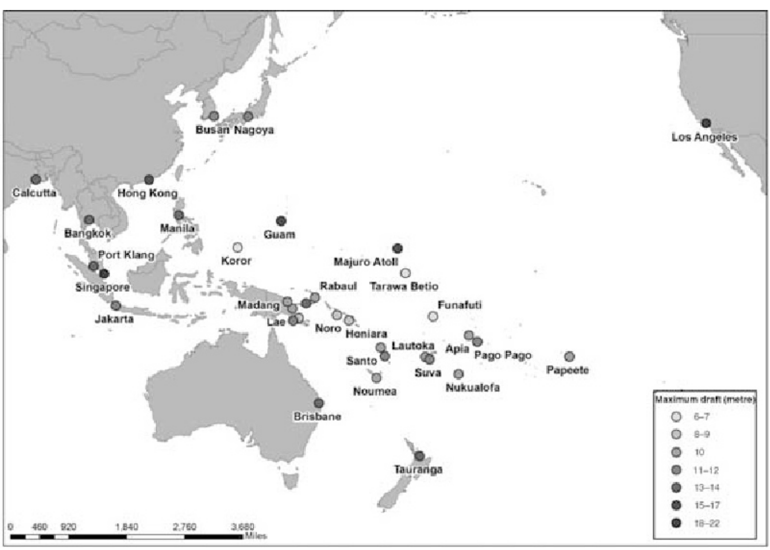

Figure 8.4 Geo-referred visualization of maximum allowed vessel draft

competitiveness which together provide direct and indirect economic and financial benefits. Port attractiveness determinants can generally be grouped into three categories: endogenous, exogenous, and subjective. Endogenous determinants are related to the technical and operational aspects of the ports, whereas exogenous determinants consider the external parameters that influence the effective operation of the port, such as national competiveness. Subjective determinants are the factors which are more linked with port reputation – for instance, the level of cooperation among shippers or the quality of communication of the port with its customers.

We construct the Port Attractiveness Index by exploiting a bottom-up statistical approach (Structural Equation Modeling – SEM) to combine and analyze causal relationships among exogenous, endogenous, and subjective determinants and to measure their significance.

SEM consists of two processes: validation of the model measurements (factor analysis) and fitting the structural model (path analysis with latent variables). The core of SEM methodology is parameter estimation, which consists of the comparison of the covariance matrices of observed variables with the estimated covariance matrices of the best fitting model. Up to three sets of simultaneous equations can be evaluated in the estimation of the model's path loadings:

- a measurement model for the dependent variables;
- a measurement model for the independent variables; and
- a structural model.

The combination of a measurement model and a structural model is applied in SEMs with latent variables. In the case of observed variables, the SEM is composed of a structural model without any measurement models. Confirmatory factor analysis is implemented through a measurement model. In general, there are no constraints on the number of dependent and independent variables that a SEM can incorporate. In the measurement model, the dependent variable y_i is related to the vector of latent variable η_i as follows:

$$y_i = \mathbf{v} + \Lambda\eta_i + Kz_i + \varepsilon_i \tag{8.1}$$

where $\mathbf{v}$ is a vector of intercepts; Λ is a $n \times m$ matrix of so-called factor loadings (the correlation coefficients between the variables and unobserved factors); z_i is the vector of observed covariates; and ε_i is a vector of measurement errors which follows a normal distribution. The matrix K contains regression coefficients that describe direct effects of the independent variables (z_i) on the latent variables.

The structural part of the model describes the relation between the latent variables (η_i) and the independent variables z_i:

$$\eta_i = \alpha + B\eta_i + \Gamma z_i + \zeta_i \tag{8.2}$$

Here α is the intercept and B is an $m \times m$ matrix of regression coefficients describing the relation between the latent variables. The diagonal elements of this matrix are zero and $i - B$ is non-singular. Independent variable coefficients are given by the $m \times q$ matrix Γ. Finally, ζ_i is an m-dimensional vector of residuals which is assumed to be independent from the error vector ε_i.

Equations (8.1) and (8.2) are resolved interactively through the minimization of the differences between the sample variance-covariance matrix and the model replicated matrix. The minimization is achieved through methods such as maximum likelihood, generalized least squares or weighted least squares.

A number of tests are used in our analysis to evaluate whether a structural model is consistent with the data. Kline (2011) identifies two categories of tests:

- Model test statistic (i.e., Chi-square);
- Approximate fit indexes (i.e., RMSEA, GFI, CFI, and SRMR).

It is beyond the scope of this chapter to discuss each of the tests in the two categories. Readers unfamiliar with SEM fitting tests can find appropriate references in Kline (2011) and in articles published in specialized scientific media, particularly *Structural Equation Modelling: A Multidisciplinary Journal*.

Following the approach proposed by Caschili and Medda (2015), we assume that port attractiveness is explained by factors that can be grouped into three categories: endogenous, exogenous, and subjective variables. Subjective variables in particular are often collected via surveys (Sequeira, 2012), but survey methodologies are expensive and time-consuming to conduct. Therefore, alternatively we consider the copious data collected from third-party organizations (i.e., World Bank, Containerisation International, UNCTAD, Internet flows, crowdsourcing data) in order to increase the scale and volume of the examined data and also include different types of data. After having collected a significant volume of multivariate data, we use SEM to define and assess variables that are not directly observable (latent variables) and examine their causal relationships. SEM is a robust statistical methodology perfectly suited to our calculation of the causal relationships between the variables influencing port attractiveness (Ullman and Bentler, 2012).

In the Port Attractiveness Index, we assume that the higher the value of endogenous, exogenous and subjective variables (hereafter called key constructs) the higher will be the Port Attractiveness Index and thus the consequent increase in a port's capacity to attract private investment.

In Figure 8.5 we schematically represent the three key constructs which are latent variables that determine the attractiveness of each port in the SPICs (*A*). The exogenous latent variables (*D*) are meant to represent the socioeconomic level of port hinterlands and the quality of their governance. *D* can be dependent upon several variables such as economic development (Mazumdar, 1996), quality of telecommunication infrastructure (Oyelaran-Oyeyinka and Lal, 2005), and integrity level (i.e., level of corruption, accountability in governance) (Montinola and Jackman, 2002).

Key construct *F* refers to the infrastructural and operational level of the port (endogenous variables). *F* is usually dependent on variables such as port facilities (Slack, 1985; Tongzon, 2002), logistics efficiency (Foster, 1978; Ha, 2003; Murphy and Daley, 1994; Tongzon, 2009),

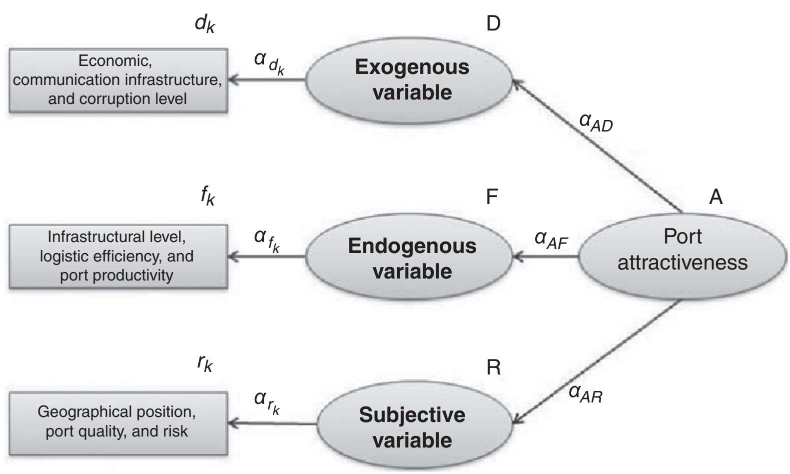

Figure 8.5 Structural equation model of causal relationships between factors in port attractiveness
Source: Caschili and Medda (2015).

and port productivity (the higher the port throughput, the higher the infrastructure level of a port). Here, R is dependent on variables such as port quality (from shippers' points of view), centrality in the international shipping network (the higher the interconnectivity of a port in the global shipping network, the higher its reputation in the industry), and level of reliability.

