DEVELOPING A GAME THEORY COMPETITION ANALYSIS FOR THE LINER CONTAINER SHIPPING

by

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ABSTRACT

The liner container shipping industry plays an essential role for the viability of international trade and continuous flow of the various semi-finished and finished products, from main production areas to end consumption points throughout global supply chains. In the recent decade, the liner container shipping counterparties faced many managerial challenges such as; strict environmental regulatory enforcement of regulatory bodies, fleet capacity oversupply, unstable bunker prices, insufficient freight rates and operational barriers in marine transport infrastructures. Therefore, significance of the robust competitive decision-makings, for both shipping liners and port managements, are critical to develop resilient strategies against the emerged challenges in the liner container shipping system.

Broadly speaking, competitiveness of the liner container shipping counterparties can be analysed with various qualitative and quantitative models and methods. The game theory is one of the quantitative tactical behaviour methods used in order to analyse competition outcomes of each player for each chosen strategy, whilst taking competitor behaviours within the game concept into consideration.

This thesis deals with the practical application of a non-cooperative four rational players' game methodology with complete/incomplete information to analyse competition outcomes of the liner container shipping operations, according to CournotNash and Bayesian-Nash equilibrium concepts. The research includes not only competitiveness of the shipping liners, but also competitiveness of the container port terminal managements and bunker suppliers.

The approach developed in this study utilises different liner shipping game concepts to achieve the determined objectives of the main methodology. The objectives of the methodological framework include new generation shipping alliance competition, holistic port competition, and a scenario based LNG bunkering supply competition. The methodological formulations are mathematically integrated to different methodological outcomes in each case study. It is proposed that the outcomes of this study will provide

significant outcomes and robust decision support rationales in order to develop adaptive competition strategies for the liner container shipping counterparties.

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NOMENCLATURE

P: Market price

Q: Total capacity supplied to the market

$Q_{-\theta}$: Total capacity except capacity of the player θ

q_{θ}: Capacity of the player θ

c_θ: Costs of the player θ

π_θ: Profit of the player θ

α: Constant market parameter

TC_θ: Total costs of the player θ

VC_θ: Voyage costs of the player θ

CC_θ: Capital costs of the player θ

BC_θ: Bunker costs of the player θ

PC_θ: Port costs of the player θ

γ: Canal charges

MC_θ: Manning costs of the player θ

IC_θ: Insurance costs of the player θ

SC_θ: Stores costs of the player θ

MAC_θ: Maintenance costs of the player θ

ADC_θ: Administration costs of the player θ

$AC_\theta =$ Additional costs of the player θ

RT_θ : Round trip time (hours) of the liner service of the player θ

$D_{\theta ij}$: Route distance of the player θ between i^{th} and j^{th} port of call

$V_{\theta ij}$: Average speed of the player θ between i^{th} and j^{th} port of call

$PT_{\theta k}$: Average port time of the player θ's k^{th} port of call

σ_θ : Average total round trip delays of the player θ

CP_θ : Cash price of the average ship of the player θ

r_θ : Interest rate of the average ship of the player θ for adequate time period

n_θ : Number of instalment for the player θ

l_θ: Loan of the player θ

y_θ: Number of round trips per year for a ship of the player θ

x_θ: Number of ships for the player θ on the liner service loop

ω_θ: Capacity utilisation rate of the liner service of the player θ

OHC_θ: Overhead costs of the player θ

OC_θ: Operational costs of the player θ

ENC_θ: Energy consumption costs of the player θ

$LABC_\theta$: Labour costs of the player θ

EAC_θ: Equipment asset costs of the player θ

MCC_θ: Miscellaneous capital costs the player θ

$OFFC_\theta$: Office costs the player θ

$CONC_\theta$: Concession costs of the player θ

STC_θ: Staff costs of the player θ

$AOHC_\theta$: Other overhead costs of the player θ

EOC_θ: Extraordinary costs of the player θ

PP_θ: Product price Index of the player θ

LC_θ= Logistics costs of the product of the player θ

PT_θ= Regional product tax rate of the player θ

SC_θ: Storage costs of the product unit for the player θ

HC_θ: Heating-cooling costs of the product for the player θ

BC_θ: Barging costs of the player θ

ISC_θ: Inspection and survey costs of the player θ

δ_θ: Additional capacity decision of the player θ

$\Delta\delta_\theta$: 0 decision or $\pm\ \delta_\theta$ decision (increasing or reducing the capacity) of the player θ

${q'}^*_\theta$: Capacity allocation of the player θ in the new scenario

P' : The new freight rates based on the capacity deployment decision

$c_\theta{}'$: The new cost per container based on the capacity deployment decision of the player θ s_μ^θ: τ^{th} pure strategy of θ^{th} player. $\theta = (1,2,3,4)$, $\mu = (1,2)$, $\tau = (1,2,3,4,5,6, \dots ,16)$.

${s_\mu^\theta}^*$: The Nash equilibrium

${s_{-\mu}^\theta}^*$: The Nash equilibrium best response strategies of the other players

${s_\mu^\theta}'$: Any alternative strategy of player θ

S_θ : Set of strategy actions for the player θ

T_θ : Set of possible types for the player θ

p_θ : Probability function of the player θ

$\tilde{a}$: Player’s action

$\tilde{t}$: Player’s type

1. INTRODUCTION

1.1. Introductory Remarks

Freight transport is a ‘sine qua non’ for the modern civilisation and its socio-economic development, and is a primary focus of the trade policy-makers and government bodies. Different freight transportation modes respond to different transportation requirements relating to the demand. It is commonly acknowledged that waterway based transport is the most cost-efficient and environmentally-friendly mode of freight transportation, which currently serves around 90% of the global freight demand as cargo volume and more than 70% as cargo value (IMO, 2012). Literally, waterway transport is considered as economically more feasible, energy efficient and more environmentally friendly in comparison to other transport modes especially for cargoes of high volume over long distances. As a consequence of that fact, the vast majority of seaborne trade is organised as bulk shipments in relatively large quantities. Undoubtedly, the deep sea bulk shipping has dominated the seaborne trade for a very long time, but gradually increasing human needs and manufacturing capacity shifting to developing countries augmented the significance of the liner shipping for the viability of global trade (Stopford, 2009). Nowadays, approximately 17% of the total seaborne trade volume is carried in container units by scheduled liner shipping services. With regards to the economic value of cargo transported, the liner container shipping industry represents a much higher proportion (more than 50%) of the total value of seaborne trade (UNCTAD, 2014). In addition, the liner container shipping is an ever-growing and adaptively changing industry increased rapidly in the past four decades and evolved in parallel to dynamic alterations of the international trade volume.

Increasing human needs drive the increase of the demand for high product variety. A large number of the product variety and complexity of the product supply chains increased the importance of the outcomes of liner container shipping activities. The liner container shipping is a significant element in the physical flow of various raw materials, and semi-finished and finished products via utilisation of the international trade infrastructure, including shipping lines and ports globally. Evidently, adaptive improvements of the liner container shipping have a big influence on further developments in business and technology of the international trade in the globalisation era. The rapid increase of the liner container shipping in comparison to other shipping sectors is attributed to various underlying factors. The main underlying factors are competitive cost, wide service network coverage, reliable sailing schedule, low transit time, capability to safely load different industrial products on board the same ship, intermodal connections, flexibility of shipment volume including LCL (Less than a Container Load) cargo, and development of customer oriented services (Rodrigue, 2013). All these factors are directly linked to the operational indicators and consequences of the liner container shipping service strategic decision-making processes.

The capacity deployment via optimal ship size selection is a critical decision-making process in order to provide viability of the liner container shipping services. In addition, port competitiveness from shipping liners, hinterland and inter-port perspectives contains various underlying selection criteria, and the holistic port competitiveness level is an important indicator for investment and operational planning decisions, in order to improve competitiveness. Another competition platform emerged in the liner container shipping, beside the shipping liner and the port terminal competition, is the bunkering supply competition with the increasing significance of sustainable shipping. From the perspective of the bunker suppliers, it is very significant to understand requirements of the industry and the direction of business transformation for the upcoming bunkering needs. Therefore, bunker suppliers could focus on satisfying the operational requirements of the shipping liners. This strategic managerial approach will also increase the competitiveness level of the bunker suppliers against competitors and provide robustness in the market in order to be viable. Other competition platforms of the logistics, supply chain, and value chain activities are excluded from this study due to the narrow focus on the liner container shipping system. In addition, competition platforms of the waterway transport infrastructural systems such as different geographical shipping routes and canal authorities are excluded as well as ship technology and maintenance supplier companies' competition.

1.2. Research Motivation

Currently, for many global investors, the container shipping is a vital part of the global supply chain system for industrial products. Hence, from industrial customers' perspective, it is very desirable to obtain a direct container liner service accessibility, adequate space availability, sufficient service frequency, reliable delivery time, and obviously competitive freight rates from the carriers (Merk and Notteboom, 2015). Thus, industrial customers show strong interest on the liner shipping services and freight rates. Therefore, in order to better comprehend this relationship, hierarchically, liner container shipping (LCS) may be considered as the main component of a logistic chain (LC). Cargo handling, intermodal transport, storage and warehouse services, custom operations, transport insurance etc. are all components of the logistics chain. Supply chain (SC) includes the manufacturing inventory management strategies and the procurement processes as well as the logistic chain. Value chain (VC) is the macro structure of the complex system spiral of production that includes marketing of product, design of its upgrades and research and development activities on the product and the process enhancements in addition to Supply Chain (SC). As a result of that fact, operational performance and competitiveness of the liner container shipping has a direct influence on the costs of products and their supply on the global markets. The following figure indicates spiral of systems hierarchy for the liner container shipping focusing its vertical integration to the value chain systems of the global trade actors.

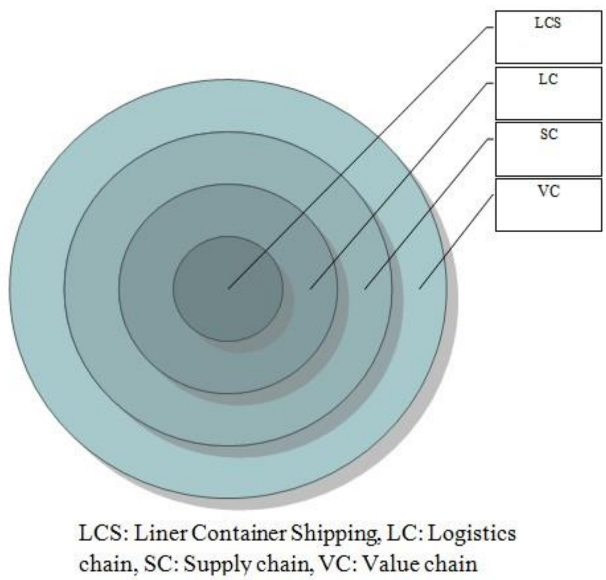


Figure 1.1: Hierarchical relationship spiral of the liner container shipping (Source: Own work)

Business competition is a popular subject attracting the interest of researchers, and many qualitative and quantitative research papers have been published on the competition dynamics and competition analysis. The competition analysis is directly related to decision-making rational of the managerial units. The decision makers of the business organisations aim to develop various tactical, operational, or strategic plans to gain competitive advantage. Especially, tactical planning or decision-making rational by consideration of the competitors' market position to maximise competition outcomes is a trend area for researchers. In the case of liner container shipping management, the requirement for the development of tactical competitive decisions by considering possible behaviours of the competitors is even more vital than many other aspects due to its unique market dynamics and characteristics. The liner container shipping market is a semi-closed shipping system where high entry barriers exist especially for the deep sea liner container shipping market. Therefore, market concentration is relatively high where there are only around 20 shipping liners generating an oligopoly (Sys, 2010).

One of the main obstacles in the liner container shipping industry is the regulatory enforcement of the International Maritime organisation (IMO). The energy efficiency, emission, and sustainability regulations of IMO require significant effort and investment of the shipping liners in order to reduce greenhouse gas (GHG) emissions, save energy, and contribute to marine sustainability. Another obstacle that the industry faces is the capacity oversupply due to enlargement of the ship size which also causes operational problems for the ports such as draft, handling and port traffic. In addition, instability of bunker prices drives the innovation requirements for energy efficiency of existing systems and available bunkering sources. Due to the capacity oversupply, freight rates in low levels and threatens the financial stability of the liner shipping companies. All these obstacles have a huge influence on the liner shipping competition outcomes and competitiveness level of the liner shipping counterparties. Therefore, there is a growing research interest for the development of alternative decision-making concepts for liner container shipping counterparties in order to tackle these obstacles.

This research mainly benefits the research focus for examining the competitiveness of the shipping liners, container port terminals, and bunker suppliers in the light of the recent developments and challenges emerged in the liner container shipping system. This thesis includes the following motivations in order to make a research effort on the liner container shipping competition analysis:

- Requirements for practically applicable logico-mathematical modelling concepts in order to analyse the competition dynamics of liner container shipping
- Complex decision-making issues of the current managerial bottlenecks
- Uncertainties about the influences of upcoming business trends on the liner container shipping competition

- Integration of shipping business economics with decision-making models
- Research trend, narrowly focusing on the shipping liners, port operators, and bunker suppliers
- Requirement for innovative ideas on decision-making process of the liner container shipping industry

1.3. Problem Definition

In order to define the problem covered in this thesis, actual business trends of the liner container shipping industry are examined and managerial decision-making concerns of the liner container shipping counterparties are investigated. As a result of this investigation, the deficiency of capacity investment planning practices for the tactical decision-making rationales is determined. This deficiency includes interoperability of the financial management of the liner container shipping operational outcomes and possible future market impacts of the capacity investment related decision-makings under perfect competition conditions. In addition, the capacity investment decisionmaking process contains various market wide consequences according to each competitor decision-maker's strategy choice. There is a clear requirement of the industry to strategic capacity investment decision-makings by considering decisional behaviours of the competitors. Therefore, the research effort of this thesis is mostly focused on answering a realistic logico-mathematical competition analysis tool requirement of the industry by applying an innovative and systematically well-developed analysis method.

In this study, academic literature is also well reviewed and research gaps of the issue mentioned in previous paragraph are identified. The outlines of this research are shaped based on filling the research gaps of the existing tactical decision-making rationale knowledge in the literature. Game theoretical methodologies are widely applied on the competition cases of the various industries as well as some shipping industry cases in the literature and various game theoretical approaches are utilised. Therefore, the primarily methodological approach of this study focuses on generating an innovative game theoretical competition analysis model which establish a new concept for the liner container shipping research field. In order to contribute to the existing literature, an innovative game theory basis methodology is developed and integration of this methodology, with other decision-making models, is provided by three carried out case studies.

First of all, this thesis assumes the deep sea liner container shipping competition as an oligopolistic/multiplayer game where heterogeneous players, with different market shares, compete with both complete and incomplete information and market awareness, and fixed price in terms of the economy theory. Moreover, the research framework structured in this study mainly investigates the liner container shipping competition tactical behaviours quantitatively, and utilises mathematical integration of the determined tactical methods to strategic and operational behaviour methods. Furthermore, this research includes impacts of the asymmetry of players. This competition form will expose the significance of the market information of the players and their adaptive responses to market changes based on their self-organisation.

In this thesis, the liner container shipping market competition platforms are adapted to a four player oligopoly. This approach refers to the recent developments in the liner container shipping market. The four fully competing non-cooperative players' market structure arose in the shipping liner alliance competition. Furthermore, game form of four players is a good indicator for the analysis of the high-level non-cooperative behaviours in the market competition platforms. These platforms are identified as shipping alliance competition, port terminal operator competition and bunker supplier competition. Due to the narrow focus of this thesis analysis, only of the liner container shipping will take place, the other competition platforms of the logistics chain and the supply chain are excluded, as shown on the following figure with their titles.

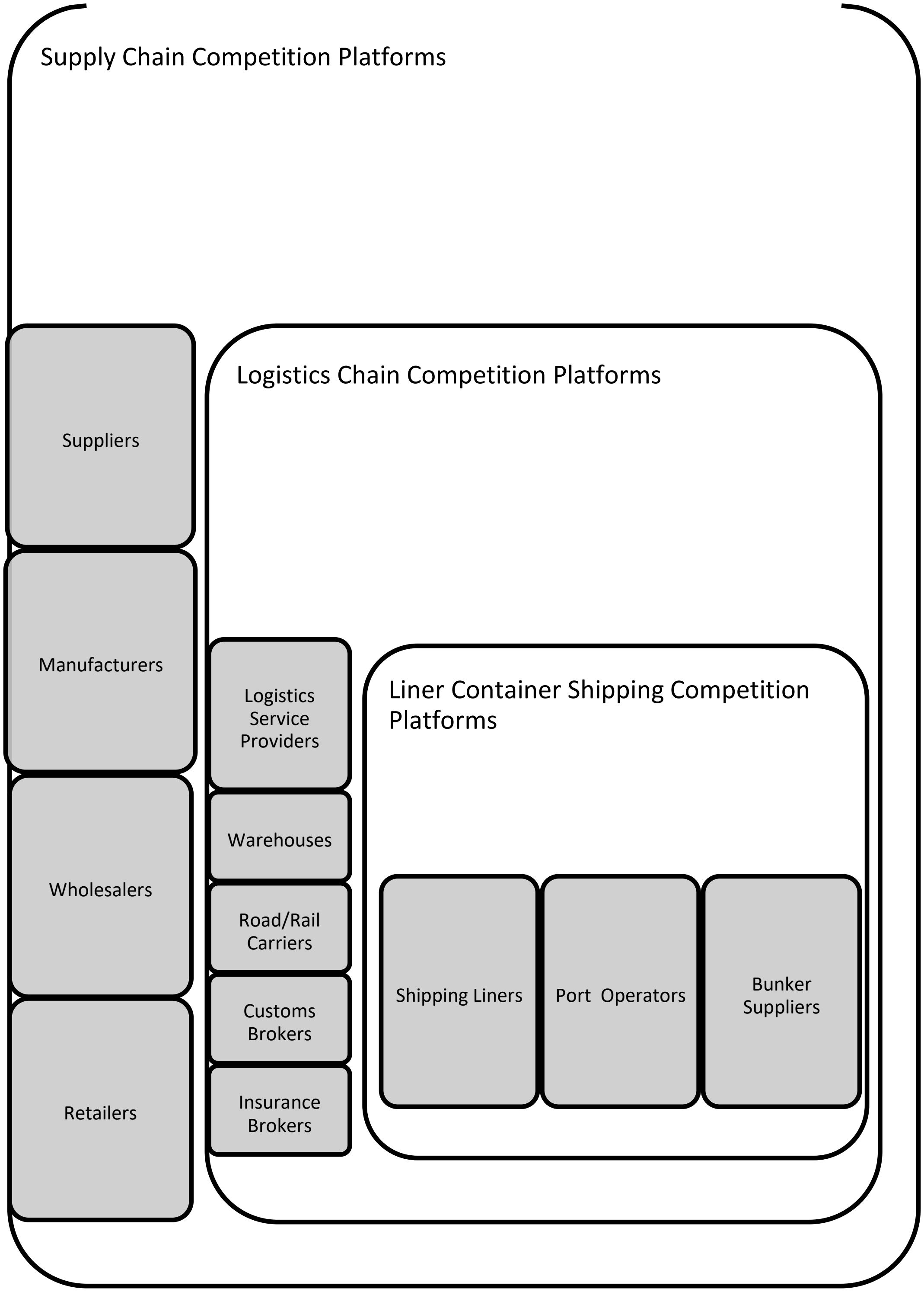


Figure 1.2: Major competition platforms in supply chain (Source: Own work)

1.4. Aims and Objectives

This study is a scientific research attempt to generate a novel game theoretical competition analysis method by the integration of different non-cooperative game theory approaches and shipping business economics in order to apply to actual managerial cases of the liner container shipping decision-making practices. The knowledge built up in this thesis is expected to provide guidance to liner container shipping market players in order to overcome the competition challenges of the upcoming business trends. The aims of the study are determined in order to meet the new knowledge requirements of the industrial practices by enhancing the available theoretical knowledge. The first aim of the study is the establishment of a theoretical framework of the liner container shipping competition reflecting the practical actuality of the market competition mathematically. The second aim of the study is to offer an innovative decision-support tool, which satisfies decision-making issues of different branches of the industry in a perfect competition environment. The third aim of the study is to apply this innovative decision-support rationale to one of the trend managerial challenges, which is identified as capacity deployment-investment problem, of the liner container shipping industry and to validate its applicability in practice. The final aim of the study is to generate a new concept of competition analysis approach in order to provide leading direction for future research.