The use of SEM allows us to quantitatively evaluate port reputation represented by the subjective key construct R.

The causal relationships among key constructs and measured variables from the SEM are linearly combined in order to build the Port Attractiveness Index Φ. The index Φ_i^j for port i in the jth year can be written in a formula as follows:

$$\Phi_i^j = \alpha_{AR} * R_i^j + \alpha_{AF} * F_i^j + \alpha_{AD} * D_i^j \tag{8.3}$$

where

$$R_i^j = \sum_{k=1}^{n} \alpha_{r_k} * r_{i,k}^j \tag{8.4}$$

$$F_i^j = \sum_{k=1}^{n} \alpha_{f_k} * f_{i,k}^j \tag{8.5}$$

$$D_i^j = \sum_{k=1}^{k} \alpha_{d_k} * d_{i,k}^j \tag{8.6}$$

Here, α_{AR}, α_{AF}, α_{AD}, α_{r_k}, α_{f_k}, and α_{d_k} are the path loadings obtained from the SEM; $r_{i,k}^j$, $f_{i,k}^j$, and $d_{i,k}^j$ are the kth observed variables for port i in the jth year.

We will discuss the results of the causal relationships obtained from the SEM in the next section.

Analysis of the results

Through the use of SEM we are able to validate and compare the factors that affect port attractiveness in the SPICs in a three-step goodness-of-fit test. By combining the collected factors at port level, we examine several models and reject or confirm them based on the results of the goodness-of-fit test (step one). In step two, we develop alternative models based on changes suggested by the goodness of fit test. Finally, we choose the best model among those that have passed the goodness-of-fit test (step

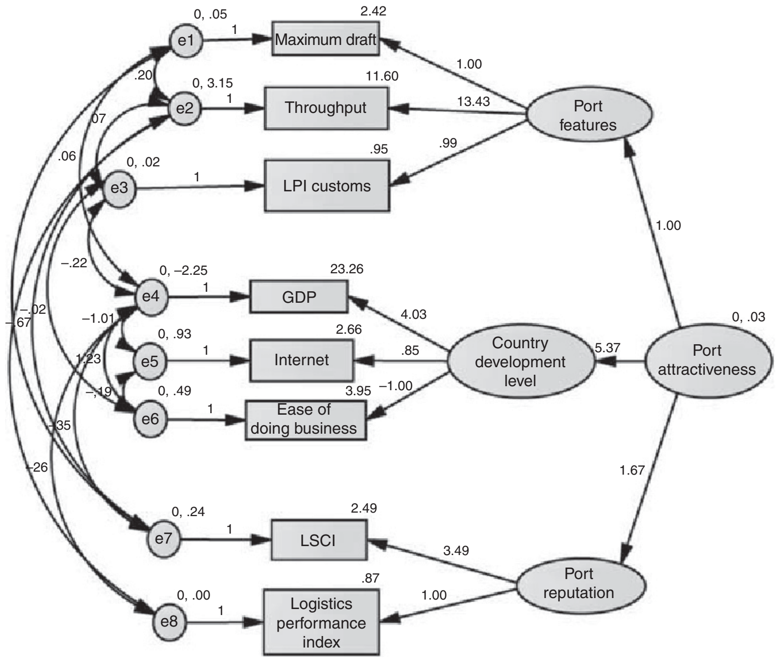

Figure 8.6 Structural equation model diagram for the estimation of port attractiveness

three). Several models have been tested prior to our finding the optimal configuration depicted in Figure 8.6. The figure illustrates the path loading diagram along with estimated unstandardized coefficients for the estimation of port attractiveness (Table 8.4).

Table 8.4 Fit indices with recommended values

Statistic	Recommended value	Obtained value
χ^2		11.4
d.f.		7
χ^2/d.f.	< 2.0	1.629
RMSEA	< 0.06	0.136
NFI	> 0.9	0.967
RFI	> 0.9	0.868
IFI	> 0.9	0.987
CFI	> 0.9	0.986
TLI	> 0.9	0.945

The goodness-of-fit indices in Table 8.4 confirm that the chosen model is consistent with the data. Most of the fitting indices have surpassed their recommended values. In terms of hypothesized links between the measured and latent variables and their statistical significance, all links show significance paths at p-value < 0.001. In other words, country development level (exogenous key construct), port assets (endogenous key construct), and port reputation (subjective key construct) all influence the attractiveness index of a port.

The Port Attractiveness Index (Φ) is rooted in the causality relationships among the determinants of port attractiveness that we have analyzed through SEM (Figure 8.6). The country development level is the major factor for determining port attractiveness in the SPICs (path coefficient 5.37). The level of GDP of the country is an important factor, as is ease of doing business, which negatively affects economic development by hampering business competitiveness, entrepreneurship, and overall growth.

The implication here is that the development of the SPICs ports, and thus possible intervention by private investment, are hindered by setbacks in economic development. Investors therefore consider country development in the SPICs as a discriminant factor in relation to possible port investments. Port assets appear in Figure 8.6 to be as important as port reputation (path coefficients of 1.00 and 1.67, respectively).

An interesting result is that for the key determinant, port reputation, the capacity of a port to be integrated in the international shipping network (LSCI) is almost four times more important than the Logistics Performance Index (LPI). Thus, in order to increase port attractiveness, port operators need to develop a wide network of commercial relationships with other ports, particularly to increase access and connectivity with international markets. Moreover, by providing effective services (LPI = 1.00), ports also benefit from the positive word-of-mouth effect: ports become more attractive when they function as hubs (i.e., carriers can exploit cooperative schemes in those ports), as they benefit from tacitly being promoted in the industry through a multiplier networking mechanism. This result is not surprising; ports with good infrastructure assets but inefficient operations are less productive, so they are less able to handle increases in container traffic.

The Port Attractiveness Index is depicted in Figure 8.7 and Table 8.5 for the 35 ports of our case study. In Table 8.5, we rank ports by Port Attractiveness Index. We first report ports in SPICs and then attend to the other ports considered in this study. In Figure 8.7, each red circle is proportional to the value of the Index, and as expected, ports in the

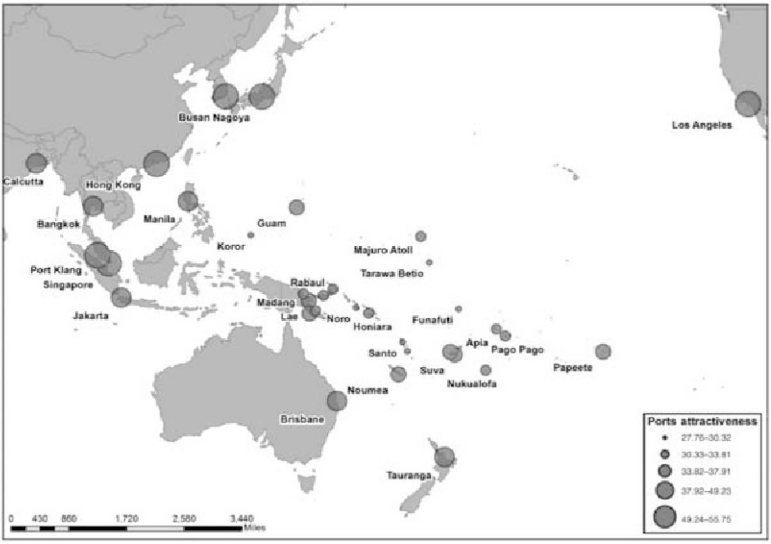

Figure 8.7 Geo-refereed visualization of Port Attractiveness Index for our case study (also includes national economic variables and port variables)

SPICs have very low port attractiveness compared to the other ports shown. SPICs ports with the highest port attractiveness are in Lae in PNG, Suva in Fiji, and Noumea in New Caledonia.