The objectives of this thesis are determined to clarify the steps taken to reach to the previously given research aims. In this determination, game theoretical competition analysis is applied on the different liner container shipping competition platforms. In addition, system approach, multi-criteria decision making, and shipping company economics methods are planned to utilise in order to strengthen the practical application of the game theoretical analysis. Therefore, complex mathematical calculation steps via utilisation of aforementioned methods are planned to be integrated in a holistic research framework. It is possible to divide the research objectives according to previously mentioned three competition platforms of the liner container shipping. Therefore, the research steps of the study are planned to achieve different objectives of each competition platform. The following actions are taken to achieve in this study in order to satisfy the research aims and competition platform based research process:

- A systematic statistical analysis of the shipping liner market share is developed by assuming the liner shipping competition as a “tight oligopoly” where the total market share of a small number of industrial players is very high. Following the market share analysis, comparative cash flow analysis of the shipping liner alliances is generated. Therefore, a comparison of the financial performance of the alliances is obtained. In addition, by employing the game theoretical methodology, capacity investment decision-making of the shipping liner alliances are analysed.

- The port competition is not only considered from only one perspective but also it is taken into account from multiple points of view. A holistic port competition analysis integrating the perspectives of the shipping liner’s port selection, hinterland’s port selection and inter-port competition by application of the methodology of the research is performed in this study.
- A detailed system approach framework of the LNG bunker as a deep sea container shipping fuel including its challenges and opportunities, inputs and outputs are generated. Furthermore, a multi-objective LNG bunkering supplier choice model framework of the shipping liners is established. Therefore, the competition dynamics of the LNG bunkering supply is revealed. Finally, the game theoretical competition analysis methodology is applied on a futuristic scenario based on the capacity investment decision-making of the LNG bunker suppliers.

The hierarchical relationships of the objectives mentioned above, as a part of main framework, are shown in figure 1.3.

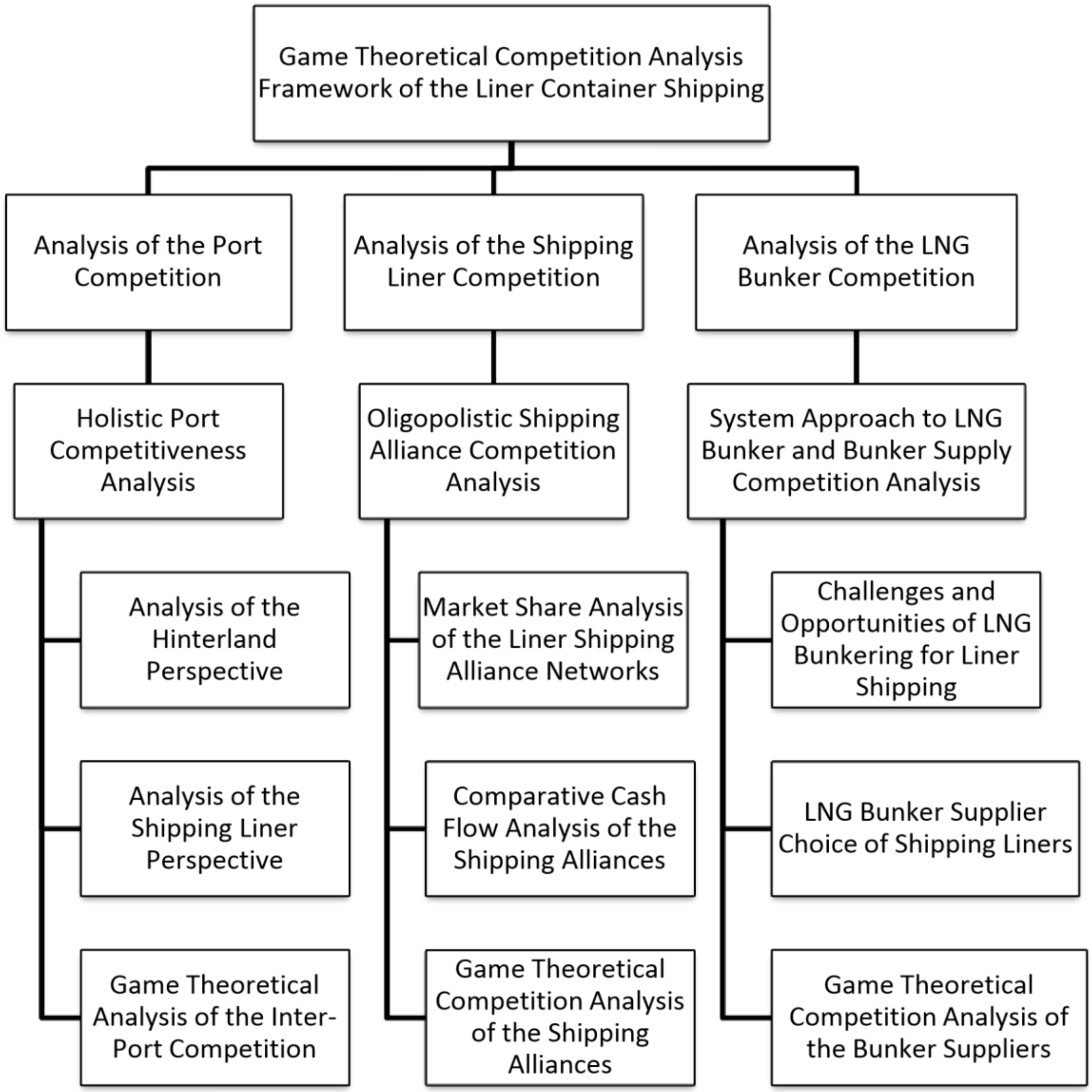


Figure 1.3: Main objectives of the study (Source: Own work)

1.5. Contribution to the Field of the Study

In the last decade, a significant amount of research has been published about the application of the game theory method on the liner shipping managerial decision-making issues. Each attempt aimed to contribute to the existing literature knowledge with different game theoretical approaches and conceptual game cases. While this thesis is contributing to the existing literature with a new methodological approach and scientific knowledge, it also generates a decision-making concept that has high practical applicability. The major contributions of this thesis may be summarised as the following statements:

- Competition platforms in global supply chains are explained in depth and the significance of the liner container shipping industry competition analysis research is emphasised.
- An original system engineering perspective is applied to the liner container shipping. Viable system structure, dynamic system characteristics and adaptation of the liner container shipping system on emerging trends in its system environment are well explained by the integration of different system theories including Viable Systems Model (VSM), Complex Adaptive Systems (CAS) and Holarchical System View (HSV) of the liner container shipping operations.
- The emerged competition challenges of the liner container shipping are identified realistically and future adaptation stages of the liner container shipping system are clarified.
- A non-cooperative four-player game theory methodology based on the Cournot – Nash oligopoly game model, for the first time, is applied to the selected liner container shipping trend cases by assuming all players as rational.
- Asymmetry and heterogeneous structure of the players are included as well as complete and incomplete information cases. The results of the study also illustrate Bayesian Nash equilibrium points of the games as well as Nash equilibrium points for all given case scenarios.

- Economic consequences, operational stability, and network coverage of the recent strategic shipping alliances are illustrated and tactical behaviours of the alliances are examined.
- The different port choice perspectives of port operators are integrated within the methodology of the thesis in order to generate a holistic port competition performance indicator, which is new knowledge for the existing literature.
- Challenges and opportunities of the LNG bunkering for the liner container shipping industry are determined. The LNG as a deep sea liner container shipping is analysed with a system approach. A decision-making framework of the ship

operators regarding to optimal bunkering point selection, by applying multi objective optimisation method, is generated.

- A game theoretical LNG bunkering supply game is developed to support the development of the profit maximisation requirements of the investment plans.

1.6. Structure of the Thesis

The content of the study covers and discusses various practical and managerial issues regarding the liner container shipping management. The framework of this thesis includes the competitive strategy identification in the liner shipping competition, the tactical strategy determination to deal with the competition challenges of liner shipping, and a holistic overview of port competition, and LNG bunkering supply business. The thesis is structured in ten chapters which deliver all required information of the research in a systematic way.

Chapter 1 provides an overview of the study, scope of the research, research aims and objectives, as well as a contribution summary of the research.

The second chapter includes existing literature and the current situation of the liner container shipping industry. A brief history of the liner container shipping is given.

Competitiveness and competitive strategy from the literature of the liner container shipping is reviewed. The current situations of the market, and competition challenges as well as competitive trends are discussed. The existing competition analysis methodologies and their applications to the industry are also introduced. Competition dynamics of shipping liners, port operators and bunker suppliers are investigated, and research gaps of the existing literature are revealed.

Chapter 3 mentions the main technical background regarding the decision-making concepts and game theory methods. It also clarifies the methodological base of the study and justifies the theoretical approach that is developed in the following chapters.

The fourth chapter explains the methodological steps including Cournot-Nash, Cournot Bayesian-Nash solution concepts, cost calculations of the liner shipping counterparties and linear programming are also explained. Furthermore, detailed formulations of the competition analysis model developed in this thesis are given.

Chapter 5 reveals the data collection sources and process of the study. It also explains confidentiality of the data as well as ethical issues regarding this thesis.

Chapter 6 includes application of the methodology on a shipping liner alliance market case study. The methodology is applied on a typical Far East-Europe liner service loop. This chapter also includes a cash flow analysis of the liner container shipping alliances.

Chapter 7 covers the application of the methodology for a port operator non-cooperative clusters case. It integrates the methodology with multi-criteria port choice models.

Chapter 8 presents the application of the methodology for bunker supplier case. This chapter also investigates adaptation of the LNG bunkering to liner container shipping. Throughout this chapter the challenges and opportunities of the LNG bunkering are holistically covered and a bunkering network optimisation method is developed as well as a future scenario based case study.

Chapter 9 reviews the research objectives. It analyses the rationale developed in the methodology and discusses the meaning of the outcomes obtained for the liner container shipping industry. It also summaries the work done in this thesis and gives a brief conclusion in combination with the limitations of the research and future research areas in the field.

2. CRITICAL REVIEW

Thus far, a very large number of previously published studies have highlighted the competition challenges and oligopolistic competition market structure of the liner container shipping counterparties. However, only a very little number of studies utilised a game theoretical approach in competition analysis, and still there is a broad research requirement for practical application of the game theory concepts. The following critical review chapter consists of eight main categories of the relevant literature and gives a detailed background about competition analysis of the liner container shipping. The first section of this chapter includes competitiveness and competitive strategy fundamentals of the liner container shipping. This category demonstrates the research milestones of the competitive advantages including resource and technology based views in the liner container shipping. In addition, this section identifies the current competitive advantage trends of the practice. The second section investigates the competition challenges in liner container shipping management based on the previous studies. The third section describes the competitive trends for liner container shipping industry with reference to existing academic and industrial publications. The fourth section includes different approaches and analysis models to measure competitiveness in liner container shipping. While the fifth section includes competition dynamics of the liner shipping service, the sixth section covers competition dynamics of container terminal management. Penultimately, the seventh section mentions the bunkering supply competition of bunker suppliers. Finally, the eighth section describes the research gaps found in the literature and draws a framework for this thesis.

2.1. History of Liner Container Shipping

The requirement for intermodal integration of different transport modes by the utilisation of standardised boxes has driven a significant growth trend of containerisation. Previous evidences in the shipping business suggested that containerisation of the general cargo trade experienced systematic evolutionary developments in the second half of the 20th century and the first quarter of the 21st century. Basically, the liner container shipping system emerged as a substantial innovation to respond to the global "door to door" transportation demand. As a result of increasing popularity of intermodal transport, the containerisation of the general cargo sector expanded tremendously. Especially around the last quarter of the 20th century, the containerisation spread worldwide and in the 2000s, it boomed and reached its peak. If we look at the developments for all ship types, ship size increased gradually in parallel to technological development in the shipbuilding industry with the rational of reducing the cost per unit transported. For instance, in tanker shipping between 1950s-1980 ship size enlarged rapidly and this trend provided up to 75% cost reduction per unit transported. Indeed, Arab-Israeli war and the closure of Suez Canal increased the significance of the ship size enlargement trend and Ultra large Crude Carrier (ULCC) ships took their place in the market (Stopford, 2009). This trend spread to other sectors of the shipping industry and continuously the ship enlargement trend has been seen in various branches of commercial shipping, including container transport.

Whether the history of the liner container shipping is researched or not, it could be recognised that the liner container shipping has been shaped according to global trade requirements since the first containers were shipped on the 26th April 1956. Initially, a run-of-the mill T-2 tanker named "Ideal X" was the first utilised ship to carry 58 containers between U.S ports. Various class ships were utilised for Malcom Mclean's Sea-Land

company until the 1970s. In the beginning of 1970s eight SL-7 (Sea-land 7) class fully cellular containerships with a 33 knot speed capacity entered the container shipping market (Cudahy, 2006). Consortia, a group of carriers sharing space on ships, in the 1970s, provided the Europe–Asia liner service. In 1972, the first container ships with approximately 3,000 TEU carrying capacities were launched by the Howaldtwerke Shipyard in Germany. In 1973, US, European and Asian containership operators were carrying 4 million TEUs all over the world. By 1983, this number reached up to 12 million TEUs (WSC, 2016). In the 1980s, different container ship designs were developed to increase maximum ship capacity for Panama Canal Passage. In 2004, the shipbuilding industry achieved sailing the first ships through the New Panama Canal after the extension project, with 10,000 TEU and over container carrying capacity. Recently, deep sea container ship size has reached up the level which cannot be included Panama Canal related ship size categories (Merk *et al.*, 2015). Currently, container boxes can serve almost all types of general cargo. Therefore, gradually, popularity of liner container shipping has been increased in the past 50 years. Especially between 1970s and 1990s the containerisation of general cargo rapidly increased, and in 2000s climbed to a new record level. An example of this is the Port of Hamburg, which today is one of the most important container hub/transhipment ports, and its development is one of the significant examples to mention about liner shipping evolution. It started its
'containerisation' back in 1967 to reach 98% in 2013 (Meisel, 2009; Port of Hamburg Marketing, 2014) as shown in figure 2.1.

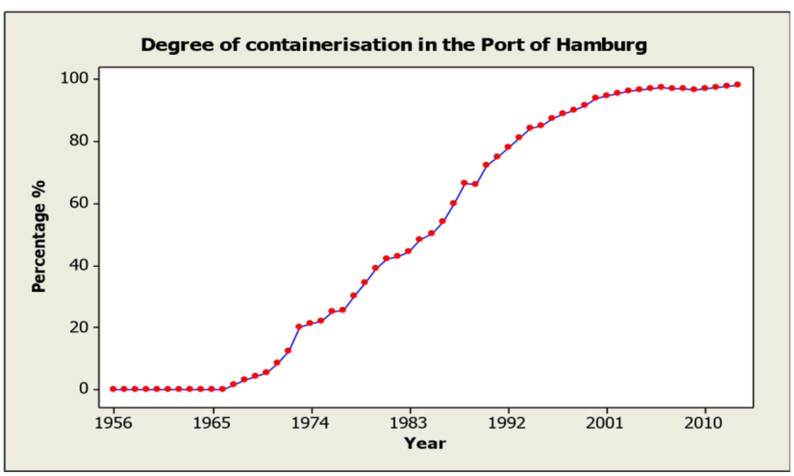


Figure 2.1: Degree of containerisation in the Port of Hamburg

(Source: Meisel, 2009; Port of Hamburg Marketing, 2014)

Currently, the ever-increasing container ship size has revealed a new unsuitable size category for Panama Canal which is ULCV (Ultra Large Container Vessel, more than 14,500 TEU) (Merk *et al.*, 2015). ULCV is a term that is frequently used in the literature, but to date there is no consensus about the exact definition of ULCV. Although the 7th generation ship design already exists on the drawing table of naval architects, it is expected that it will take some more time to see them on the liner service routes due to the current demand and operational constraints of port facilities.