When we examine our obtained results in detail, we can consider the ports of Suma in Fiji and Lae and Port Moresby in the PNG and compare their port attractiveness values with a major international port, such as the port of Busan in South Korea (Figure 8.8). The three ports in the SPICs have some of the best values of the Port Attractiveness Index in the region (over 35) and are certainly lower in relation to Busan (52). However, if we consider the port of Busan as a benchmark, we note that Port Lae and Port Moresby in PNG, although having higher throughput and GDP than Suva in Fiji, both have a significant low value for Internet users (2, respectively, whereas Suva has 20) and high value for ease of doing business (108, respectively, whereas Suva has 58).

If we compare these data with the values for the port of Busan, the port of Suva appears to be following a trend of growth which targets important economic factors such as the simplification and transparency of doing business and a greater distribution of income, which is evident from the level of Internet users variable. Internet users is a satisfactory proxy to account for the level of the middle class and also

Table 8.5 Ranking of ports by Port Attractiveness Index for SPICs and Rim ports

Port	Port attractiveness	Throughput (TEU)	Maximum draft (meter)	LPI – customs	GDP (USD)	Internet users	LSCI	LPI – Tot	Ease of doing business
Noumea	37.91	90,974	10.3	2.3*	1,080,000,000,000	42	9.4	1.98*	88*
Papeete	37.48	71,865	10.37	2.3*	814,000,000,000	49	8.9	2.02*	89*
Suva	35.53	32,169	10.97	1.95	323,000,000,000	20	9.4	1.98	58
Lae	35.51	142,146	10	2.02	948,000,000,000	2	6.4	1.91	108
Port Moresby	35.24	87,889	12	2.02	948,000,000,000	2	6.4	1.91	108
Lautoka	35.12	20,958	9.75	1.95	323,000,000,000	20	9.4	1.98	58
Kimbe	33.81	13,836	13	2.02	948,000,000,000	2	6.4	1.91	108
Rabaul	33.69	14,343	10.2	2.02	948,000,000,000	2	6.4	1.91	108
Pago Pago	33.48	175,000*	11	3*	600,000,000*	5.5	4.8	1.9*	100*
Oro Bay	32.82	5,311	9	2.02	948,000,000,000	2	6.4	1.91	108
Madang	32.80	4,752	10.1	2.02	948,000,000,000	2	6.4	1.91	108
Apia	31.76	22,000	10	3*	600,000,000*	5.5	4.8	1.9*	100*
Majuro	31.57	30,000*	15	2.5*	1,800,000,000*	9.7	6.5*	1.92*	90*
Honiara	31.42	12,500	9.14	2.08	67,900,000,000	5	5.6	2.23	92
Nukualofa	31.39	8,530	10	2.9*	36,900,000,000	16	3.7	2.05*	60
Port Vila	30.32	3,000	10.7	2.1*	70,100,000,000	8	3.7	1.93*	78
Noro	30.05	2,500*	8	2.08	67,900,000,000	5	5.6	2.23	92
Santo	29.96	2,000	10	2.1*	70,100,000,000	8	3.7	1.93*	78
Wallys	29.50	10,000*	7	3*	100,000,000*	8.4	6*	1.95*	95*

Table 8.5 (Continued)

Port	Port attractiveness	Throughput (TEU)	Maximum draft (meter)	LPI – customs	GDP (USD)	Internet users	LSCI	LPI – Tot	Ease of doing business
Koror	29.44	5,000*	6.6	2*	19,700,000,000	28.5	3.4	1.92*	114
Tarawa Betio	28.65	6,600	7	2.5*	1,500,000,000	9.1	2.9	1.85*	117
Funafuti	27.77	3,000*	6.4	2.5*	31,824,701	25	6*	1.95*	80*
Los Angeles	55.75	7,831,902	22	3.68	150,000,000,000,000	74	83.8	4.15	4
Singapore	52.98	28,400,000	22	4.02	21,700,000,000,000	71	103.8	4.22	1
Hong Kong	52.59	23,532,000	16.5	3.16	593,000,000,000,000	34.3	143.6	3.54	99
Busan	52.45	14,157,291	12	3.33	101,000,000,000,000	83.7	82.6	3.62	6
Nagoya	51.81	2,550,000	11	3.79	55,000,000,000,000	78.2	67.4	4.19	23
Port Kelang	50.09	8,870,000	13.4	3.11	24,800,000,000,000	56.3	88.1	3.5	8
Brisbane	49.23	1,000,000	14	3.68	114,000,000,000,000	76	28.1	3.78	10
Tauranga	47.33	818,000	13.2	3.64	14,300,000,000,000	83	18.4	3.54	3
Bangkok	46.97	1,497,000	14	3.02	31,900,000,000,000	22.4	43.6	3.16	18
Jakarta	46.04	6,500,000	11	2.43	70,900,000,000,000	10.9	25.6	2.54	116
Calcutta	45.94	1,000,000	13.4	2.7	171,000,000,000,000	7.5	41.4	2.91	131
Manila	44.24	3,160,000	13.4	2.67	200,000,000,000	25	15.2	2.57	133
Guam	37.05	96,952	16.2	3*	3,000,000,000*	56.3	8.8	2.01*	105*

Note: *Estimated value.

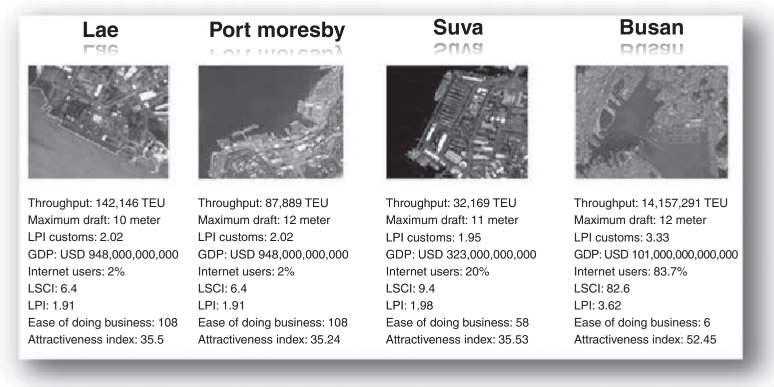

Figure 8.8 Data summary for Lae, Port Moresby, Suva, and Busan

entrepreneurship activities present in the country in order to achieve the development of the port and to attract private investment. These conclusions are also supported by the greater amount of FDI that Fiji has received in comparison with the level received by PNG.

Conclusion and policy recommendations

In this chapter we have examined through the estimation of the Port Attractiveness Index the capacity for the South Pacific Island Countries (SPICs) to attract private finance in port investments. Several important policy implications can now be raised in support of the growth of the SPICs maritime and trade industry. We can observe that with regard to the function of the ports and business activity in general, given that investors may consider country development in the SPICs as a discriminant factor in relation to possible port investments, SPIC governments should therefore streamline bureaucratic procedures and progressively reduce regulation that may limit competition and protect incumbent operators.

With regard to the interconnections of ports, the SPICs need to ensure adequate access provision for the domestic markets, but above all for international markets, by implementing consolidation of traffic and coordination between ports. The analysis has shown that the capacity of a port to be integrated in the international shipping network (LSCI) is a key determinant for the reputation of a port. Thus, in order to increase port attractiveness and private investments, port operators need to develop a wide network of commercial relationships with other ports and improve access and connectivity with international markets in particular.

However, the SPICs are, in the large majority, too small to individually be able to meet the challenges of the global shipping and trade industry. It is therefore necessary to pool resources in order to grow and emerge from their lagging economic status. The SPICs should therefore negotiate possible trade agreements that cover the entire region. Promoting such a policy would prevent bilateral agreements that cater to the special needs of each country. Bilateral agreements in maritime offer greater advantages to the most dynamic ports but may raise transaction costs for the minor ports and countries outside the bilateral agreements (legal and administrative costs, for instance). But, in particular, we may witness an increase in the incentives for rent seeking waste, 'especially by the firms in the hub seeking to influence the selection of countries or sequence of countries that will provide them with the greatest preferential benefits' (Wannacott, 1996, p. 156).

For this reason, technical assistance would be beneficial for developing the required physical and institutional infrastructure and for providing compensation to decrease the costs impacting on some groups affected by trade reforms, for example, those with vested interests in trade. We can conclude by observing that governments in the SPICs should therefore loosen regulations and foster port privatization to improve efficiency and reduce domestic monopoly positions, thereby ushering in greater competition and ultimately, private finance participation.

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9

New Concepts in the Economies of Flow, Connection, and Fusion Technology in Maritime Logistics

Paul Tae-Woo Lee and Tsung-Chen Lee

Introduction

The maritime logistics associated with the international trade of container cargoes are concerned with the flows of cargo, information, finance, and images among stakeholders. The stakeholders include shippers, consignees, freight forwarders, third-party logistics providers (3PL), land and sea carriers, ports, and government agents and customs officers.[1] The seamless, smooth flow of container cargoes and related information among the stakeholders contributes to reduced logistics costs and, consequently, to the improved competitiveness and productivity of each stakeholder and increased competitiveness in international trade. In this regard, we propose three innovative concepts of economies in maritime logistics – namely, the *economies of flow*, *economies of connection*, and *economies of fusion technology*.[2] Numerous stakeholders share the cargo information on the origin and destination of internationally sea-transported container cargoes, which relates to *economies of flow* and *economies of connection*. Information technologies (ITs) such as radio-frequency identification (RFID), global positioning systems (GPS), cargo tracking systems, and electronic data interchanges (EDIs) (Lee et al., 2000) have been applied to maritime logistics. Moreover, the single window system (SWS) collaboratively operated by the private and public sectors in Singapore and Korea has contributed to accelerating the flow of container cargoes and the sharing of the container information among the stakeholders. The SWS allows the parties involved in trade and transport to lodge standardized information and documentation at a single entry point to fulfill all of the relevant import, export, and transit-related regulatory requirements. However, the SWS is not well developed in Asian container ports, with the exceptions of Singapore and Korea (Lee and Lam, 2015; Lee et al., 2014). Thus, IT should be combined with nanotechnology (NT) and biotechnology (BT) to achieve efficient maritime logistics, which is the basis for the proposed concept of *economies of fusion technology*.

Numerous studies have examined the factors related to container transportation – such as the hub-and-spoke system, productivity and efficiency, service quality, inter-port competition, and security – from the various stakeholders' perspectives (e.g., Alyami et al., 2014; Cullinane and Song, 1998; 2007; Cullinane et al., 2002; 2004; Hu and Lee, 2011; Ishii et al., 2013; Lee and Hu, 2012; Robinson, 2002; Song and Panayides, 2012). Yet, the potential benefits of the new economies have been widely neglected. In this chapter, we aim to fill this research gap by proposing three new economies in maritime logistics, which we outline in a descriptive manner supported by some empirical evidence.

Key elements of the three new economies in container value-driven chain systems

The international transportation of container cargoes requires an intermodal origin-to-destination (O-D) system that can be roughly categorized into the following compartments: land transportation from the origin to the departure port, container handling in the departure port, sea transportation between the departure and arrival ports, container handling at the arrival port, and land transportation from the arrival port to the destination. Given the significance of ports as a crucial node in generating added value in the context of container supply chain systems (Robinson, 2002), the discussion of the *economies of flow* in this chapter focuses on two ports directly linked to inland transportation and excludes the sea transportation between the two ports. In addition, export-oriented economies usually facilitate IT and infrastructure developments in inland transportation and ports with the support of government policies, which are closely interrelated to the flow of container cargoes. Examples of this can be found in the historical cases in Korea and China. Given that ports are an indispensable infrastructure for export-oriented economies, the governments of Korea and China established trading ports as a key trade facilitator to lower business operation costs, improve international competitiveness, attract more investors interested in network production systems in the globalized economy, and implement customer-oriented service with an efficient governance system for stakeholders in the flow of container cargoes. For example, the Korean government began to establish trading ports during the process of industrialization starting from 1962 (Lee, 1990; 1996; Cullinane and Song, 1998).

A supply chain for the export and import of container cargoes is essentially a business process that links manufacturers, inland transporters, logistics service providers, and port users in the form of a chain for the delivery of container cargoes. The objective of a supply chain for container cargoes is to obtain benefits by streamlining the movement of manufactured goods in the O-D system in collaboration with a number of stakeholders, including ports. According to Robinson (2002), ports play a significant role in the supply chain:

> Ports are elements embedded in value-driven chain systems or in value chain constellations; they deliver value to shippers and other third party service providers in the value-driven chain; they will segment their customers in terms of a value proposition; and will capture value for themselves and for the chain in which they are embedded in so doing.
>
> (Robinson, 2002, p. 252)

Accordingly, to make ports "the elements in value-driven chain systems or in value chain constellations," we need to investigate and remove any possible impediments to their improvement (Robinson 2002, p. 241). The value-driven systems can only be realized if the speed, efficiency, and service quality at the ports are guaranteed. Recognizing the dynamics of business processes and the interaction among business stakeholders with multiple objectives in a supply chain of container cargoes, Lee et al. (2003) developed a multi-agent system and simulation model to describe a supply chain network and its components; characterize the business entities as agents; model the involved information and material flows using a coordination method for collaboration among agents; and identify the strategic factors of a supply chain with multiple objectives. Synthesizing the key dimensions of logistics and supply chain management and the corresponding roles of ports and maritime transport can be considered within the wider framework of supply chain management (Lee and Cullinane, 2005).