Table 1.1: Evolution of container ship size

Generation	**Type**	**Year**	**Capacity (TEU)**	**LOA (m)**	**Beam (m)**	**Draft (m)**
1st	Early Containership	1956	500-800	137	17	9
2nd	Panamax	1980	3000-3400	215	20	10
3rd	Post Panamax	1988	4000-5000	290	32	12.5
4th	New Panamax	2004	12500	300	43	14.5
5th	Post New Panamax	2006	15000	366	49	15.2
6th	Malaccamax Plus	2018	20000-25000	440-450	59-61	16.5
7th	Malaccamax Future	2025	27000-30000	450-480	59-61	21

Source: Adapted from (Yip and Wong, 2015) and (Rodrigue *et al.*, 2013)

2.2. Competitiveness and Competitive Strategy

2.2.1 Competitive Advantage in Liner Container Shipping Industry

Micro level business policy-makers aim to develop robust competitive strategies to increase their organisation's adaptive capabilities under dynamic competition and to deal with the competition pressure. Michael Porter (1980) put forward the milestones of the research field of competitive strategy and competitive advantages in order to increase the market share of a company. According to a basic definition by Porter (1980) competitive strategy of a business unit is "plan for how a firm will compete, formulated after evaluating how its strengths and weaknesses compare to those of its competitors". In another study of Porter *et al.* (1996) identified the three strategies, differentiation, cost leadership, and focus, which a company can utilise in a competing market in order to get competitive advantage.

Porter (2008) also determined the five forces that shape the competitive strategy: the rivalry among existing competitors, the threat of new entrants, the bargaining power of suppliers, the bargaining power of buyers and the threat to substitute product or services. Porter's generic strategies of competitive advantage are commonly applied in liner container shipping research. However, Porter's competitive advantage perspective is widely criticised due to the assumption of the competition environment as very basic and not complex (Davies and Ellis, 2000). Therefore, it is required to consider the complexity and adaptive capability dynamics of the liner container shipping system and to include innovation, diversification, alliances, specialisation, concentration, and capacity investment focus into the generic model (Niamie and Germain, 2014). The generic competitive advantage strategies model of the liner container shipping is indicated in figure 2.2.

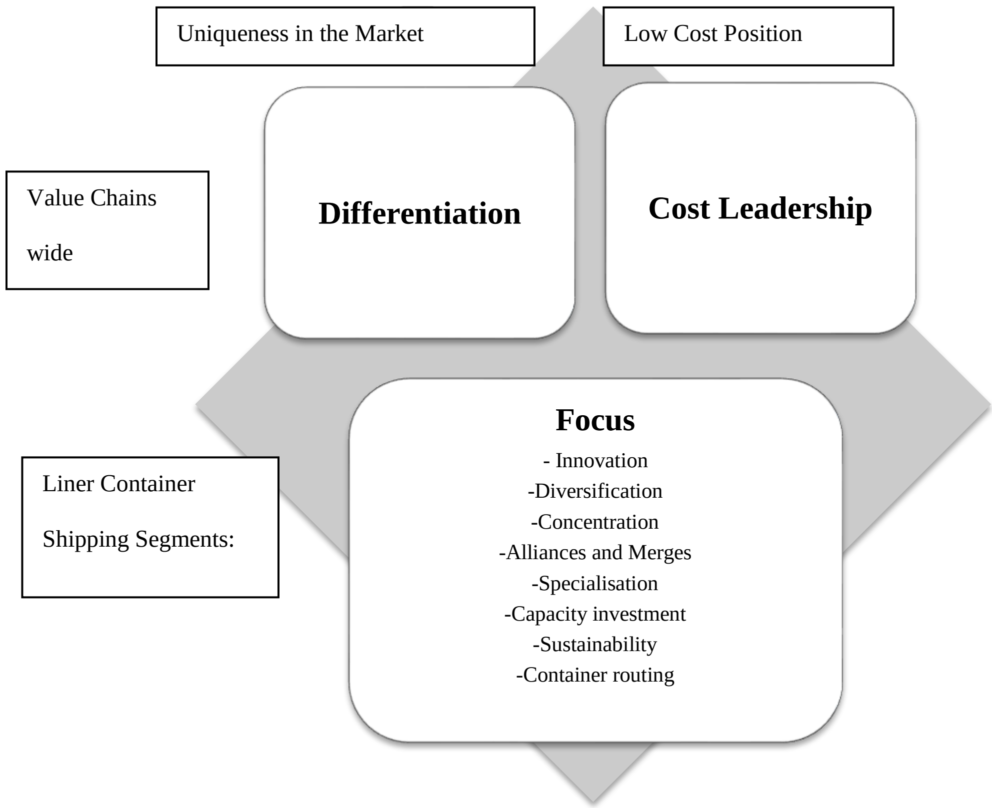


Figure 2.2: Competitive advantage focus of the liner container shipping industry
(Source: Adapted from Porter, 1980)

Holistically, Panayides and Cullinane (2002) addressed the issues of the competitive advantage in liner container shipping. They expressed that *vertical integration and logistic chain overview*, strategic alliances, merges and acquisitions, cost reduction, network connectivity, economies of scale, regulation, pricing and customer relationship were significant subcategories of the liner shipping competitive advantage. They clarified theoretical background of competitive advantage in the liner shipping industry by applying Porter's ideas and a *resource based view*. In addition, Srivastava *et al* (2001) mentioned a market based view and as Grant (1996) explained a *knowledgebased (technology) view* should be considered as other theories could be applied to the liner container shipping in order to gain competitive advantage. The literature of the competitive advantage in liner shipping industry could be summarised under these three perspectives.

The majority of the studies maintain the logistics chain overview to a competitive advantage. As an example, Wong and Karia (2010) identified strategic logistics resources of the logistics service providers (LSPs) in order to gain competitive advantage. They defined competitive advantages of the LSPs as long-term profit growth, long-term revenue growth, and length/continuity of contracts. In a shipping industry resources focused study, Progoulaki and Theotokas (2010) investigated the resource based view in shipping competitiveness. In their research they adapted the resourcebased view to human source and crew management sections of a shipping company in order to gain competitive advantage. In their case study, they examined the resource based competitiveness of Greek-owned shipping companies.

Technology is a significant factor influencing competitiveness. Greve (2009) studied diffusion of technologies that provide competitive advantages in the maritime industry. He defined the maritime industry as an international industry, with a few entry barriers and experienced companies and capital. He mostly focused on the impact of innovation on shipping competitiveness and compared the diffusion of Panamax container ships with that of double hull oil tankers. In another similar study, Poulis *et al.* (2013) compared the competitiveness of shipping companies keeping their information communication technologies in consideration. They used qualitative interviews on three different shipping companies including one traditional shipowner, one modern shipowner and one ship manager to collect related data related to their information communication requirements and outcomes.

The majority of the studies utilised a market-based view. For instance, Zhang (2014) adapted a game theory approach to supply chain management in his PhD thesis. He considered both cooperative and non-cooperative game theory and utilised a game theoretical model with asymmetry. He applied a three-person game where the supplier, retailer and consumer identified as players. In another research, Leng (2005) also used a game theory application on the Supply Chain Management (SCM) issues. He structured the market as a two-player leader-follower game under complete information where the seller is the market leader and the buyer is the follower, and found the Stackelberg Equilibrium solution of the game.

In a shipping industry focussed market based view study, Dimitriou *et al* (2007) utilised an agent-based simulation and a game theory approach in order to generate a competitive short sea passenger shipping network for Greek islands. In their model, they combined game theoretical framework with co-evolutionary genetic algorithm in order to determine optimal strategies of each competitor. In terms of liner container shipping, Yong (1996) carried out research on the competition of the deep sea shipping liners in a three-player game where players are an incumbent firm, a potential entrant and a buyer. He assumed the market information as complete. His results claimed that exclusive dealing contracts could be a significant market barrier to entry when the entrant player has a limited capacity.

2.2.2 Cost Reduction Strategies in Liner Shipping

Cost reduction is one of the main motivations behind the research of competitiveness in the liner shipping industry. The main costs of a liner shipping company are voyage costs, operational costs, capital costs, and additional costs (Gkonis and Psaraftis, 2007; Stopford, 2009). In addition, economy of scale also provides significant amount of cost reduction per unit transported. Lim (1998) studied principles of the economy of scale in liner container shipping. He highlighted the significance of bigger ship investments in order to reduce costs. However, he also emphasised the possible negative impacts of the capacity increase on freight rates with a steadily increasing demand case. According to his analysis, some situations might exist where economy of scale results in cost increases with a lack of consideration of the demand potential.

Minimisation of the costs in liner shipping industry requires a strict managerial focus on the operation, investment and resources. Especially optimisation methods are very popular approaches in order to minimise the operation cost of the liner shipping management. For instance, Yang et al (2011) investigated the stability of the shipping alliance cooperation. They determined the cost function based on the assumptions of vessel slot sharing and mega ship deployment. In a recent study, Wang et al (2015) carried out a detailed investigation on the seasonal revenue management of a shipping liner. They developed a mixed integer linear programming profit maximisation model with a convex objective function based on a tailored branch and bound method. Their numerical applications showed how the optimal solution changed the cost variations in bunker price, demand and freight rate.

In a port related study, Malchow (2001) studied competition among container ports. He applied a multinomial choice model considering correlation among the decisions made by shipping liners in order to choose ports of call. He highlighted the importance of the time and cost issues in liner container shipping and argued that the most significant factors in the selection of the shipments were the geographical factors including inland transportation distances for both export and import cases.

In the case of bunkering, Yao *et al* (2012) developed an optimisation method in order to determine the optimal ship speed, bunkering ports and inventory costs in consideration with port arrival time. The objective of their study was to minimise the costs for a liner service loop. They enhanced their model by including the revenue loss due to the amount of bunker inventory taken to the ship. In a recent study, Sheng *et al* (2014) developed an objective function of the minimum total cost of bunkering for liner container shipping. In their model, they considered different bunkering prices of the different bunker suppliers and significance of the bunker inventory for shipping liners.

2.2.3 Differentiation Strategies in Liner Shipping

Differentiation is a key factor influencing the liner shipping market in order to gain competitive advantage against other shipping liners and container port services. For shipping liners, container port terminals, and bunker suppliers different strategies applies in order to establish differentiation. Different strategies are applied to shipping liners, container port terminals and bunker suppliers in order to establish differentiation. Based on combining the studies of (Bektas and Crainic, 2007; Notteboom and Rodrigue, 2009) the differentiation factors of a shipping liners are categorised below;

- Low transit time
- Direct service line connection
- Ports of call network
- Reliability of schedule
- Available slot capacity
- Efficient intermodal integrations
- Ocean freight stability

- Value added logistics services
- Good customer relations and marketing activities
- Cargo-specific services
- Performance of the selected ports of call
- Technology

In addition to above factors, Zhang and Lam (2015) analysed the impact of liner shipping sailing schedule with high frequency for shippers and consignees. Their numerical analysis indicated that high liner shipping frequency is very significant for the products that have high value density, high inventory cost, low demand variability and a high service level requirement. The study was in favour of the shipping alliance ideology based on increasing the liner shipping port call frequency on a certain liner service loop and creating differentiation.

Some innovative ideas were also applied on the differentiation strategies of the liner container shipping. Acciaro (2011) proposed a liner container shipping service differential model based on advance booking. His model included different pricing for loyal customers and integrated logistic service provider's customer relations strategies to the shipping liners. In a recent study Linstad *et al* (2015) suggested that shipping liners could provide two different kinds of liner services in order to satisfy different customer requirements on the same liner service loop: one fast and one relatively slow service in terms of transit time. Their approach suggested that while a fast service with higher price would be more competitive against airfreight and fast moving goods, the slow service would be more competitive against traditional general cargo and minor bulk trade.

2.2.4 Focus Strategies in Liner Shipping

Focus strategies leads liner container shipping industry counterparties to concentrate on innovative and case-based solutions for the narrow branch of the operations in order to support differentiation and cost leadership ideology. There is an unambiguous relationship between sustainability and strategic focus of the liner shipping industry at present. Magni (2014) identified sustainability as a strategic tool in liner shipping. He emphasised that the investment focus of the shipping liners to increase sustainability creates a significant amount of cost advantage and firm differentiation in addition to be compatible with the environmental regulations. On the other hand, Mason and Nair (2013) investigated the strategic flexibility capabilities in the liner container shipping by applying the UDSO (understand, document, simplify, optimise) methodology. Their study aimed to provide a strategic flexibility focus tool which could be utilised in flexibility tactics of the shipping liners in order to balance demand and vessel carrying capacity supply. AlixPartners (2015) determined two focus trends in the liner container shipping industry as focus on core business activities, and focus on customer and service profitability. In a recent study, Xia *et al.* (2015) developed a holistic operational focusing model addressing the speed optimisation, fleet deployment and cargo allocation so that the profit maximisation would be possible. They considered that the fuel consumption depends on the speed and container carried. They applied a mixed integer liner programming approach and utilised iterative search algorithm, which was generated based on the column generation heuristics technique (Joncour *et al.*, 2010).

2.2.5 Competitive Strategies for Shipping Liners

The structural design of shipping alliances and the strategies of alliance partners have been attracting a lot of research interest for many years and there are still many professionals and academic researchers who analyse these alliances and their interrelationships. Sys *et al.* (2008) investigated the influences of the ship size enlargement on liner container shipping operations. Slack *et al.* (2002) examined the evolution of the shipping alliances and analysed their operational consequences. Midoro and Pitto (2000) have also researched the evolution of liner shipping alliances and they pointed out the reasons of instability in the shipping alliances are mainly from an organisational complexity perspective. Sys (2009) studied the oligopoly market structure in the containership market. She mainly focused on the degree of concentration in the shipping alliances. According to her findings, the container liner shipping industry could be considered as a tight oligopoly with a degree of concentration depending on the line service route. Yang *et al*. (2011) applied a core theory to analyse the stability of the shipping alliances, investigating mostly the effect of ship size trends on the robustness of shipping alliances. Lu *et al.* (2006) applied the Delphi method to investigate the CYHK shipping alliance and to comprehend the underlying factors in shipping alliances. Ryoo and Thanopoulou (1999) analysed the strategic shipping alliances and they categorised the strategic co-operation in liner container shipping as contract agreements (Slot charter) and operational agreement (including joint service, pooling agreement, consortium, joint venture and strategic alliances). Das (2011) published a longitudinal (over an extended time) study on shipping alliances. According to the outcomes of this research, shipping liners prefer partners from their home region and partners without prior partnership experience. Also synergy and market uncertainty are other key drivers in the selection of partners. In addition to these basic studies, a variety of academic research has been published, in the 2000's, on the application of the game theoretical analysis to liner shipping service transport network and the stability of strategic shipping alliances. Fisk (1984) applied Nash non-cooperative and Stackelberg game theory models for system modelling of some practical transport problems, including the carrier competition for passenger travel. Song and Panayides (2002) developed a conceptual framework for application of cooperative game theory on liner shipping alliances to indicate cooperation pay offs among shipping alliance members. Shi and Voss (2011) provided a survey on game theoretical approaches within the shipping industry. Agarwal and Ergun (2010) applied mathematical programming and game theory to address tactical problems such as liner container shipping network design mechanism. Panayides and Wiedmer (2011) studied three big alliances in deep sea liner container shipping and compared them to each other. Ding and Liang (2005) focused on the partner selection for shipping alliances. They used fuzzy MCDA methodology to assist the partner selection process. Gkonis and Psaraftis (2009) applied game theoretical modelling to analyse oligopoly in LNG shipping market. They used a combination of Cournot, Stackelberg game theories and Nash's best response function.

As a holistic overview, Baird (2000) investigated strategic management principles of the liner container shipping industry in detail in his PhD thesis. In his study, he gathered raw data from face-to-face interviews with the decision makers of the industry and attempted to draw a framework of strategic decision-making concepts and strategies that provides competitive advantage to liner shipping counterparties. He identified the strategic choices in liner shipping management holistically under the two titles- asset related strategies and operation related strategies. He identified the asset related choices of the deep sea shipping liners as building ship, owning ship, leasing ship, chartering ship, second-hand ship buying/selling, vessel slot sharing, contact management of ship, and flag out option. For global carrier's feeder ships that are connected to the deep sea shipping services, he added choices of being part owner of a ship, being common-user of a ship and wayporting (cargo flow between regional markets) while he excluded choices of the vessel slot-sharing and the second-hand ship buying/selling. He also mentioned that carriers might build, own and lease container boxes, and might include inland transport services as well as value added logistic services and port terminal operating business. Although his thesis established a good strategic decision-making concept for the shipping liners, his research did not cover strategic decision collision between different liner shipping managements.

2.2.6 Competitive Strategies for Container Ports

Container port terminals are interface gateways of the container shipping operations due to their significant node functions of enabling intermodal connection and serving operational and maintenance requirements of the container vessels (Rodrigue and Notteboom, 2006). From a wider perspective of the global trade, the container port terminals are also connected to each other's ports via direct and feeder service transport networks of the container shipping fleet. The container terminal operations provide a physical concept of connection between ships and inland warehouses of exporter or importer via intermodal transport. Briefly, operational sections of container terminals may be categorised in four main pillars: ship-to-shore area, container transfer area, storage area and delivery/receipt area (Henesey, 2006). The ship-to-shore area is a port terminal section where gantry cranes are located and loading-unloading operation is performed and the port is interfaced with the ship. The transfer area is demonstrated just behind the ship-to-shore area in order to store the containers temporarily. The storage area is the area where containers are stowed and wait for clerical procedures to be complete, or where the ship gets ready for loading. The delivery/receipt area is the port interface with land-rail transportation modes. The efficiency of the container terminal operations is a significant indicator for the competitiveness. The following figure illustrates the holistic view of the container export-import terminal operations.

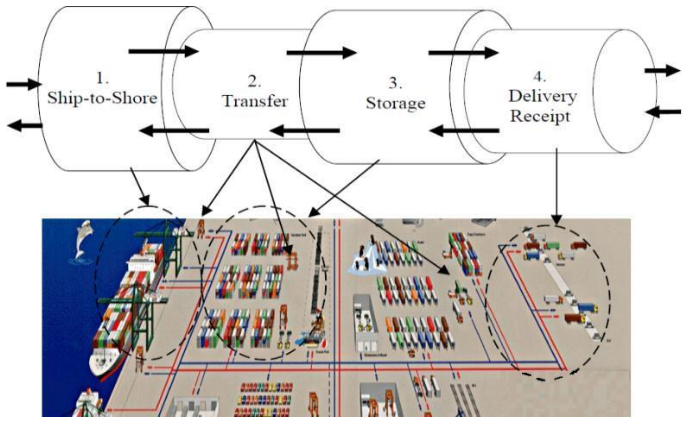


Figure 2.3: A holistic view to container terminal operations (Source: Henesey, 2006)

The container port terminal operators have experienced significant challenges in the recent years such as ship size enlargement, bunkering source switch, increasing port competition, and financial management problems (Brooks *et al.*, 2014). Especially, tough competition conditions forced the terminal operators to act more customer-centric and to develop more competitive strategies. In competitive container terminal management strategies, high quality of port services supplied to shipping liners are desired to provide viability of reliable liner shipping service. On the other hand, customer satisfaction is another significant indication about the competitiveness level for the container port terminal operators (Saeidi *et al.*, 2013). It is obvious that competitiveness of a container port terminal in a shared hinterland is dependent on multiple factors including location, price/cost, service speed/time, service variety/quality, and foreland network connection (Ducruet and Notteboom, 2012). However, the competitiveness level of the container port terminals may not only be measured with hinterland perspective but also should be considered more holistically to include shipping liner perspective and inter-port competition dynamics. Shao (2012) researched the cooperative and non-cooperative competition between Shanghai and Ningbo container ports and applied a two-player game theory model to this issue. His findings revealed that intra-competition between port terminals might turn to cooperation where a win-win situation exists for both competitors and they both gain competitive advantage from each other's strengths.