To accomplish a value-driven chain system, individual stakeholders in the flow of container cargo need to address a number of essential multi-dimensional factors. In particular, the container liner services within ports are time-sensitive. Therefore, the terminal operators need to work with the container ships and land carriers to provide their service users with a customer-oriented service that incorporates several service attributes. Hu and Lee (2011) and Lee and Hu (2012) classified port service attributes into tangibles, reliability, responsiveness, assurance, and empathy based on a comprehensive literature review. By comparing the satisfaction levels of service quality attributes among major ports in Asia, the two studies identified 19 attributes relating to the operational and managerial strategies for improving the value-added services in ports. Among the 19 attributes, the attribute of "ready information of port-related activities, e.g., port management information system and EDI," which contributes to saving ship's time costs and increasing a port user's utility (Lee and Hu, 2012, p. 203) is closely related to the *economies of flow* of container cargoes in a supply-driven chain system and the corresponding need for transparency and less bureaucracy in customs, immigration, and quarantine (CIQ) services. To remove the financial, legal, institutional, and political constraints hindering cooperation among stakeholders, there is a need to develop a system or special task team with the authority to bridge all of the relevant private and public stakeholders, as well as a feedback and post-review system for performing regular reviews of the implementation, performance, and governance of actions and projects. A case study on improving the economies of flow of container cargoes is provided below, using Korea and Singapore as examples.

Recognizing Korea's competitive location, the Korean government launched the "National Logistics Master Plan, 2011–2020" to link the entire area of Northeast Asia with the rest of the world using Incheon International Airport, the Busan seaports, and the surrounding free trade zones. In light of this comprehensive policy, on 19 April 2010, the Korean government implemented Port Management Information System (Port-MIS) 2.0, which was an upgrade of the previous version of Port-MIS that had been operated using the EDI method since the early 1990s (Lee et al., 2000).

The "Yes! U-Port" integrated management brand for shipping and port logistics is the first collaborative business project planned by the government and private enterprise to upgrade the maritime industry in Korea. The mission of the brand is to (i) develop a one-stop service system that supports the organic flow of port business ranging from the civil affairs in ports and logistics/asset management to safe ocean transport operations and (ii) ensure that shipping and port logistics hubs are constructed using ultra-modern high-end technology. The "Yes! U-Port" port-logistics system was developed through the integration of the domestic Shipping & Port Internet Data Center (SP-IDC) (see Figure 9.1). The SP-IDC covers seven major services: international logistics information, policy support, shipping line analysis, port harbor customer service information, terminal customer service information, statistics, and information zones. It provides complete logistics information to realize a safer, faster, and easier port IT network that supports the harmonious flow of port-logistics business, regardless of the time or place. The SP-IDC provides real-time services through Port-MIS with the one-time input of all users' information on the computer system. As depicted in Figure 9.1, major users are connected by Port-MIS and SP-IDC and can share cargo and ship information with several government agencies. This approach is exemplary of the *economies of connection* and *flow* in maritime logistics and the above mentioned systems incorporate the *economies of fusion technology*.

Port-MIS is a comprehensive online port management system that provides e-port clearance services and real-time access to the operational information of a vessel from its arrival to departure. The system aims to realize a fully electronic paperless port business and links, provide real-time e-port services to both the domestic and global port community, and integrate the operational information of a nation's ports to support knowledge-based decision and systematic policymaking. The Korean government has used Port-MIS run by the EDI method to operate ports since the early 1990s. Following the rapid penetration of high-speed internet and development of web technology, the upgraded Port-MIS 2.0 was introduced on 19 April 2010. This new system reduces the time and cost of logistics and its web-based function enables users to access without establishing a network or program, or paying fees. They can report information anywhere and at any time on the Internet through Port MIS 2.0. In addition, the system automatically corrects errors and immediately shows the permission process with widgets. Port-MIS is available within and between ports in Korea and the computerized management system handles vessel and cargo movement activities in and out of ports using electronic documents processed on Port-MIS and the logistics EDI network system. In February 2011, the Korean government launched a Port-MIS mobile service for nationwide trading ports, which enables smart phone users to submit applications for vessel movements without the need to visit a local government office. Accordingly, the system aims to link the

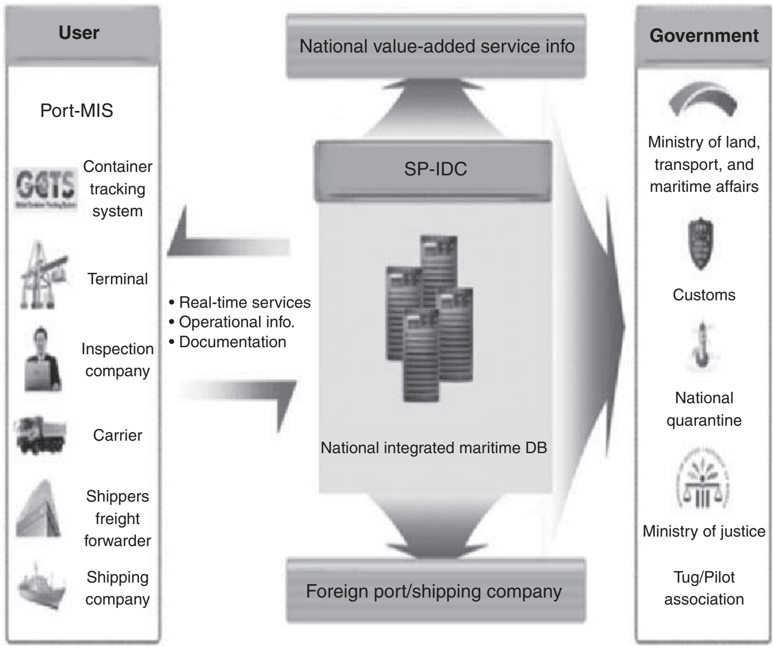

Figure 9.1 Concept of the Shipping & Port Internet Data Center (SP-IDC)
Source: KL Net http://www.klnet.co.kr/english/product/product1_2.html, accessed 30 October 2013.

nation's ports via a paperless administration process and provide an integrated port service to users. Moreover, the service users do not have to hold face-to-face meetings with government CIQ officers. This means the system helps not only to reduce documentation but also to save cost and time. Through online civil service and information sharing, the system has achieved a cost reduction of USD 24 million per year. The simplified export/import process has also reduced the number of public documents from 75 to 22. By mitigating vessel and cargo congestion, the system lowers the vessel standby time and container handling time. All of these factors reduce the total logistics cost. Furthermore, abolishing paper documents can have several ancillary benefits, such as (i) cost saving by reducing the number of port authority officers dealing with civil applications, (ii) reduced manpower, and (iii) cost saving by pooling PORT-MIS information between governmental agencies, such as the port authority, CIQ, and maritime police. Although we do not conduct a quantitative analysis on the benefits of the above system, we can summarize them as follows:

- For the port community (private sector):
  - minimize documentation time and cost;
  - link the relevant agencies involved in export/import.
- For the port operator (public sector):
  - establish a unified port information network that serves as a logistics hub;
  - make effective use of limited port facilities according to real-time facility occupancy; and
  - prevent unexpected accidents by the real-time monitoring of vessel/cargo traffic and facility status.

The “Yes! U-Port” system also helps users to avoid possible bribes between private sector agents and government officers. This issue is further discussed below. Moreover, the system serves as the Korean integral port system comprising of the Advanced Terminal Operation and Management System (ATOMS), Global Container Tracking System (GCTS), and General Information Center on Maritime Safety and Security (GICOMS). Therefore, the integrated system is a typical example to incorporate the *economies of flow* and *economies of connection* in collaboration with the *economies of fusion technology* among the stakeholders in container cargo transportation.

In terms of IT, the Port of Singapore Authority (PSA), the container terminal operator in Singapore, has achieved a great deal of global recognition, particularly in regard to its flagship product Portnet, which is the world’s first nation-wide business-to-business (B2B) port community solution system. Portnet helps shipping lines, hauliers, freight forwarders, and government agencies to manage information and synchronize complex operational processes. The PSA’s new product Portnet® Mobile allows users to access the site via any mobile device at anytime and anywhere and obtain relevant information such as container and berthing status. The Maritime and Port Authority of Singapore (MPA) also provides a community-based system named Marinet, which is an e-service that helps to achieve faster clearance of port and shipping documents and to disseminate critical ship arrival and departure information (MPA, 2013). Singapore also introduced the TradeNet system, a nation-wide EDI system, in 1989. The system aims to facilitate trade through simplifying and harmonizing formalities and procedures and through doing away with paperwork for the trade community. The Singapore system also includes the financial function of online billing, which integrates with customers' in-house systems for the financial electronic data interchange (FEDI) of bills, and facilitates rebilling processes for shipping lines through online viewing of the Portnet charges.

The Singaporean government agencies (e.g., Trade Development Board, port authorities, and customs offices) use the TradeNet system for exchanging trade and shipping information with the private sector. Accordingly, the agencies are able to cooperate and coordinate faster in facilitating trade by simplifying and harmonizing the formalities and procedures and by doing away with paperwork. TradeNet links the multiple parties involved in external trade transactions (including 35 controlling agencies) to a single point of transaction for most trade documentation tasks. The system contributes to the reduction in logistics costs, including duplicated time costs for the preparation, submission, and processing of trade and shipping documents, and it expedites the clearance of cargo. Korea and Singapore are among the leaders in seaport electronic information systems. However, unlike Korea, Singapore has unique online billing functions that are integrated with the customers' in-house systems. The 2007 survey report by the World Bank indicated that Portnet is a key factor in Singapore's ranking as the world's number one logistics hub (Lee and Lam, 2015).

The use of IT in ports is interrelated among the stakeholders in the logistics and maritime cluster. IT facilitates the development of maritime logistics chains, the generation of value-added services, and the activation of free trade zones adjacent to ports. The IT based SWS in ports is a facility that allows the parties involved in trade and transport to lodge standardized information and documents using a single entry point to fulfill all of the import-, export-, and transit-related regulatory requirements. It simplifies processes by integrating with the government agency and port authority systems, as well as the port users' individual systems. The architecture of the SWS provides a single point for the one-time submission of all required information and documentation to all governmental agencies responsible for export, import or transit procedures. In summary, the SWS provides a one-stop service which only requires the one-time submission of electronic documents. As a single-view and consolidated platform, the SWS not only improves efficiency by eliminating repetitive data entry, processing, and transcription errors, but also simplifies processes by integrating the government agency and port authority systems, as well as port users' individual systems. The SWS *connects* all of the parties involved in trading, port usage, and various transport sectors, including government agencies, on the same platform. The SWS contributes not only to reducing documentation costs but also improving efficiencies because once a submission is made by the user, the system (e.g., Port-MIS 2.0 in Korea) automatically distributes the information to the relevant governmental agencies. Moreover, the system helps users to simplify the import/export process and reduce the number of declaration forms (e.g., in the Korean case, from 75 to 22 documents). Overall, the *economies of flow*, *connection*, and *fusion technology* are well reflected in the SWSs in Korea and Singapore.

To illustrate the concepts of *economies of flow*, *connection*, and *fusion technology*, it is meaningful to compare the overall IT systems used in the container ports of Busan, Shanghai and Singapore. Table 9.1 presents a comparison of the IT systems, stakeholder collaboration and integration functions in the three container ports. The focus of IT is on one-stop services and security to improve port performance and users' satisfaction. IT is not only used for the tracking and tracing of cargoes and information via a "single-window" system, but also for performance measurement, including gas emission information (Lee and Lam, 2015). Directly linked to the established logistics infrastructure, Shanghai Port is also the biggest transportation hub in China. The port is connected to an extensive transport network, including waterway, rail, road, and air transport penetrating the vast hinterland of the Yangtze River Delta and

Table 9.1 A comparison of the IT systems of container ports in Asia

Service and function items	**Yes! U-port (Busan)**	**No specific system (Shanghai)**	**PORTNET (Singapore)**
Single window system	✓	×	✓
Integrated function	✓	Limited	✓
Collaboration between government and private enterprise	✓	Limited	✓
Cargo tracking system	✓	✓	✓
Maritime safety and security	✓	✓	✓
RFID	✓	✓	✓
Service using mobile smartphone	✓	×	✓

Source: Lee and Lam (2015).

central China. However, Shanghai port has not implemented an SWS to share cargo information among the Chinese ports. In addition, there is limited integration of stakeholders in the public and private sectors in handling container cargo. Shanghai and the ports in the Pearl River Delta and some Chinese coastal ports, such as Ningbo, Qingdao, and Tianjin, are gateway ports to the vast hinterlands in China. Although Shanghai Port plays a leading role in handling container cargo volumes, it will not be able to meet the transportation needs of port users and service providers in response to the increasing cargo volumes unless the three economies proposed in this chapter are implemented. Therefore, from the perspective of the *economies of flow* and *connection*, the ports of Busan and Singapore can be considered to be more efficient and competitive than Shanghai Port.[3]

The *connect effect* of dynamic clustering in container hub ports is closely related to the *economies of connection* proposed in this chapter. The connect effect has multiple benefits. First, it develops strong personal, professional, and virtual networks among the stakeholders involved in container transportation and handling in ports. Second, a network is a powerful problem-solving resource with mutual benefits. Third, an effective network can make the clustering more informative and accelerate collaboration and cooperation among cluster actors. In this regard, clusters are characterized by two relations among firms/businesses along a supply chain: (i) the "production linkages" among firms in an industry and (ii) the "cooperation linkages" among firms within an industry and with other related industries, supporting institutions and public agencies. Therefore, clusters need to have the connect effect because they are "geographically proximate firms in vertical and horizontal relationships, involving a localized enterprise support infrastructure with a shared developmental vision for business growth, based on competition and co-operation in a specific market field" (Cooke and Huggins 2003, p. 52). Fourth, the connect effect can be a powerful force that can enable the cluster players, participating organizations and the overall cluster society to overcome weaknesses. Lastly, the connect effect can serve as a catalyst for creating new modes of production in the globalized economy.

The following factors should be considered in analyzing the *economies of flow*, *connection*, and *fusion technology* (Lee et al., 2000, pp. 133, 140):

- The planning, requirement analysis, and design of EDI should provide a framework for its implementation that reflects stakeholders' needs.

- Because the customs clearance data are an integral part of a logistics EDI system, government agencies including the customs office should be connected and integrated on the same platform, the so-called one-stop service.
- Integrating the sharing of cargo data into the framework of the logistics EDI should improve the efficiency of data interchange.
- It is necessary to adopt a regional message standard to facilitate communication among the stakeholders involved in container cargo flows.
- The EDI system for container cargo should create value-added services and minimize documentation costs with online retrieval services for vessel schedules, container cargo movements, ship and cargo statistics, ship status in port, safety and security processes, and so on.
- The most important issue is that a "win–win" environment should be created between EDI suppliers and users and between the private and public sectors.
- The development of EDI should focus on customer centric services and the removal of bureaucratic elements and corruption.