Trandafir (2009) employed a non-cooperative game theory methodology to research price and investment based competition of the container port industry in her PhD thesis. She analysed three different scenarios: a static scenario which ports compete based on price without any investment, a static scenario which ports compete with both pricing and investment adjustment decisions, and a dynamic scenario which consider a construction lag. Her results suggested that the port operators might make significant investment decisions and price reduction in order to protect market share.

2.3. Competition Challenges in Liner Container Shipping Management

2.3.1 Environmental Regulations

IMO regulations and national-international environmental policies enforce the liner shipping counterparties to take some action against environmental pollution. All these regulations take place based on the MARPOL convention of the IMO. The MARPOL convention addresses marine environment pollution prevention, air pollution and GHG, pollution preparedness and response, ballast water management, bio-fouling, antifouling systems, ship recycling and energy efficiency (IMO, 2016). In recent years, significance of the air pollution and GHG emissions, and ballast water management have increased rapidly. Recently, the global SO_x emission limit has been reduced to 3.5% worldwide and 0.1% in ECAs (Emission Control Areas). On the other hand, NO_x Tier III has been applied to new buildings. Furthermore, EEDI (Energy Efficiency Design Index, and SEEMP (Ship Energy Efficiency Management Plan) became mandatory in developed countries (Helfre and Couto, 2013).

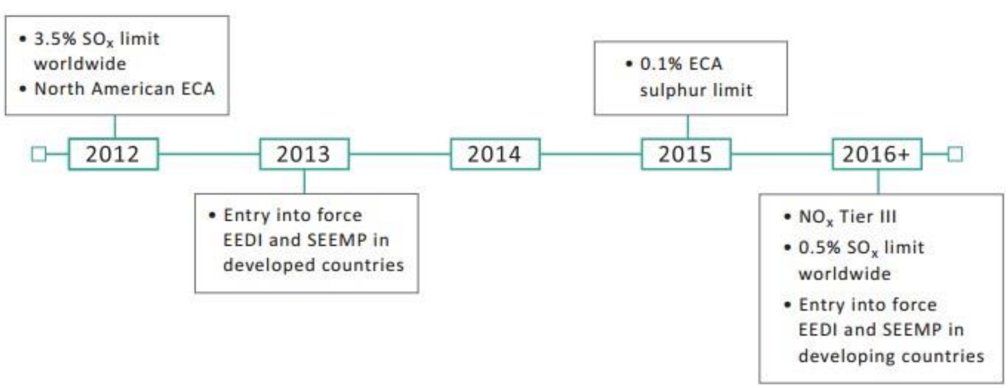


Figure 2.4: Recent regulative enforcements of the IMO (Source: Helfre and Couto, 2013)

Regarding the near future of regulative enforcement, the global sulphur emission limit will be reduced to 0.5 %, recycling convention will entry into force and ballast water treatment systems will be mandatory for all ships in 2020. However, due to the targets having a lack of practical applicability; it is argued whether they might be delayed for a few years (DNV GL, 2014). The following figure illustrates the upcoming IMO regulations for the near future.

Figure 2.5: Upcoming regulative enforcements of the IMO (Source: DNV GL, 2015)

A considerable amount of academic literature has been published in order to develop sustainable liner shipping management strategies to comply with the environmental regulations. As an example from recent studies, Lirn *et al* (2014) identified the green shipping management capability of a liner shipping company based on survey data. Their results proved that policy-making is significant in order to have sustainable liner shipping. In addition, their research suggested that greener suppliers, green policies and ships with green technologies would contribute to environmental performance of the shipping liners. Especially, the issue of the GHG and non-GHG emissions sourced from international shipping occupies a significant place in the literature. In a recent study, Dulebenets *et al.* (2015) considered impacts of the emission constraints on the sustainable vessel scheduling problem of the liner container shipping. They developed a mixed integer non-linear optimisation model in order to minimise total route cost. Their total route costs consist of operating cost, bunker cost, port handling cost, delayed arrival penalty cost, inventory cost. They included CO_2, SO_2, and NO_x emissions in constraint sets. In another study, Yin *et al.*

(2014) investigated both economic and environmental impacts of the slow steaming decisions in liner container shipping. They pointed out that capacity oversupply, bunker prices, and environmental regulations were provoking slow steaming practices in the liner container shipping industry. They developed a cost model to express influence of slow steaming on revenue and applied to the Far East- Northern Europe liner service loop. Their results indicated that the optimal speed was correlated with design speed of the ship, bunker price and emission. Sampson *et al* (2015) investigated actual implementation of the air emission regulations in the Baltic and North Sea ECA. They described the difficulties in implementation and suggested improvement for the bunker test process.

2.3.2 Fleet Capacity Oversupply

In the liner container shipping industry, it is aimed to provide reliable, fast, safe, competitive, standardised and a modally integrated way of cargo transportation with a maximum consideration of the customer satisfaction (Nasir, 2014). The increase of the fuel prices, the environmental regulative enforcements, and the fluctuation of the freight rates directed container shipping liners to order larger ships. Larger ships create economies of scale, increase the operational efficiency and decrease the harmful emissions per TEU. Yip *et al* (2012) examined the empirical data of liner shipping capacity enlargement gained from the period of 1997-2008, by employing an S-curve statistical method, in order to investigate the relationship between ship capacity and shipping liner company performance. They validated the scale and shape parameters of the S-curve model with the empirical data, and they found that the shape parameter was linked to the liner container shipping demand and the scale parameter was linked to the cost of the liner container shipping service.

On the other hand, the increasing number of larger ships means more operational barriers (especially for ports and narrow waterways) and overcapacity supply to the market. Kuo and Luo (2015) investigated overcapacity supply and developed a twoplayer game theory model to analyse the outcomes of uncoordinated optimal ship capacity investment strategies under perfect competition. They assumed a liner service competition between two shipping liners operating their ships between two ports. In their research, they found that the prisoner's dilemma exists whenever the capacity investment was in favour of the shipping liners. On the other hand, their results suggested that the ship capacity investment has higher benefits with reduction of the bunker consumption and increase of the energy efficiency. In another study, Styhre (2010) studied the capacity utilisation in feeder container vessels. She found that frequency, trade imbalances and demand variations, types of customers and cargo, and competitive situation have an influence on vessel capacity utilisation.

The new generation of shipping alliances has been shaped based on the concept of efficient capacity utilisation by the enlargement of the fleet. Ship capacity sharing, service network and schedule design, and operational experience transfer are the main benefits of shipping alliances. Abito and Miguel (2005) grouped the literature on liner shipping on two fields: stability of the alliances and capacity based competition of the shipping liners. He modelled excess capacity in the liner shipping alliances with noncooperative two player game theory. He assumed price as equal to cost per container slot in his model. He emphasised that an agreement without explicit control on the investment would cause capacity oversupply and less cost efficiency.

The strategic behaviours of the shipping alliances and their members are essential to comprehend the market dynamics in the marine container transport system. The outcomes have a huge effect on the smaller container shipping liners but also to the industrial customers. Tezuka and Ishii (2015) demonstrated a non-cooperative game theoretic model of two players in order to explain shipowner behaviour and freight rate relationship. They found a unique Nash Equilibrium in asymmetric duopoly market with capacity constraint existence.

2.3.3 Bunker Price Instability

Bunkering expense is very significant operational cost of the container shipping. As a literature milestone, Buxton (1985) defined the mathematical link among ship fuel and OPEX (Operational Expenditure) and CAPEX (Capital Expenditure) of ship management. According to his study the fuel cost of a container ship represents more than half of the ship operation cost and around 15% of overall annual expenses of a shipping liner. The high oil product prices in recent years and instability of the bunker prices have forced the shipping liners to develop robust bunker management strategies including slow steaming, optimum bunkering point selection and energy efficient operational solutions (Huang and Yoshida, 2013). The price comparisons of the bunker sources based on the Rotterdam product prices data of the BP are given as following.

Figure 2.6: Comparisons of the Rotterdam product prices (Source: BP, 2015)

Research by Notteboom & Vernimmen (2009) has a significant place in the literature regarding the impacts of bunker costs on the liner container shipping service network design. They correlated the optimal ship speed decision with the number of sister vessels deployed on the service and aimed to minimise the transportation costs per unit carried. In a different study, Wang *et al.* (2013) demonstrated a hybrid Fuzzy-Delphi-TOPSIS multi-criteria decision model by utilisation of survey questionnaires in order to apply to bunkering point choice problem of the shipping liners. Tran and Haasis (2013) investigated academic literature of network optimisation including bunkering networks for shipping liners. They determined that the strategic bunker management is one of the critical decision rationales of the fleet and liner shipping service network planning. The study of Yao *et al.* (2012) identified fundamentals of the bunkering management in liner container shipping industry. They found that the strategic bunker management of the liner container shipping consists of three vital decision elements: bunkering point selection decision, determination of the bunker purchasing amount from each bunkering points, and the optimal ship speed decision. In a more recent study, Sheng *et al.* (2014) attempted to determine the optimal ship speed by considering strategic bunkering management planning for single container vessels utilised on a liner service loop under stochastic environment. They also considered the inventory cost of bunker in their model.

Nowadays, the bunker prices reduced to a very low level due to the increasing production of oil and oil products. Although this situation would seem to favour the shipping liners for short time, the instability of the prices and speculative structure of the oil market increases the motivation for alternative shipping fuel sources.

2.3.4 Insufficient Freight Rates

The emission regulations and high bunker prices are dominated by the ideology of the ship size enlargement. However, while the increasing number of large ships in the operation was providing cost efficiency per container transported, it also caused significant amount of overcapacity supply in the liner container shipping market (Merk *et al.*, 2015). Even if various strategic shipping alliances were established in order to increase capacity utilisation rate, freight losses in the liner container shipping market reached the lowest record levels due to the 2008 Mortgage system and 2012 Eurozone crisis, and increasing oil production. Also it is expected that potential future container demand is going to be structurally reduced (Danish Ship Finance, 2015). The following figure indicates the China- Europe freight rates of the last five years.

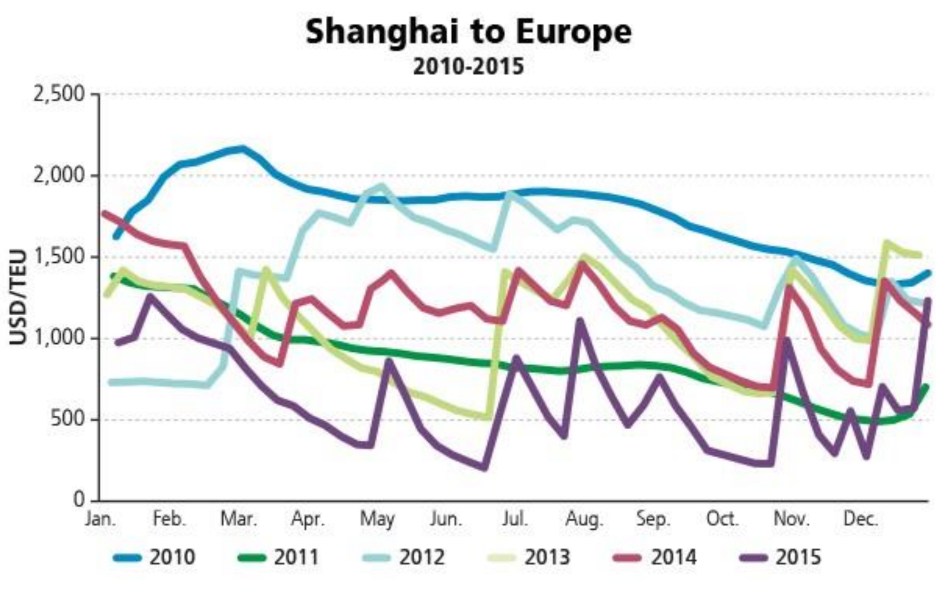


Figure 2.7: Average container freight rates from China to Europe (Source: BIMCO, 2016)

Directional imbalance of the international trade is another reason for low freight rates for some shipments. Wang (2014) considered directional imbalance of the liner container shipping service in his study. He included head haul and back haul of the container shipments as joint products. His empirical results confirmed the competitiveness of the Transatlantic and Transpacific freight rates. In another study, Song and Dong (2012) studied empty container repositioning for multiple liner service loops. Their optimisation objective function aimed to minimise the total costs including container handling costs, customer demand backlog costs, the demurrage costs at the transhipment terminals, inventory costs of the empty containers, and empty container transportation costs. The number of liner service loops is limited with three service routes. Two methods were used in order to find a solution to the optimisation problem; two-shortest-path based integer programming methods and two-stage heuristic-rules based integer programming methods. Their results indicated that the solution methods suggest better outcomes than the practical policy. De Oliviera (2014) investigated the determinants of the freight rates on the main shipping routes from Europe to the Other Continents. He considered the influence of the trade imbalance on the freight rate determination by carriers.

2.3.5 Operational Barriers

The operational barriers influence competitiveness of the liner container shipping industry and logistic chain directly. Ishiguro and Inamura (2005) categorised barriers of operation and management of shipping and multimodal transportation as following:

- Legal and Institutional
- Financial and traditional
- Technological
- Physical
- Discrimination/restrictions

Based on the studies of Plant *et al.*, (2007) and Fink (2002) the main operational barriers in container shipping are identified as the following statements:

- Port draught and handling performance

- Narrow waterways and Canal infrastructures, and their geographical limitations
- Weather conditions
- Accident risk, war risk, political instability risks
- Human factors

The maritime canal structures have attracted interest of academia a great deal recently and their operational impact on the liner container shipping is a trend topic. Specifically, there is a massively growing research interest on the consequences of the Panama Canal extension, and Nicaragua Canal construction projects. For instance, Rodriguez *et al.* (2015) used a mixed integer linear programming model with minimum cost objective function in order to determine the impact of ship size enlargement in the market after the Panama Canal expansion. Their results indicated that the canal expansion would not change container transhipment percentage significantly. In addition, their work suggested that the canal expansion had a positive influence on the efficient capacity utilisation of the container ships. In addition, Liu *et al.* (2016) applied a cooperative game theory methodology among the supply chain players in the US container import market in order to analyse influence of the Panama Canal extension on the liner container shipping market. Their results indicated that while Panama Canal extension increases the market power of US East Coast market players, it also reduces the market power of the US West Coast players. In another recent study, Yip ad Wong (2015) analysed possible future role of the Nicaragua Canal for the liner container shipping based on the green gold and the green split scenarios. They determined possible positive impact of the canal for cargo flow of the global liner trade.

2.4. Competitive Trends in Liner Container Shipping

2.4.1 Optimum Fleet Management

Several studies focused on the selection of an optimal ship size for particular trade routes. Kendal (1972) discussed the theory of optimum ship size in marine trade practices. Ryder and Chappel (1980) studied optimum speed and ship size for liner trades. In these studies, it is determined that port of calls, cargo types, handling equipment and organisation of trade were important factors on ship size decisionmaking. It is described that optimum ship size is the specific size providing minimum per unit cost for ship and port terminal operations. Scenario based analysis of the optimum ship size is another direction of research in academia. For instance, Talley (1990) investigated optimum containership size under different scenarios such as changes in the number of port of calls, distance in the round trip, and port time. According to his results, in the case of a given round trip distance and same port time for each port of calls when port time or number of port of calls increases, optimum container ship size declines. In addition, for the same number of port of calls and same port operation time per port of calls, optimal containership size increases as the distance of the route increases. Therefore, he pointed out that economy of scale of larger containerships provides a notable advantage when the proportion of the time at voyage increases. In another study, Sys *et al.* (2008) focused on the both qualitative and quantitative details of the relationship between ship size and operation. As per their methodological approach, optimal container ship size is dependent on the transport segment (short or deep sea), trade lane, terminal type, and technology. Therefore, all relevant operational details should be considered collectively in determination of the optimal containership size for a specific case. In contrast to the aforementioned studies, Wu (2007) developed an analysis approach to answer the question of the capacity utilisation analysis of container shipping fleet rather than deciding on optimal ship size. He applied his theoretical model to four container shipping liners of Taiwan and his results showed that during the period analysed in the study significant capacity oversupply occurred due to ship size oriented operational motivation of shipping liners.

Many research papers have been published in attempt to analyse the operational implication of the economy of scale in a specific liner container transport system. For instance, Cullinane and Khanna (2000) modelled the economy of scale principles in container shipping. They developed a sensitivity analysis model to determine the optimal large container ship size for a specific service line under different scenarios regarding the port time. Their results validated that larger ships reduce the shipping cost per TEU significantly and for longer distance voyages their cost benefits were even much higher. In a more cost analysis focussed study, Stopford (2002) discussed the economy of scale requirement in container shipping finance and analysed the economic feasibility of the large container ships. He emphasised the significance of the operational implications of ship size in global transport system. According to his findings, in an Atlantic round trip case, for container ships with over 6,000 TEU capacity cost saving per TEU are determined as very small. He disagreed on the operational feasibility of 18000 TEU capacitated ULCVs with single operators and he defended a gradual transition. From a more holistic point of view, Hsu and Hsieh (2005) analysed shipping economies of large container ships by an approach of minimisation of the whole transport and related inventory costs. Results of their two-objective optimisation model indicated that the operational utilisation possibility of larger ships increases where port efficiency, route distance increases and the number of the port of calls and operational cost of larger ships decreases. In another similar study, Hacegaba (2014) investigated impact of the mega container ships on the port operations and port capacity utilisation. He emphasised the significance of port productivity and strategic investment decision to adapt port systems to mega container ships for port authorities. Lim (1994) explained ship size enlargement trend not only with economy of scale but also combining various factors such as ship's buying price, running costs, freight rates, voyage length, and fixed cost. In addition, Tran and Haasis (2015) used multiple regression models to measure the impact of fleet capacity and ship size on the liner service. They pointed out increasing costs of shipping, ports, inventory and inland transportation by utilisation of larger ships and warned the shipping liners about oversupply of capacity slot and its diseconomy of scale.

A limited number of studies have focused on the analysis of the utilisation of large container ships in a global shipping network. Imai *et al.* (2006) studied the economic viability and competitiveness of large containerships. They used a game theoretical concept to analyse the impact of utilisation of mega large containerships on the liner service networks. They applied their model on both Far East- Europe and Far EastNorth America shipping lines. According to their research outcomes, mega-ships were competitive in all scenarios for Far East- Europe line and it was viable for Far East- North America with the condition of low freight rates and feeder cost. In another study, Chao and Wei (2012) designed comprehensively integrated operational models for multi-port calling network and hub-spoke network. As a result of their mathematical modelling, they found that integrated operational models were very useful to analyse the adaptive evolution of container shipping network structures. As well as the liner shipping network the perspective of container port terminals is also emphasised. In a discussion-based research paper, Saanen (2013) focused on the impacts of mega containerships on the container port terminals. According his study, while mega-ships are providing cost savings for shipping liners they also cause operational problems for container terminals. Therefore, it is required for terminal operators to increase speed of container handling. This seems only possible by new investment and additional costs for the container terminals.

2.4.2 Network Connectivity

Cargo demand volume of the liner container shipping on the trade network requires allocation of the periodic regular schedules on specific shipping routes. Allocating certain shipping service routes with regular ship scheduling enables liner trade connection between various ports of origin and destination globally through a complex distribution network. Therefore, a liner container shipping network is commonly thought of as “blood vessels of international trade” (Christiansen *et al*., 2013). The liner container shipping route networks also evolve according to the requirements of the international trade. The density of liner trade is mostly concentrated on the three main routes: Transatlantic, Transpacific, and Asia-Europe routes. These are routes with high trade volume connecting the world’s east-west trade activities. In addition to these main routes intra-Asian, intra-European, South-North trade could be considered as other important shipping routes (Grammenos, 2010).

One of the most significant discussions in the line container shipping industry at present is the shipping network connectivity. Container shipping activities represent a vast majority of the liner shipping trade but there are some other small scale liner shipping activities such as Ro-Ro, conventional general cargo and cruise shipping. Advanced liner shipping services provide development for the marketing activities of finished or semi-finished products to wider geographies. Thus, a higher liner shipping connectivity to global consumption points is a desired fact. The liner shipping connectivity of a port or a country improves the industrial competitiveness of its serviced exporter manufacturers against global competitors and in parallel it increases the import of goods and provides additional options. The high liner shipping connectivity provides (Hoffman, 2012):

- More choice for the importers and exports
- Lower transport and transport related costs for the importers and exporters
- Lower transit time and higher service frequency for the importers and exporters
- Direct income for the port operators and authorities
- Indirect income for value added logistics services

The World Bank (2016) is using the Liner Shipping Connectivity Index (LSCI) of countries as a measurement to illustrate an international trade portfolio of the countries. The following figure indicates LSCI of countries on a map. Darker colours represents higher LSCI, lighter colours represents lower LSCI. As seen in the figure,
Liner shipping connectivity of Far Eastern, Western European and North American countries are very high in comparison to other geographical regions. The LSCI index

map also indicates geographical distribution of the main production and consumption areas.

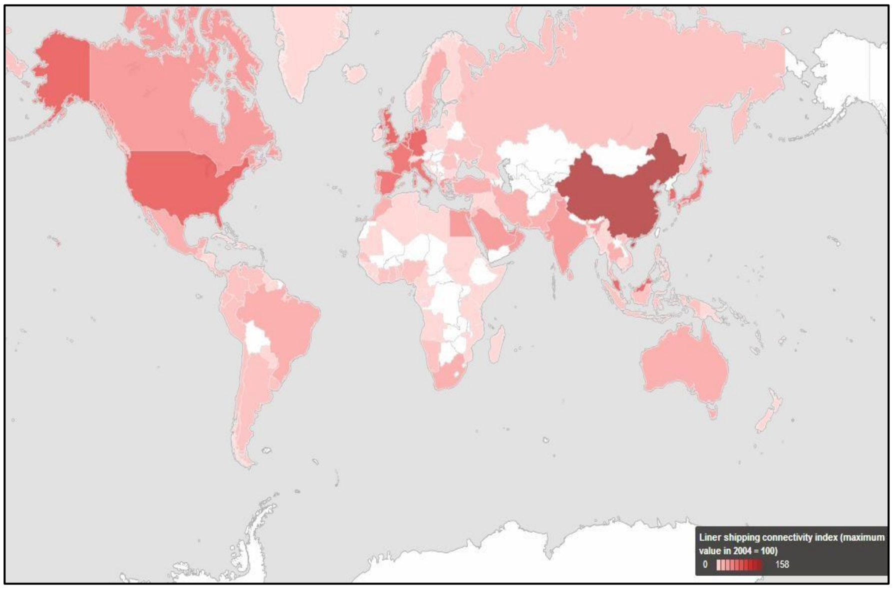


Figure 2.8: Global liner shipping connectivity index map (Source: The World Bank, 2014)

2.4.3 Energy Efficiency

Energy Efficiency Design Index (EEDI) and Energy Efficiency Operation Index (EEOI) regulations of IMO have significant impacts on liner container shipping industry operation management decision-making. The energy efficiency design measures for a ship can be categorised as following (ABS, 2015):

- Hull form optimisation
- Energy saving devices
- Structural optimisation and light weight construction
- Machinery technology
- Fuel efficiency of ships in service

With regards to energy efficient shipping motivation, Rehmatulla and Smith (2015) investigated the energy efficiency barriers in commercial shipping. They developed a novel methodology called “triangulated approach” in order to apply to principal agent problems in shipping. They determined the charter party agreement types as a barrier for energy efficiency strategies. Sames and Kopke (2012) analysed historic energy efficiency data of the world container fleets. They highlighted t that it would be very difficult for container shipping to reach IMO’s emission target unless innovative application in shipbuilding and ship operation took place. They also compared the cost efficiencies of the energy efficiency improvement measures shown on the following figure.

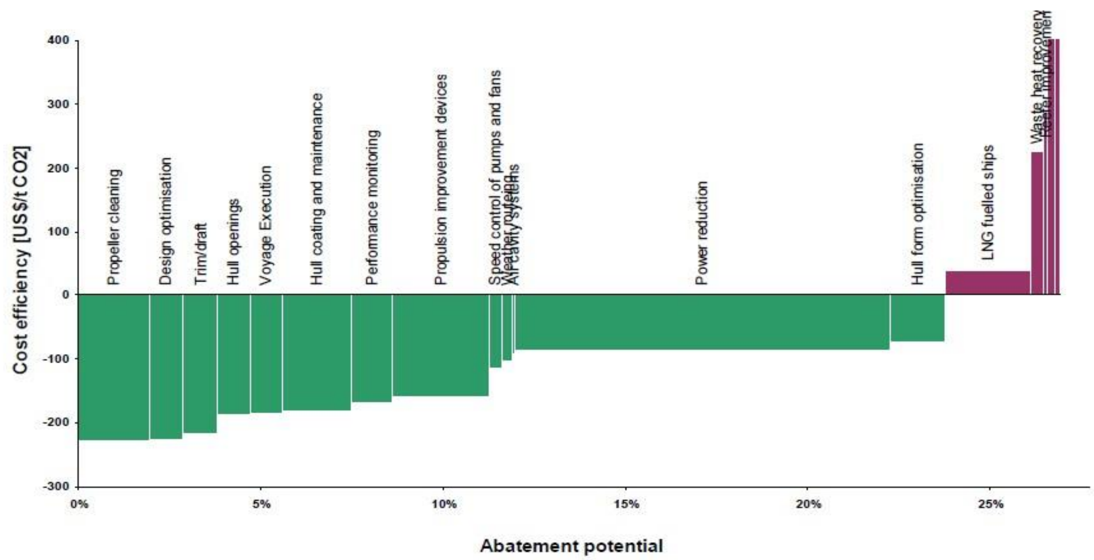


Figure 2.9: Marginal abatement cost curve for 2019 (Source: Sames and Kopke, 2012)

Armstrong and Banks (2015) applied an integrated approach to vessel energy efficiency. Their holistic approach considered the business perspectives of technical, operational and commercial stakeholders. They also emphasised the significance of the identification of the energy efficiency KPIs (Key Performance Indicators) for all stakeholders. Therefore, the focus would be maximisation of KPI potentials for each stakeholder.

Lu *et al* (2015) developed a ship operational performance prediction model in order to optimise ship voyage and provide energy efficiency. Their study described energy efficiency of operation (EEO) as an indicator representing the main engine fuel consumption per unit transported. They applied the prediction model on two oil tankers with different ship sizes. The outcomes of their work provide a decision rational in order to select voyage route by considering fuel consumption, safety risks, time, distance and frequency parameters. DNV GL (2015) published an energy management study and determined impacts of SEEMP on the ship operating business. They determined that hull maintenance, coating, slow steaming, performance monitoring, voyage optimisation, weather routing, engine performance optimisation, trim and draft optimisation and port optimisation as popular energy efficiency applications. They also researched the impact of the bunker prices on speed arrangement of the container indicated on the following figure.

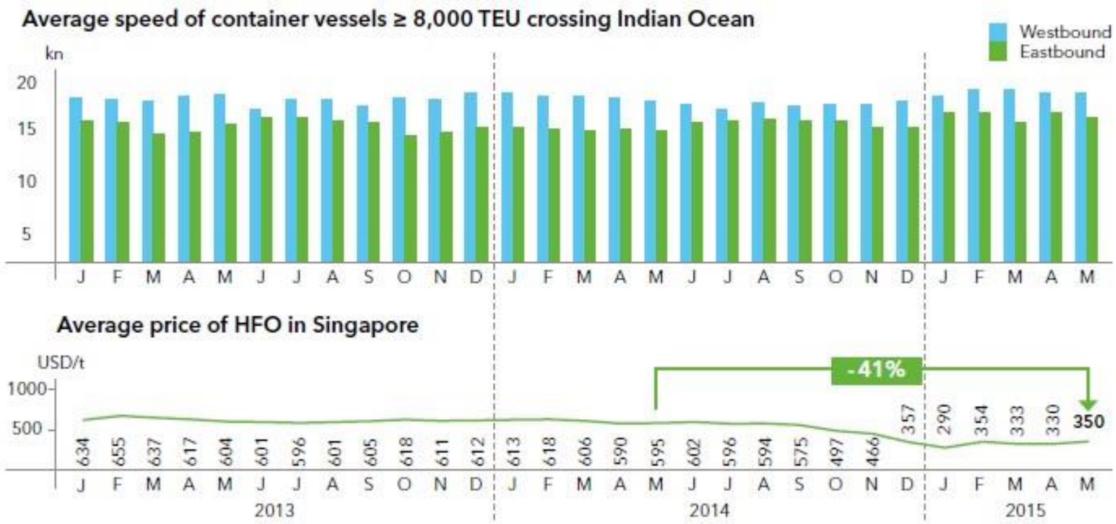


Figure 2.10: Liner shipping vessel speed and bunker price relationship (Source: DNV GL, 2015)

Schoyen and Brathen (2015) investigated operation energy efficiency for feeder container vessels based on two survey questionnaire asked to the shipping company and crew on-board. Their results suggested that optimum ship speed, port time/sailing time ratio and capacity utilisation need to be considered in order to increase energy efficiency.

Woo and Moon (2014) also studied influence of slow steaming on the sustainable performance in liner container shipping. Their study focus was to confirm positive contribution of the slow steaming on the environmental performance of the liner container shipping. Thus, they set three targets:

- Analysing the link among voyage speed and emission and predict changes by slow steaming practices.
- Analysing the link among voyage speed and operating costs on a liner service loop.
- Finding the optimal voyage speed maximising the emission reduction with the lowest operating costs and satisfying the IMO target for CO_2

Meng *et al* (2015) developed ship fuel efficiency for liner container shipping in order to connect bunker consumption and container ship determinants based on log data of ships. They used real data from four container ships for their six month operation period. They highlighted the potential influence of their study on sustainable liner shipping network modelling approaches. Laine and Vepsalainen (1994) explained economic impacts of the speed optimisation in shipping industry. They emphasised the importance of voyage and port time for round trip frequency and cost-revenue link. They recognised that determinants of the voyage time were route length, cruising speed, fuel economy, and fuel price. In addition, they found that determinants of the port time were ship utilisation rate, optimal loading speed, port costs and wage rate. The following figure explains the relationships between speed optimisation in liner container shipping.

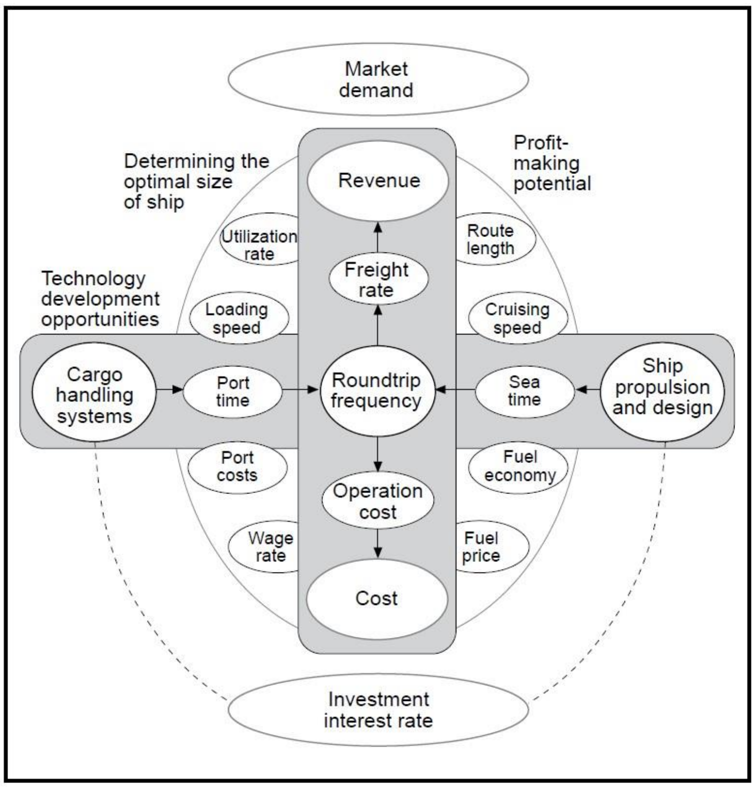


Figure 2.11: Speed optimisation basics in shipping (Source: Laine and Vepsalainen, 1994)

Moon and Woo (2014) emphasised reduction of port time in terms of energy and operational efficiency by increasing quality of the port services. They especially put forward the improvement requirements of the ports in order to serve mega vessels. Johnson and Styhre (2015) focused on port time of the ships in order to increase energy efficiency. They applied a case study on two bulk short sea shipping services of a shipowner. They determined that the 40% of the total shipping service time was in the ports and almost half of them were waiting. They divided the reasons for waiting into five categories:

- Port's working hours
- Early arrival
- Port congestion and clearance procedures
- Waiting for pilot
- Other unspecified reasons

Kurt *et al* (2014) analysed the influence of offshore container port structures on energy efficiency. Their results showed that mega ships providing energy efficiency required mega hub ports and offshore container port systems were feasible solutions in a location where small ports with low draft exists and requires a hub port.

2.4.4 Bunkering Source Switch to LNG Bunker

LNG is a promising fuel source alternative for the liner container shipping. El-Gohary (2012) discussed the utilisation of the LNG as a bunker for the LNG tankers. He determined that LNG was a cost-efficient fuel source for the long distances over 400 NM. Herdzik (2011) studied LNG for all ship types and he suggested that LNG could be a feasible option for only new-building orders due to its high installation cost to the existing fleet. Adamchak & Adede (2013) discussed the LNG challenges that the proposed LNG bunkered shipping would come across as: "the investment required in ships propulsion and fuel handling systems and in bunkering facilities, need for new international safety regulations and availability of the LNG on the main shipping routes".

Lloyd's Register (2012) published a report on "LNG fuelled deep sea shipping" in order to study the feasibility of the LNG fuel for large scale shipping. Lloyd's register suggested LNG as viable option for large scale shipping in the long term, particularly for the deep sea liner container shipping sector. Semolinos *et al.* (2013) predicted that, by 2020, there would not be a big increase on the utilisation of the LNG for the liner container ships. However, it is expected that the LNG bunker utilisation of the of deep sea liner container shipping would reach up to 15 Mtpa by 2030.

GL (Germanischer Lloyd) and MAN Diesel & Turbo prepared a study report on the economic benefits of LNG as a ship fuel for container vessels. The study investigated economic performance parameters of the LNG fuel and it concluded that LNG would be feasible if its price stays under HFO (Heavy Fuel Oil) price. LNG determined feasible bunker solution even for the new building of a container ship with 2400 TEU. In the case of mega container ships, for instance ships with 14,000 TEU or 18,000 TEU capacities, the shorter payback time has been predicted and applicability seemed high
(GL & MAN Diesel & Turbo, 2012). However, the LNG fuel's availability on the ports of call is a significant problem that needs to be prevented. In Norway, the LNG pioneer country, only small operational scaled ships have been utilised with the LNG bunker and practical operations of the LNG for deep sea container shipping still has many operational unknowns (Skramstad, 2013). Therefore, the very first applications of LNG fuelled vessel are planned as LNG ready by utilisation of the dual fuel engines. In addition, LNG Fuel tank requires approximately 80% more tank volume for the same energy contents (DNV GL, 2015)

2.5. Competition Dynamics in Liner Shipping Service

2.5.1 Conference Era Monopolistic Dynamics

Liner conferences, which began in the 1870s cargo-liner trades to address the problems of over-competition, seasonality and cut-throat pricing, have always attracted opposition. The conferences were fundamentally cartels (BIMCO, 2007).

Containerisation has weakened the ability to enforce cartels due to the antitrust law and the shipping liners have resorted to other strategies such as mergers, alliances, and consortia. The time of the conferences remained in the past. However, their fundamental impacts are still influencing the liner shipping business today. During the United Nations Conference on Trade and Development (UNCTAD), held in 1974, a Code of Practice for Liner Conferences was adapted. The code "40/40/20" targets the distribution of the carrying capacity between origin A and destination B as 40% of the vessels is of relevance to of country A, 40% of the vessels interests country B and 20% of the vessels is pertinent to a third country (Munari, 2012). Nowadays, conferences are not allowed and several investigations have even been arranged on the liner shipping cooperation regarding the antitrust law. China's rejection to the former shipping alliance P3 (Pioneer 3) referred more than 40% monopolistic control (47%) on the Far East-Europe route (JOC, 2014).