Port-MIS and EDI are preferable for sharing the high levels of information associated with the container cargo supply chain. Lee et al. (2003) classified the level of information sharing into low and high levels. According to their conclusions, incorporating a high level of information sharing in a container terminal is a more effective strategy than using a low level of information sharing, and it enables all of the performance measures to be enhanced. Specifically, a high level of information sharing between the ship operator and the terminal operator increases the number of vessels that can be served, reduces the average service time per berth, and increases the berth utilization, as compared with a low level of information sharing. Lee et al. (2003) conducted a simulation of the selection of partnership strategies in a port supply chain and found that a reliable and strong partnership strategy with sufficient resources is more effective than the other partnership strategies. In regard to a reliable partnership with sufficient resources, it is assumed that the terminal operator supplies satisfactory resources, such as cranes and tractors. Moreover, a reliable partnership between the ship operator and terminal operator shortens the cargo handling time, assuming that the ship operator and the terminal operator have a good partnership, and the latter is willing to supply a skilled crane operator to maintain customer loyalty (see Table 9.2).

Table 9.2 Types of economies by dimensions in a port supply chain handling container cargoes

Dimensions	**Types of economies**	**Strategies**	**Description**
Supply chain information	Economies of flow	Sharing information among partners	This strategy increases supply chain visibility and information sharing and reduces the uncertainty in decision making.
Supply chain relationship: weak or strong partnership	Economies of connection	Maintaining a stable partnership	This strategy improves the understanding of a partner's situation which helps to build trust among the stakeholders. For example, a reliable partnership between a ship operator and terminal operator shortens the cargo handling time.
Integration of IT, BT, and NT for cargo handling services	Economies of fusion of technology	Integrating cargo handling process with all available technologies, i.e., IT, BT, and NT	The level of integration can be measured by the degree of application of IT, BT, and NT for handling container cargoes.

Source: The authors, compiled and updated based on Lee et al. (2003).

Last but not least, government policy is another important factor to consider in the three new economies in maritime logistics. Lee and Flynn (2011) proposed the conceptual model of the Asian (Port) Doctrine to explain the successful development of top ranking container ports in Asia over the past four decades. They also suggested a new paradigm for the role of government as a third governance approach in addition to the Anglo-Saxon and European doctrines (Bennathan and Walters, 1979) by describing how Asian countries have developed container hub ports through investing in infrastructure as social overhead capital to support export-led growth. Similarly, China has considered ports as a gateway to attract foreign direct investment in tandem with free trade zones and to protect its social economic system from foreign negative influences (Lee et al., 2003). China's rise as a trading power in the 1990s and its emergence as the global engine of growth were built on the backbone of a state-financed port infrastructure where government control was predominant, and the participation of privately owned global terminal operations was seen as a tool rather than an end result. Despite the different economic systems of Korea and China, the central governments in the two countries have developed major ports according to a series of economic development plans and the forecast port capacity demand and to coordinate the national ports. China and Korea have included the development and expansion of ports in their consecutive economic plans to meet their international trade demands (Lam and Yap, 2011). Owing to the significance of independent national port services, inter alia, foreign private sectors were not considered for terminal operations and port investment until the Korean government felt sufficiently confident in port management and the need for port efficiency surpassed the desire for a nationalized port service.

Lee and Flynn (2011, p. 798) summarized the characteristics and elements of the Asian Port Doctrine as follows:

- At the initial stage, the central government acts as a multi-dimensional player, such as investor, port designer, port manager, and policymaker.
- The central government primarily invests in port infrastructure such as breakwaters, dredging, land purchases, and connecting road and rail.
- Initially, overall port policy and pricing is governed by the port authority under the control of the central government, although this arrangement tends to devolve to local government control after the system matures.
- Landside connectivity is part of the integrated planning under the central government, although regional or local authorities are involved in some cases.
- Although customs administration is controlled by a different division of the government and can be fragmented geographically (as is particularly the case in China), improvement of the cargo clearance process is partly facilitated by the central government.
- Special economic zones for distribution or manufacturing under the auspices of the central government are generally established in the neighborhood of ports to generate container cargo, with several incentive policies based on regulations and/or special laws.
- New private terminal operators are generally not granted monopoly positions in the port.

- Infant industry arguments are commonly applied to ports, but port capacity is expanded to avoid monopolistic pricing of port services and is done well in advance to meet the demand for port services.
- Financing is allocated to achieve national economic goals, and the port infrastructure is seen as social overhead capital by the central government.
- The social overhead costs (SOC) covered by the central government offset insufficient capital accumulation by the private sector and local governments.
- Overall port pricing is governed by the port authority under the control of the central government to determine national price levels for stable economic growth.
- There is cross-subsidization for additional new port development and/or expansion.[4]

The above characteristics highlight the influential and multi-dimensional roles of central government in designing an integrated logistics development policy for container ports, as confirmed by Lee (1990; 1996) and Cullinane and Song (1998). Lee (2013) argued that the Asian Doctrine motivates the central government to play a leading role in implementing integrated logistics policies, promoting the competitive edge of logistics companies, and supporting their globalization, and it listed the Korean government policies for the logistics industry including the port sector as follows:

- application of the concept of SOC in building IT infrastructure;
- application of IT platforms for logistics hubs (seaports and airports) and land transportation;
- investment in training logistics professionals at graduate schools;
- logistics standardization and the development of packaging containers;
- introduction of a certified integrated logistics company system;
- incentive policy to encourage private sector investment in IT infrastructure in logistics systems with the introduction of tax breaks;
- development of a logistics center in association with free trade economic zones;
- utilization of more knowledge based industry to form a hub of high value-added services;
- development of dynamic clustering with integrated logistics facilities in the globalized economy;

- lowering the cost of business and consequently improving competitiveness in international trade;
- application of fusion technology to clustering systems; and
- introduction of the SWS for clustering systems in collaboration with the national logistics system.[5]

Following Flynn et al. (2011) and Lee and Lam (2013), Lee et al. (2014) revised their criteria and added more detailed evaluation criteria for fifth generation ports (5GPs). The new concept of 5GP[6] has the potential to become a guide for benchmarking in the port industry in terms of port evolution and development. To become a 5GP, a port is expected to provide services at a highly customer-centric level by using market mechanisms, incentives, and government policies. Customer orientation, service, technology, and hubbing are vital factors for a 5GP (Lee and Hu, 2012), which is characterized by 5 factors, 8 features, and 12 criteria (the names and definitions of the criteria are listed in Table 8.4 in Chapter 8 of Volume 2 of this book). With reference to the literature and the latest industry trends, the features and criteria are formulated in line with specific performance measurements in practice. The technological features of the 5GP model are represented by the criteria of SWS and RFID or other applications. The use of RFID for container cargo tracking accelerates the speed of the container cargo flow and, as a consequence, increases the level of customer satisfaction. However, if the system is only used to control staff movement, it will do little to improve customer satisfaction. Therefore, RFID in association with IT, that is, fusion technology, should be applied to container cargo flows in hub ports in a number of ways. The use of such fusion technology in tandem with its intensive and comprehensive application contributes to enhancing logistics competitiveness in the hub ports, which is regarded as a new dimension of hub port quality (Song and Lee, 2005). In other words, the economies of fusion technology are not only a new dimension for establishing a consolidated maritime logistics network and sharing information and resources among the stakeholders in the container supply chain, but also accelerate the seamless flow of container cargoes with their related information.