2.5.2 Strategic Alliance Era Oligopolistic Dynamics

Container shipping liners are operating on specially designed cellular 'lift on, lift off' vessels with carrying capacities up to 18000+ TEUs at present. In December 2013, 4976 containerships were on operation on the global sea geography. Competition level of container transport is lower than bulk transport. On the same date, the first 100 companies were operating 4933 container ships which mean they hold 99.13% of the total container global fleet capacity (Alphaliner, 2014). However, only around 21 of them operate a wide number of Panamax (3000-5000 TEU) and bigger ships (Post Panamax, New Panamax, Ultra Large Container Carrier), which are capable of supplying sustainable deep sea liner container shipping services on the main shipping routes. These major companies operate 85% of the total market capacity supply including deep sea and short sea liner shipping

(Alphaliner, 2014). Obviously this high proportion of concentrated capacity supply is one of the main indicators of an oligopoly in the liner container shipping system (Sys, 2009).

Sys (2010) investigated the liner container shipping industry and examined the competitive conditions for the period of 1999-2009. She measured the concentration ratio of the liner container shipping and analysed the degree of the concentration by applying the Hymer-Pashigian Index. Her results highlighted the difficulties of achieving the predicted success in the shipping liner cooperation. Panayides and Wiedmer (2011) studied shipping alliance competition in liner container shipping system. They described main characteristics of the shipping liners as the liner shipping service network coverage and vessel capacity deployment.

Bergantino and Veenstra (2002) applied network theory on liner container shipping industry. Their findings suggested the key variable in the cooperation is the difference between coordination costs and coordination savings. Therefore, the cost saving aspect is the most significant parameter for the establishment of the liner container shipping cooperation. They applied Bernard-Nash equilibrium to find the solution of the game. Agarwal and Ergun (2010) studied form of the shipping alliances between shipping liners. They identified the tactical decision-making problems of the liner container shipping alliances as design of the large scale networks by integration of the service of the alliance members and operational problems such as capacity allocation of the alliance members on the liner service loops. They applied cooperative game theory mechanism design among 3-4 players in order to apply to the problems of the shipping alliance cooperation. Their results were in favour of the shipping alliances in terms of cost reduction.

Shi *et al.* (2008) designed slot chartering agreements between competitor and ally shipping liners in a win-win game form. They defined the players as the owner of the slot and charterer of the slot. They determined cost allocation of the slot chartering agreements between players. They found subgame-perfect Nash equilibrium of the infinitely repeating game of owner and charter's utility-profits. Zhao *et al.* (2014) analysed vessel sharing agreements of the liner shipping alliances as a sustainable management strategy. Their optimisation model was applied on two shipping liner sharing vessels aiming total revenue maximisation. Their findings suggested that while vessel sharing cooperation provided financial benefit to shipping liners, it also reduces emission per unit carried and provided sustainability. Wang *et al.* (2014) developed three different game theory models to analyse competition between two shipping liners. They determined the market share of each shipping liner by the Logit-based discrete choice model. The three game theory model consisted of Nash game, Stackelberg game, deterrence game that considers economy of scale and ship capacity decisions. They generated the payoff functions based on the profit maximisation of the players.

2.6. Competition Dynamics in Container Port Services

2.6.1 Competitiveness from Hinterland Perspective

A very wide academic literature exists regarding the port competition and the port choice. Particularly, the selection of the relevant criteria to measure competitive performance of the container port terminals is the main focus of the vast majority of publications. For instance, Feng (2010) studied the determination of the factors for port performance measurement and port choice process. She used thematic analysis to investigate interview data obtained from a port expert survey. By using a survey questionnaire, Hoshino (2010) determined that the main drivers of the port competition were distance, cost and efficiency, concentration, advanced facility, bargaining power of a customer, and bargaining power of an operator. Similarly, Musso *et al* (2013) defined the main variables influencing port competition as price, capacity, and productivity. Furthermore, Yeo and Song (2006) accepted cargo volume, port facility, port charges, port location and service level as the port competition criteria. Additionally, Kim (2011) used geographical advantages, container transport volumes, cost advantage, and national port policy as port competitiveness assessment criteria.

Some studies focused on the port choice process of the hinterland counterparties. Alonso and Soriano (2009) investigated port selection problem from a hinterland perspective. They applied a discrete choice model on the hinterland port choice of Spanish and analysed the port competition in Spain. Malchow and Kanafani (2004) also used a discrete choice model to analyse the distribution of shipment among port alternatives. They found that geographic location, port characteristics and vessel characteristics influence port choice. Especially, they pointed out location as the most significant factor for port choice of hinterland. Tongzon (2009) focused on the port choice of the hinterland customer side, specifically freight forwarders, by utilising a regression analysis model. He defined frequency of ship visits, operational efficiency, adequacy of port infrastructure, location, competitive port charges, quick response to customer requirements and port reputation as significant in port choice of freight forwarders.

2.6.2 Competitiveness from Shipping Liner Perspective

Numerous studies are specific to the criteria from the perspective of the shipping liners in the port selection. Slack (1985) defined the criteria that shipowners employ in the port selection process. He provided a survey to shipowners to define the criteria. His results indicated that sailing frequency, inland freight cost, proximity of ports, port equipment, port congestion and port charges are the most significant criteria in the port choice. Chang *et al* (2008) focused on port choice factors by shipping liners including trunk and feeder service providers. They determined that most significant factors are local cargo volume, terminal handling charge, berth availability, port location, transhipment volume, and feeder connection. Tongzon and Sawant (2007) also emphasised the requirements for an identification of the port choice criteria from shipping liner's perspective. The chosen criteria for identification was efficiency, location, adequacy of infrastructure, port charges, connectivity, cargo size and wide range of port services. According to their research outcome, hub ports are the most preferred and frequently used ports by shipping liners.

2.6.3 Inter-Port Competition Dynamics

Hoyle and Charlier (1995) pointed out that port hinterland development and changing nature of the inter-port relationships are two significant factors affecting the evolution of port competition. Game theory methods were used commonly to analyse inter-port competition dynamics. Yap *et al.* (2011) developed a conceptual game theory framework to analyse inter-port competition strategies and their expected pay offs. The framework focused on the number of container handled, prices charged, and profit earned to analyse a variety of strategies which may be employed by port operators improve competitiveness. In a more case-based study, Yip *et al.* (2014) modelled interport competition between two competitor ports with a non-cooperative three-strategy game concept. According to the results obtained from their model, profitability of a terminal operator increases in parallel to its market power in the selected region. In another similar study, Park *et al.* (2010) used two static game models, Cournot oligopoly model and Bertrand model, in analysis of port competition strategies. Saeed and Larsen (2010) also applied cooperative game theory among different container terminals of a single container port to analyse the benefits of coalition for port terminals. They assumed that market share of the port is likely to increase due to coalition of the different terminals in a container port.

Ishii *et al.* (2013) constructed a non-cooperative game model with stochastic demand, competitive market and strategies for port charges dependent on port decision time for port extension. Minju *et al.* (2013) investigated duopolistic competitiveness between hub container ports to analyse container transhipment competition. They applied a noncooperative two-stage game on a seaport market where ports are upstream players and shipping liners are downstream players. By utilisation of this method, they suggested a mathematical output to apply to a port pricing optimisation problem. Xu *et al*. (2015) compared both cooperative and non-cooperative cases to illustrate their impact on the profitability of the container ports. In this study, they described the user demand to container ports in a specific geographic area based on the logit model as following:

$$D_i = D * q_i = Ae^{\theta * ln(\sum_i e^{u_i})}\left(\frac{e^{u_i}}{\sum_i e^{u_i}}\right) \tag{1}$$

Where;

D_i = Users' capacity demand in certain area

D = The total demand of users

q_i = Market capacity share of the container port i in a certain geographical area

A = The total demand coefficient

θ = Single container port facing demand which depends on all container ports with handling fees and other costs

u_i = Utility function of the container port i in a certain geographical area

Park and Suh (2015) applied a cooperative game model on a six-player container terminals' competition case in the Republic of Korea. They applied both cooperative and non-cooperative game theory models based on Bernard's oligopoly game in order to find consequences of the behaviours of the port operators in a perfectly competitive situation. Julien and Manios (2015) developed a framework based on Porter's generalised diamond model to analyse Caribbean region's port transhipment competition. Their results showed that the framework could be utilised to emphasise the inconsistency among the competition indicators and to determine improvement areas of competitiveness.

2.6.4 Other Competition Dynamics

A few studies in the literature mentioned integration of the different competition perspectives. Malaga and Sammons (2008) developed a concept of integration of the port selection problem by applying to a system approach. They considered both shipping liners' and hinterland's perspective in their Multinomial Logit Model. In another study, Talley (2014) investigated the impact of carrier profit, port throughput and shipper logistics cost on the maritime transport chain choice by carriers, ports and shippers respectively. He concluded that while carrier's profit chain and port throughput chain have positive influence on the carrier and port choice in maritime transport chain, shipper's logistics cost has negative influence on the shipper's choice of maritime transport chain.

2.7. Competition Dynamics of LNG Bunkering

The bunker fuel market is a highly competitive market. Ship size enlargement and fuel capacity increase has created demand for more flexible bunkering operations, and increased competitiveness of the bunkering supply market. The slow steaming and cruising ranges increased demand for bunker in order to make longer trips without receiving another bunker. On the other hand, some more challenges exist and are faced by the bunker supply in competition. As aforementioned the bunker supplier business is a high volume, low profit margin business. A typical bunker supplier buys fuel inventory and sells bunkers by utilising long-standing purchase contracts. Suppliers have three main sales channels - supplying fuel from their own inventory, back-to-back from other suppliers, and brokering and trading deals with other suppliers (Bunkerspot, 2013) Small issues in bunker logistics (storage and delivery) or supply costs may reduce market opportunities of the supplier significantly and cause permanent shifts in bunker supplier selection (Port of Los Angeles, 2012). Acosta *et al* (2011) investigated competition of the bunker suppliers at the ports of the Gibraltar Strait area. They provided a survey questionnaire to the port bunker suppliers. Their results suggested that the bunker prices and geographical locations were the most significant parameters influencing the bunkering supply competition. Also they clarified that the port performance and expenses also have a significant impact on the bunkering point selection.

Before mentioning the LNG bunkering supply, it is required to mention development of the LNG fuelled container shipping. The Norwegian Ro-Pax ferry named "Glutra" was the first LNG fuelled ship built in 2000 (Stokholm & Roaldsøy, 2000). However, orders for LNG fuelled container vessels have just been initiated due to the tough market conditions. Two sister container vessels of Brodosplit and 2 container ship orders of TOTE Shipholdings are the first LNG fuelled container vessels (DNV GL, 2014, Deal, 2013). On the other hand, Crowley also ordered two LNG powered ConRo (a combination of container & Ro-Ro) ship. These ships will have approximately 2400
TEU cargo capacities (Crowley, 2013) and will be flexible to be used as Ro-Ro or container ships. Moreover, Matson Navigation also ordered 2 LNG fuelled container ships to be delivered in 2018 (DNV GL, 2014). From main container shipping liners, only UASC group has declared their first 14000 and 18000 TEU LNG-ready new building orders with a number of agreements with South Korean shipyards (Porter, 2013).

The Port of Rotterdam showed serious intentions to add LNG bunkering hub capability among its known high quality level port services for deep sea container ships. Existing LNG prices in Rotterdam are also supportive of this strategy. However, in the United States of America and Canada there is a rapidly growing interest on LNG fuelling ships and construction of required onshore-offshore bunkering facilities due to low natural gas prices in that region. Far eastern countries are following the LNG fuelling trend relatively slower. Their position in the LNG bunkering supply is very significant for encouragement of ship-owners to invest LNG fuelled giant container ships. So far, except Goalan Port of China having LNG bunkering facilities, only Port of Singapore has showed major interest in LNG and LNG fuelling facilities (Lloyd's Register, 2013). However, adaptation of LNG bunkering operations in this country may take longer times due to lack of experience for LNG infrastructure and LNG supply chain (IGU, 2013). Some other European ports, including significant container hub ports such as Antwerp and Piraeus ports, have also announced their interest to invest in LNG bunkering facilities in upcoming years with a perspective of predicting adaptation of deep sea container liner shipping to LNG in the future. The approaches of the 10 most popular bunkering points of the commercial shipping to LNG bunkering investments are broadly positive. As container terminals, Rotterdam and Antwerp ports have already scheduled the LNG bunkering facility investments. Port of Singapore, United Arab Emirates ports and Busan port are also keen to invest in LNG bunkering supply business. Although Hong Kong and Gibraltar have not proposed LNG bunkering facility yet, planned and proposed other ports in China and Spain could handle LNG bunkering needs in the future. According to this development trend it will not be a big surprise to see significant development on LNG bunkering supply for the liner container shipping in middle term (Aymelek *et al.*, 2014).

2.8. Research Gaps in the Literature

Previously, many studies have been carried out on the competitiveness and game theoretical analysis of the shipping operations and management. However, there is still very little scientific understanding about the consequences of the oligopolistic behaviours, ship size enlargement, operational decisions and future evolutions of the liner container shipping system on the global supply chain of the industrial customers. Moreover, the practicability of generated knowledge by scientists in recent years is not very high in consideration to actual requirements of the liner shipping business. For instance, in the case of shipping liner, whilst a lot of research focused on a single optimal ship selection for a route or fleet profile selection of a shipping liner on a specific route, only a few research mentioned the consideration of the tactical investment behaviours of the competitors in liner service decision-making. Many of these researches did not include the cases of incomplete information available to the players in the competition game scenarios. In addition, there is no application of the game theoretical analysis for holistic port competition and multi-player bunker supply competitions. Furthermore, LNG bunkering for the liner container shipping is a trend research subject in the academia and this research is enlightening many unknowns regarding the LNG bunkering supply. The scientific approach of this study investigates competition dynamics, inputs and outputs, and the evolution of the liner container shipping counterparties. It also explores the behaviours behind tactical competition when gaining advantage over competitors.

3. THEORETICAL BACKGROUND

In this section, a concise theoretical background regarding game theory methods, adaptive system behaviours of the liner container shipping, and multi attribute value analysis are given in summary. Firstly, the management decision-making models are divided to three categories including strategic, technical, and operational models. Game theory models are described as a tactical decision-making models consisting of cooperative and non-cooperative game theories. Secondly, the historical development of game theory and game theory types are briefly explained. Thirdly, the system theory of the liner container shipping is briefly explained and complex adaptive evolution of the liner container shipping is mentioned. Lastly, mathematical modelling steps of the MAVA (Multi Attribute Value Analysis) are explained, and the related formula is given.

3.1. Game Theory Methods for Liner Container Shipping Competition

The competition dynamics in liner shipping are shaped and diversified based on the developments of the market trends. In recent years significant competitive managerial behaviours have been determined especially for the shipping liner and container port operators. These behaviours can be categorised under three titles as operation management, strategic management and tactical behaviours (Bourne *et al.*, 2003). While operation management is more interested in optimising the operational outcomes, strategic decision-making assists to complex decision-making processes, and the tactical decision-making assists to survive under tough competition pressure.

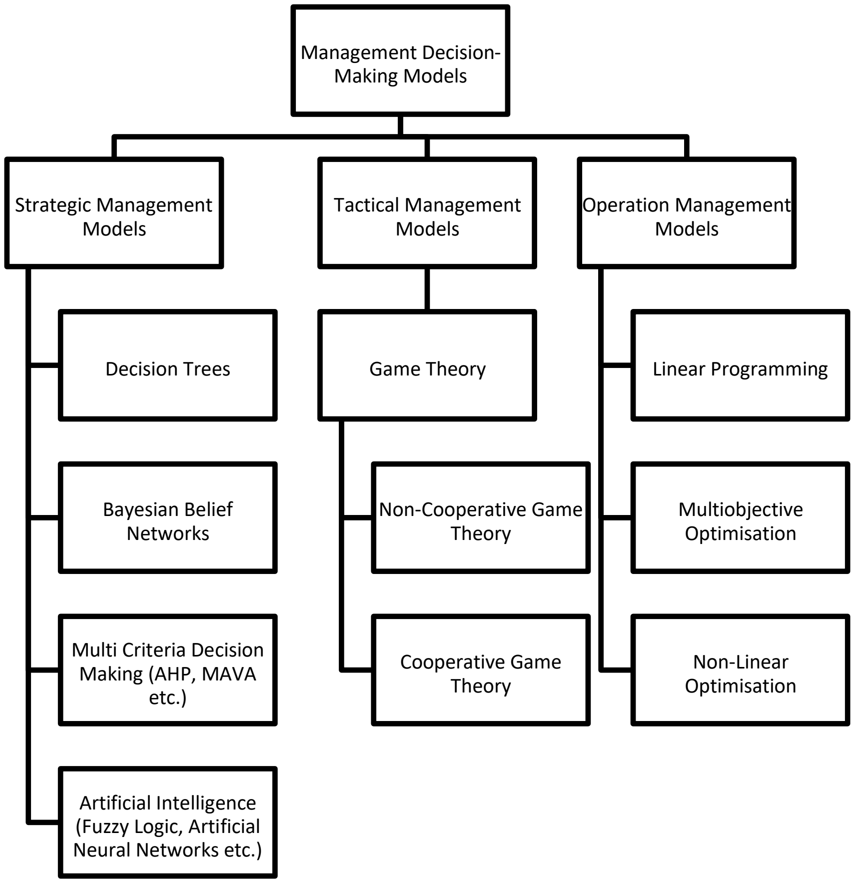


Figure 3.1: Quantitative management decision-making models (Source: Own work)

The game theory is widely utilised as a tactical decision-making/analysis tool in mathematics, economics, psychology, and computer science (Manuel, 2013). It also has an emerging application area for the liner container shipping management decisionmaking. As a brief inter-sciences description, a game is a formal description of tactical strategic situation and game theory is a strategic decision-making concept approaching complex real life problems in a mathematically well described game format and indicates numerical outcomes of each player for each chosen strategy in consideration of the strategy choices of other players. In game theory, several players must take certain tactical position by selecting available strategy options (Turocy and Von Stengel, 2001). The game theory highlights behavioural relations and connections where outcome of the strategic decision-making have strong interdependencies with the behaviour of the other players.

Originally, game theorists, such as Carmona and Carvalho (2016), and Yano and Nishizaki (2016), focused mostly on two-player zero-sum games (Geckil and Anderson, 2010). However, many different game types emerged to meet the requirements of the comprehended player interdependencies in various complex game rules. The first application of the game theory analysis is the duopoly game analysis of Antoine Cournot in the first half of nineteenth century. The matured form of the game theory was demonstrated as a science field, after 1944, following the publication of "Theory of Games and Economic Behaviour" by von Neumann and Oskar Morgenstern (Neumann and Morgenstern, 1947). In 1950, John Nash found that finite games had always an equilibrium point and established a significant milestone for non-cooperative game analysis (Nash, 1950). Since the 1970s, game theory has been widely applied in economics. Additionally, it has been applied in sociology, psychology, evolution and biology. Game theory has received more academic impact and attention after 1994 following the Nobel Prize awards in economics to Nash, John Harsanyi, and Reinhard Selten (Turocy and Stengel, 2001).

The games could be in static or dynamic forms. The static form of games requires a single move of each player at one time simultaneously. The dynamic games include sequential moves of the players (Reniers and Pavlova, 2013). In addition, noncooperative players may have complete and incomplete information. They may also be symmetric or asymmetric players. The following figure shows the overall view of the different game forms.

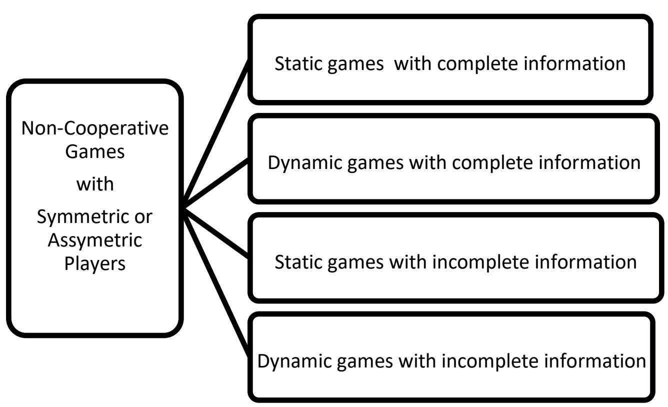


Figure 3.2: Types of non-cooperative games (Source: Own work)

The various game theory applications are developed afterwards in cooperative and noncooperative forms (Pavel, 2012). The hypothesis used in this thesis is non-cooperative. Therefore, it is worth mentioning the theoretical background milestones of the four player non-cooperative game in order to justify the methodological approach. The noncooperative game theory could be used in tactical decision-making processes in the case of the competition interaction among fully competing players existing and each players selecting its own competition strategy in order to maximise a particular utility (Jamus, 1999). In the case of finite multiplayer oligopoly, Elabbasy *et al.* (2007) studied the dynamics of triopoly competition with heterogeneous players. They applied Cournot game and Nash equilibrium to analyse the oligopolistic behaviour of the triopoly. In addition, Elsadany (2012) analysed triopoly competition with bounded rational heterogeneous players. Elabbasy *et al.* (2013) also investigated the complex dynamics of four player games. They used Cournot-Nash competition game theory and applied a numerical simulation in order to represent the complex behaviour dynamics of the best responses of the players.

Nash equilibrium plays an essential role in the development of game theoretical applications for various different branches of science. As aforementioned, the Nash equilibrium was established by the famous mathematician John Nash in 1950 (Nash, 1951). The Nash equilibrium is a pure solution concept of a game involving two or more players. In the Nash equilibrium solution, each player is assumed to have perfect information about the equilibrium strategies of the other players. Therefore, none of the players would want to change their equilibrium strategy (Osborne and Rubinstein, 1994). Shi (2011) analysed the applicability of solution concepts on the different game forms. She determined that Nash equilibrium was suitable for complete information games and Bayesian Nash games were more appropriate for incomplete information games.

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

Figure 3.3: Solution concepts of the game theory (Source: Shi, 2011)

3.2. Adaptive Behaviours in the Liner Container Shipping Competition

In order to analyse the complex adaptive behaviours and evolution of the liner container shipping system, it is essential to comprehend basic background knowledge about complexity, systems science, and complex adaptive systems. Briefly, 'Complexity' practices are constituted as something of a self-organising global network that is spreading 'complexity' notions around the globe (Urry J., 2006). As etymological origin the complexity is a Latin word (complexus) meaning many things which are interwoven and interconnected. This means that something is composed of many parts and links so that it attracts research interest to understand interconnections and systematics of its parts (Goulielmos, 2002). General Systems Theory (GST), the basic theory of modern systems, is a study which describes the system analysis as a logico-mathematical discipline, which is in itself purely formal, but is applicable to all sciences concerned with systems and complex problems (Von Bertalanffy, 1950). Complex Adaptive Systems (CAS) are commonly used in biology science to explain adaptive behaviours and self-organisation of complex system agents. It is possible to apply complex adaptive system models to evolutionary analysis of liner shipping network problems (Aymelek *et al.*, 2014).

Global container shipping is a network-centric marine transport system of systems (MTSoS), consisting of various mechanical and business systems which interconnect, interface and interact together (Mansouri *et al*., 2009). In consideration to cybernetics of the liner container shipping network, it is obvious that the system's components obtain main behavioural characteristics of the complex adaptive systems. Emergent, selforganisation and non-linear interaction in evolution are considered as the main complex adaptive behaviours of container shipping (Caschilli and Medda, 2012). The liner container shipping system emerged to respond to the intermodal transport service demand of the global trade. It evolves gradually via self-organisation of the system properties and functions according to the adaptive learning of rational agents from the system operations and the changing-coercive external environment. As a result of these adaptive evolutions of marine transport system; ships, seaport terminals, intermodal (including road, rail, air, short sea or inland waterways etc.) transport vehicles, and the organisation itself of shipping and the logistics companies, are all specialised container cargo types and related services to provide enhanced operational services and solutions for their industrial customers (Aymelek *et al.*, 2014).

The liner container system model consists of three main sections: system leadership mechanism, system operation, and system environment. The system leadership represents the top 20 ship operators and emphasises their effective oligopolistic control of the system. Their policy makings and investment decisions have a big influence on the system operation. The system operation of the liner container shipping consist of Vessel Systems (VS), Port Systems (PS), Waterway Systems (WS), Intermodal Systems (IS), System Users (SU) and Supportive Systems (SU) such as education, law, banking, insurance etc (Adapted from Mansouri *et al.*, 2009). System operation in the liner shipping industry is characteristically ship centric and under domination of developments regarding VS. The ship size enlargement decision of the system leadership is due to their interaction with system environment, which enforces other systems to show self-organisation. Therefore, it is possible to illustrate all these 6 system operation agents as complex adaptive systems including VS itself. The system leadership also develops future planning strategies by applying tactical, operational and strategic decision-making processes and aims to have robust control on system operations. The vessel and fleet related policy-making of the liner container system leadership has significant enforcements on the port systems, intermodal systems, system users, supportive systems and waterway systems.

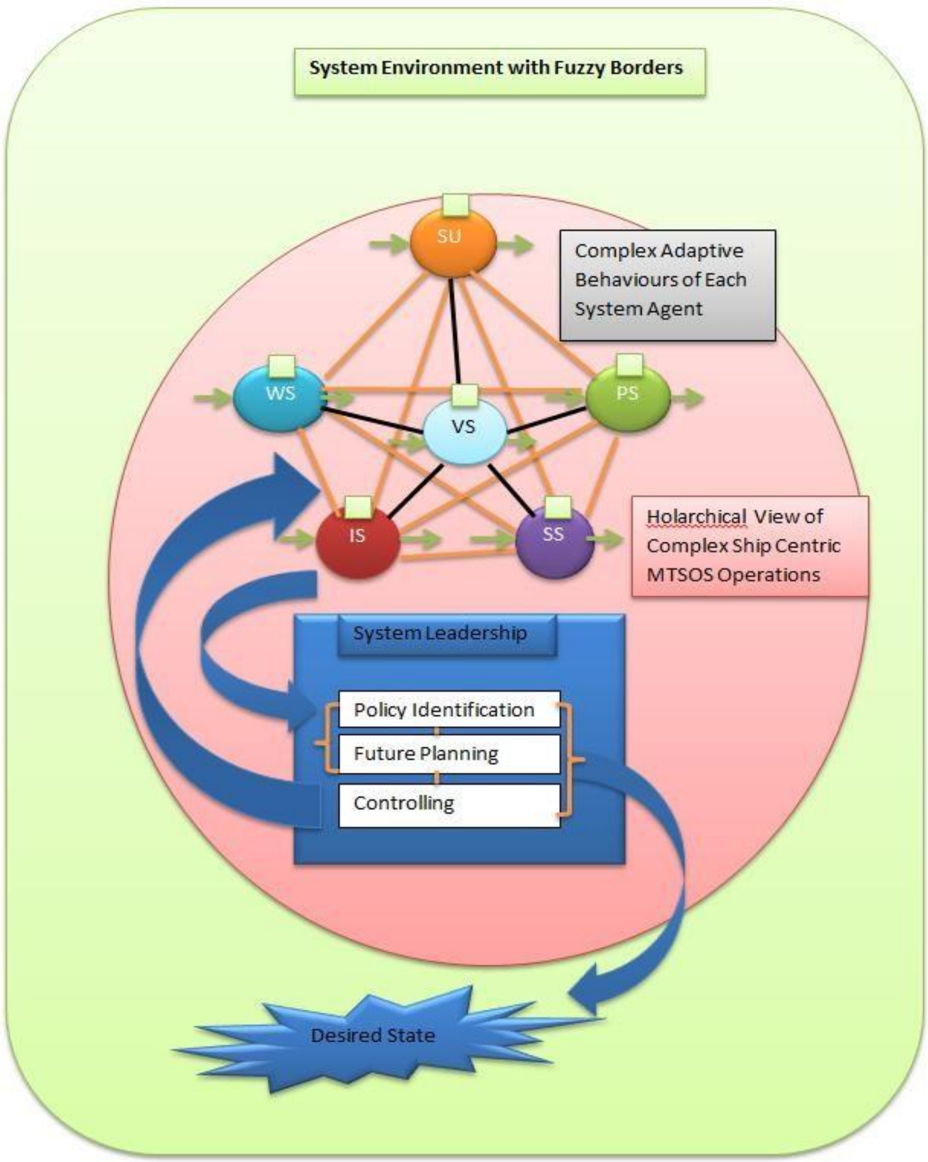


Figure 3.4: System model representation of liner container shipping industry

(Source: Developed based on Beer, 1985, Mansouri et al., 2009, and own work)

Figure 3.4 illustrates the system model of the liner container shipping industry and explains interconnections of system elements and relationship between operation and policy making holistically. According to the aforementioned system state, the ship size enlargement by utilisation of the ULCVs are expected to cause some essential selforganisation impulses for further evolutions of all systems under domination of VS. It is possible to illustrate the self-organisation inputs and outputs of ULCV utilisation on the global liner shipping network, as shown in figure 3.5.

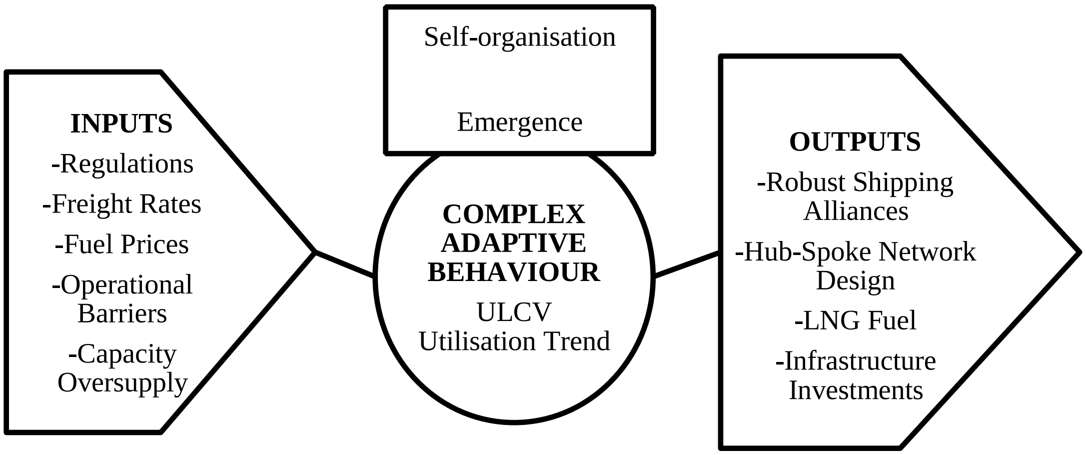


Figure 3.5: Inputs and outputs of adaptation to ULCV trend (Source: Own work)

The theoretical framework developed in this study utilises non-cooperative Cournot oligopoly game theory forms with Nash equilibrium and Bayesian-Nash equilibrium solution concepts, in order to analyse consequences of the ship capacity deployment decisions and its output and input relationships in static game forms. Therefore, it would be possible to holistically analyse adaptive evolution process and competition dynamics of the liner container shipping system.

3.3. MAVA Modelling Fundamentals

Modelling competitiveness criteria by applying multi-criteria decision-making requires significant background information regarding the MAVA (Multi Attribute Value Analysis) process. Therefore, firstly some basic information regarding the modelling steps of MAVA will be given to justify the analysis of port competition from both a hinterland perspective and a shipping liner alliance perspective. The MAVA may be used as a robust decision-making approach to analyse the perspective of hinterland and shipping liner in relation to a port choice problem. MAVA models provide a decisionmaking concept for the explanation and justification of complex decisions with multiple criteria. MAVA is only a decision support tool for decision makers to guide them in order to develop a rational in the decision-making process. Analysis outcomes of MAVA models may commonly be utilised to generate a discussion on the complex decision-making processes. MAVA modelling steps facilitates a logico-mathematical rational to create a decision support unit for complex decision-making process. In MAVA models, firstly, a criteria hierarchy is defined and value tree of the problem is established. Secondly, the importance weights of all criteria are added to model. Thirdly, the performance of each alternative is scored on each criterion. Due to the utility function, MAVA provides overall utility of each alternative in decision-making. In addition, MAVA models indicate robustness of the performances of alternatives for each criterion (Belton and Stewart 2002). MAVA decision concept may be very useful to apply on the port competitiveness due to its simple and robust utility functions.

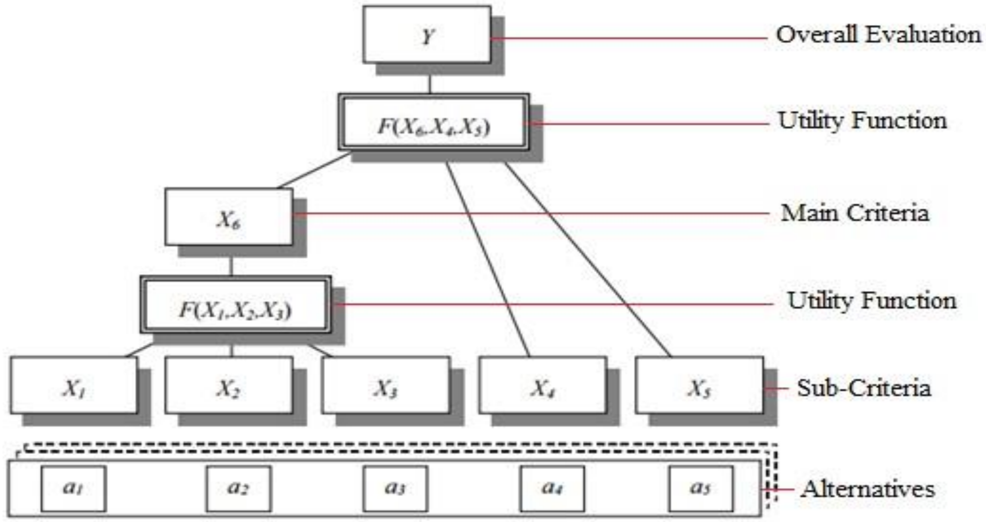


Figure 3.6: Logico-mathematical steps of multi criteria decision modelling

(Source: Bohanec *et al.*, 2000)

As shown in figure 3.6, the utility functions are embedded in the multi criteria decision models. In MAVA model, briefly, the utility function can be formulated as following (Belton and Stewart 2002).

$$V(a) = \sum_{i=1}^{m} w_i \cdot v_i\,(a)$$

Where:

$V(a)$ represents the overall utility of alternative a.

$v_i\,(a)$ is the score reflecting alternative a 's performance on criterion i.

w_i is the weight assigned to reflect importance of criterion i.

(2)

4. METHODOLOGY

The most complex decision problems contain multiple objectives, multiple options, uncertainty and sequentiality (Bunn, 1984). Complexity of the decision-making process requires development of a well- structured decision-making rational in order to minimise uncertainties and to simplify the complexity. Especially, for the tactical management decision-making, where the decision maker needs to consider various competitor behaviours, the uncertainties are even higher in comparison to other decision-making processes (Hasan *et al.*, 2011). Therefore, tactical decision-making processes require a systematic structuring of the logico-mathematical content of the decision rationale.

In this section, the methodology of the study is established with the motivation of clarifying decision uncertainties and justifying the decision rationale by development of mathematical logic. In order to address the aim and objectives mentioned in the chapter 1, an integrated game theoretical decision analysis approach is developed and presented in this chapter. The integrated game theoretical approach consists of the static Cournot quadropoly game theory, cost calculation of the shipping liner, port operator and bunker suppliers, and decision scenario based approach and solution concepts based on complete and incomplete information. While Nash equilibrium pure strategy solution concept is applied on the complete information state of the players, Bayesian-Nash equilibrium solution concept is applied on the incomplete information state of the players.

4.1. Formal Methodological Steps of the Study

The methodological framework generated in this section, is combining both operational and tactical decision-making processes of the liner container shipping management. Therefore, the mathematical steps generated in the methodology includes cost calculations of the players for each liner container shipping competition platforms, Cournot competition optimal capacity deployment and freight mechanism, additional capacity increase or capacity reduction decision scenario building, and Nash and Bayesian-Nash solutions for the both complete and incomplete information states. By the novel methodological application, it would be possible to determine the price dynamics of the market as well as the equilibrium points of the market for different information related decision-making states. The methodological steps of the thesis can be summarised as in following figure.