Contribution of the three new economies to competitive edge

In the previous section, we noticed that the SWS contributes not only to reducing documentation costs but also to improving efficiency by automatically distributing information to the relevant governmental agencies. Moreover, the system helps users to simplify the import/export process and to reduce the number of declaration forms. As a result, the frequency of direct face-to-face meetings between users and government officials is considerably reduced because the SWS *connects* all of the parties involved in trading, port usage, and various transport sectors, including government agencies, on the same platform. However, what would be the effect of reducing the number of face-to-face meetings needed to deal with the various documents related to export/import container cargoes (which constitutes a bottleneck)? It is implicitly predictable that the elimination or reduction of meetings would increase the flow of cargo and significantly decrease costs. If that is the case, it is necessarily implied that other steps of the container cargo flow process in dry ports lead to cost reductions and improvements in service quality, which can be measured once the bottleneck is broken. Leaving aside the reduction in documentation cost and time, an SWS would help users to avoid bribes or other corrupt practices requested by government officers. Some users may refuse the requests, which could consequently delay their business processes. In this regard, we assume that this would be an impediment to the *economies of flow* of container cargoes. In other words, it would constitute friction in the process of flow. Although it is difficult to quantify this effect, future studies could try to make an approximation using proxy data, such as the Corruption Perceptions Index (CPI) issued by the Berlin-based organization Transparency International. Given the secrecy surrounding most corrupt dealings, the annual report measures perceptions of graft rather than actual levels, using a scale where 100 stands for the most clean and 0 for the most corrupt (Transparency International, 2015). Accordingly, we believe that unless SWS and EDI*zation*[7] are established in advance, the economies of flow associated with container cargo movements will not be improved in countries with a lower CPI. Nonetheless, IT does help to mitigate corruption and bureaucracy to some extent.

With respect to the contribution of SWS in collaboration with EDI*zation*, the overall process of EDI*zation* has to overcome considerable economic, practical, and legal obstacles among stakeholders, in particular among different departments of the same government. The previously unchallenged and dominant positions of these stakeholders are threatened by the EDI system. Agents whose small companies cannot afford the hardware or the change of attitude necessary to adapt to the new environment have difficulty in dealing with the competition of EDI. Moreover, agents who prefer security and stability and are averse to change are affronted by the uncertainties and hazards of the new dynamic system. Many examples of resistance to change are available from developed and developing countries. A field survey in Asia by one of the authors of this chapter showed that customs officers prefer not to introduce the SWS because it undermines their chances of getting kick-backs from businessmen. This argument is supported by Tongzon and Lee (2015) who argued that although the Vietnamese government implemented the SWS, the customs clearance process was not fully integrated, but instead remained highly fragmented, and that the traditional and human-oriented business practices in Vietnam's logistics industry were impediments against achieving smooth import and export processes. In contrast to customs officers, officers in the central government departments of economy and trade highly appreciated the change to the SWS. In other words, customs officers hesitate to give up their vested power and influence in their business related to export and import cargo flows because the SWS dramatically reduces the need for face-to-face meetings. This situation can lead to conflict among the relevant departments within the same country in designing and implanting the SWS and EDI*zation*, as was the case in Korea. No country in which the SWS and EDI*zation* have been implemented has been free of such impediments and conflict. It has been observed that the intensity and rigidity of such resistance vary considerably and is usually directly related to the relative backwardness of the country concerned during the early stages of the introduction of EDI*zation*. Gupta et al. (2011) argued that a common EDI for all ASEAN countries for all gateways (including payment) is not currently available. This has led to the delay of cargoes and a lack of streamlined and friendly practices, which impede the streamlining of the documentation procedure. Gupta et al. (2011) listed the major barriers to logistics services, customs procedures, and cargo inspections as (i) time-consuming documentation requirements, (ii) burdensome inspection requirements, (iii) different classifications of goods in different countries, (iv) lack of border-crossing coordination, (v) inefficient inbound clearance processes, (vi) arbitrary independent rulings, (vii) volatility in border traffic and multiple uncoordinated offices, and (viii) improper penalties. They further rated the barriers as critically significant, very significant and moderately significant. Their test results showed that items (i)–(iii) are critically significant, items (iv) and (v) are very significant, and the rest are moderately significant.

The logistics market among the ASEAN countries has expanded significantly in recent years and the ASEAN economic ministers have identified "logistics" as one of the priority sectors for accelerating economic integration. Accordingly, the ASEAN countries have tried to introduce the ASEAN Single Window (ASW) to link the stakeholders involved in international trade as a pre-requisite to mitigating the above barriers and as "an integral part of achieving an efficient communication system within each member country and across the region" (Tongzon and Cheong, 2012, p. 325). There is little difference between the ASW and the SWS and both require the leadership of government agencies to implement the systems and to resolve the conflicts among the stakeholders within a country and between the ASEAN members. Although Vietnam, Philippines, and Indonesia have introduced the SWS, their performance is still poorer than expected owing to, among other things, a preference for the offline submission of documents by customs-related organizations in the Philippines and the traditional and human-oriented business practices in Vietnam (Tongzon and Lee, 2015). As a result, manufacturers, maritime logistics providers, academics, and policymakers have demanded the creation of an integrated logistics environment in the globalized economy. Therefore, the *economies of flow*, *connection*, and *fusion technology* need to be promoted in the transportation and supply chain system to minimize freight and time costs and risk and to improve collaboration, segmentation (e.g., commodity, region), coordination, and system optimization in terms of maximization of profit, benefits, efficiency, reliability, service quality, standardization, containerization, liberalization, deregulation, the role of government intervention, and governance among stakeholders.

Conclusions

In this chapter, we propose three new economic concepts for the international transportation of container cargoes, namely, the *economies of flow*, *economies of connection*, and *economies of fusion technology.* The key benefits of the new economies include, among others, lowering the logistics costs and handling time of container cargoes; the sharing of knowledge and information among the stakeholders; capturing the economies of synergy; promoting joint R&D efforts between the government and private sectors; obtaining mutual benefits from the combined use of complementary assets and knowledge; and overcoming (or mitigating) social impediments such as bribes and bureaucracy.

We have not provided statistical and empirical evidence confirming the existence of the three new economies in maritime logistics, as a sine qua non, in this chapter. Nonetheless, this shortcoming does not lessen the significance of this chapter because we have outlined and developed the proposed concepts to some extent. In other words, the proposed economies provide a raison d'être for developing efficient maritime logistics systems in tandem with promoting international trade flows, particularly in the ASEAN region where there are several obstacles in CIQ. Given their transhipment function in hub and spoke networks, the proposed three new economies are closely related to savings in cost and time, improving service quality and mitigating social impediments such as corruption and bureaucracy. We plan to conduct a future study to extend the theoretical foundation and provide empirical-quantitative evidence associated with the three economies.

Notes

1. For the definition of maritime logistics, see Song and Lee (1999) and Lee, Nam, and Song (2012, pp. 9–21).
2. Lee (2011), "Elegance of Flow, Connexion, and Fusion in the Flat World," Lecture at National Taiwan University, Taipei, March 25.
3. Please refer to Lee and Lam (2015) for the issues concerning whether major Asian container ports have reached the next evolutionary stage of 5GP, which extends the existing fourth generation ports (4GPs) in terms of service quality, IT, community environmental impact, port clusters, maritime clusters, logistics hubs, inland connections, and waterside connections.
4. On the cross-subsidization for additional new container port development, see Lee and Flynn (2011) and Lee and Lee (2012).
5. Pointing out the government was failing to work with localities to integrate science and technology advancement into their social and economic development, Deputy Prime Minister Nguyen Thien Nhan urged the implementation of a national strategy for the development of science and technology during 2011–2020 (Viet Nam News, March 9, 2013).
6. On the second version of 5GP, see Chapter 8 in Volume 2 of this book.
7. The term of "EDI*zation*" was coined by Lee et al. (2000).

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