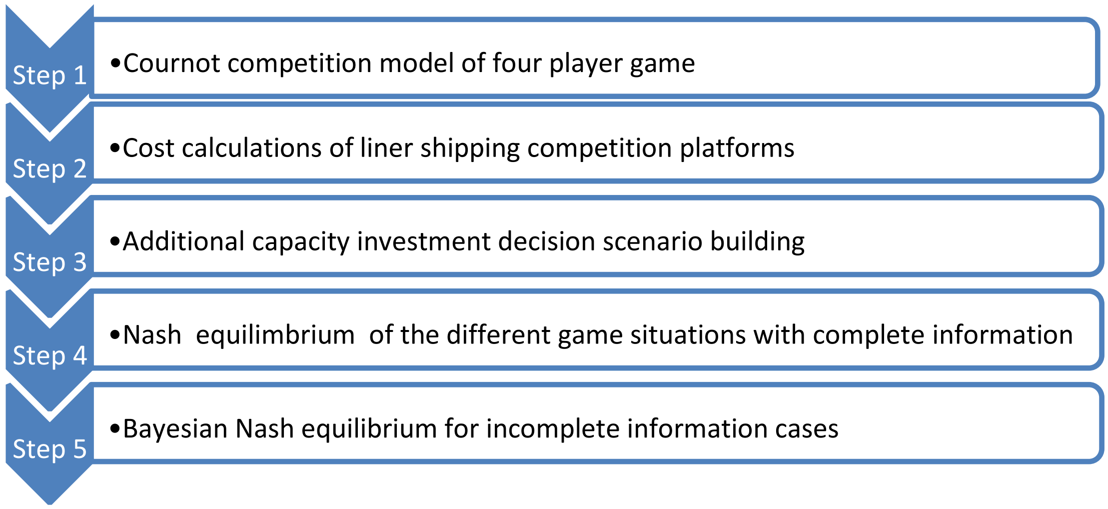


Figure 4.1: Methodological steps of the thesis (Source: Own work)

4.2. Cournot Competition Game of the Four Players

The Cournot competition model is commonly applied for the case of oligopolistic control of a group of firms on the freight determination in a particular market. This research assumes the deep sea liner container shipping market as a four player oligopoly which can be called “alliance quadropoly”. In addition, cooperation between competition counterparties is disregarded and it is assumed that a perfect competition state exists with complete information between players.

In the case of four non-cooperative fully competing players, let $q_\theta(t)$, $\theta = 1,2,3,4$ indicate the capacity deployments of the quadropolistic competition counterparties during a certain (t) time period in the market boundaries. It is assumed that the price/freight of the liner shipping services (P) has a direct mathematical relationship with the total deployed capacity

$$Q = \sum_{\theta=1}^{4} q_\theta$$

(3)

through inverse demand function $P = f^{-1}(Q)$ of economy theory which is a linear function assisting to simplify the capacity-price relationship. The average price (freight) of the liner service on a specific case that quadropoly supply can be shown as

$$P = a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4$$

(4)

where a is a constant parameter representing the market behaviour, and b_1, b_2, b_3, b_4 are the constant slopes of the market from each player's market position. In order to calculate the profit functions of the players, let the average cost function be

$$C_\theta(q_\theta) = c_\theta q_\theta, \qquad \theta = 1,2,3,4$$

(5)

and revenue of the players be q_θ, $\theta = 1,2,3,4$. Therefore, the profit function of players 1 to 4 is

$$\pi_\theta = Pq_\theta - c_\theta q_\theta \quad \theta = 1,2,3,4$$

(6)

Then it is possible to formulate the profit functions of each player as below.

$$\pi_1 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_1)q_1$$

$$\pi_2 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_2)q_2$$

$$\pi_3 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_3)q_3$$

$$\pi_4 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_4)q_4$$

(7)

According to Cournot's oligopoly model marginal profit functions of each player can be found as the following (Elsadany, 2013).

$$\emptyset_\theta(q_\theta, Q_{-\theta})\frac{\partial\pi_\theta(q_\theta, Q_{-\theta})}{\partial q_\theta} = a - 2b_\theta q_\theta - b_{-\theta}Q_{-\theta} - c_\theta = 0$$

Where;

$$Q_{-\theta} = \sum\nolimits_{\mu=1,\theta\neq\mu}^{4} q_\mu$$

(8)

Using the above model it is possible to show marginal profit of each of the counterparties of the quadropolistic game as follows.

$$\frac{\partial\pi_1(q_1, Q_{-1})}{\partial q_1} = a - 2b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_1 = 0$$

$$\frac{\partial\pi_2(q_2, Q_{-2})}{\partial q_2} = a - 2b_2q_2 - b_1q_1 - b_3q_3 - b_4q_4 - c_2 = 0$$

$$\frac{\partial\pi_3(q_3, Q_{-3})}{\partial q_3} = a - 2b_3q_3 - b_1q_1 - b_2q_2 - b_4q_4 - c_3 = 0$$

$$\frac{\partial\pi_4(q_4, Q_{-4})}{\partial q_4} = a - 2b_4q_4 - b_1q_1 - b_2q_2 - b_3q_3 - c_4 = 0$$

(9)

Then optimal capacity allocations of each player can be written in the form of Nash equilibrium Cournot oligopoly model.

$${q_1}^* = \frac{a - b_2q_2 - b_3q_3 - b_4q_4 - c_1}{2b_1}$$

$${q_2}^* = \frac{a - b_1q_1 - b_3q_3 - b_4q_4 - c_2}{2b_2}$$

$${q_3}^* = \frac{a - b_1q_1 - b_2q_2 - b_4q_4 - c_3}{2b_3}$$

$$q_4{}^* = \frac{a - b_1 q_1 - b_2 q_2 - b_3 q_3 - c_4}{2b_4}$$

(10)

In order to show a mathematical relationship between optimal capacity deployment of the players and the fixed shipping price of four-player oligopoly by the Cournot model, the following equations are generated.

$$q_1{}^* = \frac{P - b_1 q_1{}^* - c_1}{2b_1}$$

$$q_2{}^* = \frac{P - b_2 q_2{}^* - c_2}{2b_2}$$

$$q_3{}^* = \frac{P - b_3 q_3{}^* - c_3}{2b_3}$$

$$q_4{}^* = \frac{P - b_4 q_4{}^* - c_4}{2b_4}$$

(11)

In final form of the previous equations, we can simply illustrate the optimal capacity allocations as:

$$q_1{}^* = \frac{P - c_1}{3b_1}$$

$$q_2{}^* = \frac{P - c_2}{3b_2}$$

$$q_3{}^* = \frac{P - c_3}{3b_3}$$

$$q_4{}^* = \frac{P - c_4}{3b_4}$$

(12)

These equations will assist us to find optimal capacity allocation by the utilisation of b_θ constant player slopes of the market ($\theta = 1,2,3,4$) and a constant values of the market, representing price dynamics of the market, where fixed price is known and cost per capacity allocation unit of each player is calculated. In the following section the cost calculations of the different liner shipping counterparties are given in a systematic order. Therefore, it will be possible to integrate shipping economics with game theory methods in order to analyse tactical behaviours in a fully competitive oligopolistic market.

4.3. Cost Calculations of the Liner Shipping Counterparties

4.3.1 Costs of Shipping Liners

In the case of liner shipping services, in order to calculate the total cost (TC_θ) of each player ($\theta = 1,2,3,4$) on a specific round trip service, with identical ships, it is required to calculate voyage costs (VC_θ), operational costs (OC_θ), and capital costs (CC_θ).

$$TC_\theta = VC_\theta + OC_\theta + CC_\theta \tag{13}$$

Simply the voyage cost of each player ($\theta = 1,2,3,4$) may be calculated as sum of the average bunker costs (BC_θ) , average port charges(PC_θ) and any required canal charges (γ).

$$\sum_{i=1}^{n-1}\sum_{j=2}^{n} VC_{\theta ij} = \sum_{i=1}^{n-1}\sum_{j=2}^{n} BC_{\theta ij} + \sum_{k=1}^{n} PC_{\theta k} + \gamma \tag{14}$$

The operational cost of players ($\theta = 1,2,3,4$) may be calculated as sum of manning cost (MC_θ), insurance cost (IC_θ), stores (SC_θ), maintenance (MAC_θ), and administration costs (ADC_θ).

$$OC_\theta = MC_\theta + IC_\theta + SC_\theta + MAC_\theta + ADC_\theta \tag{15}$$

In order to calculate number of round trips for a ship per year, it is required to calculate total round trip time. The total time required for a liner service round trip is calculated as below.

$$RT_\theta = \sum_{i=1}^{n-1}\sum_{j=2}^{n} \frac{D_{\theta_{ij}}}{V_{\theta_{ij}}} + \sum_{k=1}^{n} PT_{\theta_k} + \sigma_\theta$$

Where;

RT_θ =Round trip time (hours) of the liner service of players

$D_{\theta ij}$= Route distance between i^{th} and j^{th} port of call

$V_{\theta ij}$= Average speed between i^{th} and j^{th} port of call

$PT_{\theta k}$ =Average port time of k^{th} port of call

σ_θ = Average total round trip delays from unexpected port waiting, maintenance and weather

(16)

Capital cost per ship round trip of each player (CC_θ) may be calculated with the following formula.

$$CC_\theta = CP_\theta + n_\theta * \frac{r_\theta * (1 + r_\theta)^{n_\theta}}{(1 + r_\theta)^{n_\theta} - 1} * l_\theta$$

Where;

CP_θ = Cash price of the average ship of each player

r_θ = Interest rate of the average ship of the players for adequate time period

n_θ = Number of instalment for each player

l_θ= Loan of the players

(17)

Then number of round trips per year for a ship is $y_\theta = \frac{365*24}{RT_\theta}$ with the largest integer possible excluding maintenance time. If it is assumed that the liner service provides a weekly service from each port of call, it is required to allocate $x_\theta = \frac{52}{y_\theta}$ number of ships with the largest integer possible. The total annual cost of a liner service loop for a shipping alliance/shipping liner is shown as below.

$$c_{\theta-Annual} = (y_\theta * x_\theta * TC_\theta) + AC_\theta \quad , \quad \theta = (1,2,3,4)$$

Where;

$AC_\theta =$ Annual additional costs per service loop

(18)

Based on the given total annual cost, the average per container shipment cost c_θ could be shown as follows.

$$c_\theta = \frac{c_{\theta-Annual}}{y_\theta * x_\theta * q_\theta * \omega_\theta} \quad , \quad \theta = (1,2,3,4).$$

Where;

ω_θ= Capacity utilisation rate of the liner service of player θ

(19)

4.3.2 Costs of Port Operators

The main costs of port operators consists of operation costs (OC_θ), capital costs of the port facilities (CC_θ), overhead costs (OHC_θ), and additional costs (AC_θ). $\theta = (1,2,3,4)$ (Busk and Smyth, 2013).

$$TC_\theta = OC_\theta + CC_\theta + OHC_\theta + AC_\theta$$

(20)

Operational costs of port operators are calculated as follows.

$$OC_\theta = MAC_\theta + ENC_\theta + LABC_\theta$$

Where;

MAC_θ: Maintenance and repair costs

ENC_θ: Energy consumption costs

$LABC_\theta$: Labour costs

(21)

Capital cost of the each port operators (CC_θ) may be calculated with below formula.

$$CC_\theta = EAC_\theta + MCC_\theta$$

Where;

EAC_θ: Equipment asset costs including IT (Information Technology) costs

MCC_θ: Miscellaneous capital costs

And,

$$EAC_\theta = CP_\theta + n_\theta * \frac{r_\theta * (1 + r_\theta)^{n_\theta}}{(1 + r_\theta)^{n_\theta} - 1} * l_\theta$$

Where;

CP_θ = Cash price of the facilities each port operator invested

r_θ = Interest rate of the player's infrastructural facilities for adequate time period

n_θ = Number of instalment for each player

l_θ= Loan of the players

(22)

Overhead costs of the port operators are calculated as sum of office costs ($OFFC_\theta$), concession costs ($CONC_\theta$), staff costs (STC_θ), and other overhead costs ($AOHC_\theta$).

$$OHC_\theta = OFFC_\theta + CONC_\theta + STC_\theta + AOHC_\theta$$

(23)

Additional costs (AC_θ) is given as sum of insurance costs (IC_θ) and extraordinary costs (EOC_θ).

$$AC_\theta = IC_\theta + EOC_\theta$$

(24)

4.3.3 Costs of Bunker Suppliers

The total costs of the bunker suppliers are defined as sum of the bunker product cost (PC_θ), operation costs (OC_θ), Capital Cost of the bunkering facilities (CC_θ) , and other additional costs (AC_θ). $\theta = (1,2,3,4)$

$$TC_\theta = PC_\theta + OC_\theta + CC_\theta + AC_\theta$$

(25)

The bunker product cost (PC_θ) of the bunker suppliers is determined as following.

$$PC_\theta = PP_\theta + LC_\theta + PT_\theta$$

Where;

PP_θ= Product price Index

LC_θ= Logistics costs of the product

PT_θ= Regional product tax rate

(26)

The operation costs (OC_θ) of the bunker suppliers are illustrated with the following formula:

$$OC_\theta = SC_\theta + HC_\theta + BC_\theta + ADC_\theta + LABC_\theta$$

Where;

SC_θ= Storage costs of the product unit for the players

HC_θ= Heating-cooling costs of the product for each player

BC_θ= Barging costs of the players

ADC_θ=Administration costs of the players

$LABC_\theta$= Labour costs of the players

(27)

Capital cost of the each bunker supplier (CC_θ) is calculated as following.

$$CC_\theta = EAC_\theta + MCC_\theta$$

Where;

EAC_θ: Equipment asset costs of the bunker facilities

MCC_θ: Miscellaneous capital costs of bunker suppliers

$$EAC_\theta = CP_\theta + n_\theta * \frac{r_\theta * (1 + r_\theta)^{n_\theta}}{(1 + r_\theta)^{n_\theta} - 1} * l_\theta$$

Where;

CP_θ = Cash price of the facilities each player invested

r_θ = Interest rate of the player‘s facilities for adequate time period

n_θ = Number of instalment for each player

l_θ= Loan of the players

(28)

In addition to given costs, some additional costs have also arisen for the bunker suppliers. Additional costs (AC_θ) of the bunker suppliers could be considered as sum of insurance cost (IC_θ), and inspection and survey cost (ISC_θ).

$$AC_\theta = IC_\theta + ISC_\theta$$

(29)

4.4. Capacity Investment Decision

Let δ_θ be a particular additional capacity decision that shipping liners could employ on the liner shipping service by enlarging the average ship size. New capacity of a shipping alliance could be expressed as:

$$q'^{*}_{\theta} = q^{*}_{\theta} + \Delta\delta_\theta$$

Where;

$\Delta\delta_\theta$ is 0 or $\pm\ \delta_\theta$ (increasing or reducing the capacity) q'^{*}_{θ}

is capacity allocation of in the new scenario.

(30)

In the final form of the previous equations, we can simply show the capacity allocations as:

$$q'_\theta{}^{*} = \frac{P\prime - c_{\theta}\prime}{3b_\theta}, \theta = 1,2,3,4$$

Where;

P' is the new freight rates based on the capacity deployment decision $c_\theta{}'$ is

the new cost per container based on the capacity deployment decision.

(31)

The same formulations given in this section can also be utilised for the capacity investment decisions of the port operators and bunker suppliers.

4.5. Nash Equilibrium of the Game with Complete Information

In a heterogeneous four player game let $N = \{1,2,3,4\}$ be the set of the players. The pure strategy set of the player $\theta \epsilon N$ is denoted by $S^\theta = \{s_\mu{}^\theta | \mu \epsilon M_\theta\}$ with $M_\theta = \{1, \ldots m_\theta\}$ where it is assumed that all players have m_θ=2 pure strategies in order to simplify the model (Adapted from Wu *et al.*, 2014). The set of all pure strategy profiles is $S = \prod_{\theta=1}^4 S^\theta$. The profit payoff function of player $\theta \epsilon N$ is denoted by $\pi^\theta: S \to R$.

It is possible to represent the total number of pure strategies in the quadropoly game as $\sum^4{}_{\theta=1} m_\theta$, and pure strategy combinations in the game as $\prod_{\theta=1}^4 m_\theta$. Thus, the number of pure strategies in game is 8 and the pure strategy combinations in the game is 16.
Briefly, all pure strategy combinations in the game could be shown as following.

$(s11, s21, s31, s41)$

$\coloneqq Combination\ 1$

$(s11, s22, s13, s14)$

$\coloneqq Combination\ 2$

$(s11, s12, s23, s14)$

$\coloneqq Combination\ 3$

$(s11, s12, s13, s24)$

$\coloneqq Combination\ 4$

$(s11, s22, s23, s14)$

$\coloneqq Combination\ 5$

$(s11, s22, s13, s24)$

$\coloneqq Combination\ 6$

$(s11, s12, s23, s24)$

$\coloneqq Combination\ 7$

$(s11, s22, s23, s24)$

$\coloneqq Combination\ 8$

$(s21, s22, s23, s24)$

$\coloneqq Combination\ 9$

$(s21, s12, s23, s24)$

$\coloneqq Combination\ 10$

$(s21, s22, s13, s24)$

$\coloneqq Combination\ 11$

$(s21, s22, s23, s14)$

$\coloneqq Combination\ 12$

$(s21, s12, s13, s24)$

$\coloneqq Combination\ 13$

$(s21, s12, s23, s14)$

$\coloneqq Combination\ 14$

$(s21, s22, s13, s14)$

$\coloneqq Combination\ 15$

$(s21, s12, s13, s14)$

$\coloneqq Combination\ 16$

Where;

$s_\mu{}^\theta$ means τ^{th} pure strategy of θ^{th} player and each player has 2 available strategies in a four player game for $\theta = (1,2,3,4)$ and $\mu = (1,2)$.

(32)

With the given strategy combinations the utility profit payoff (π) combination matrix of the players in quadropoly is identified as below.

$$
\begin{matrix}
\pi 11 & \pi 12 & \pi 13 & \pi 14 \\
\pi 21 & \pi 22 & \pi 23 & \pi 24 \\
\pi 31 & \pi 32 & \pi 33 & \pi 34 \\
\vdots & \vdots & \vdots & \vdots \\
\pi 151 & \pi 152 & \pi 153 & \pi 154 \\
\pi 161 & \pi 162 & \pi 163 & \pi 164
\end{matrix}
$$

Where;

$\pi_\tau{}^\theta$ means τ^{th} utility profit payoff of θ^{th} player in a four player's game with two strategy choices for $\theta = (1,2,3,4)$ and $\tau = (1,2,3,4,5,6, \dots ,16)$.

(33)

F, the solution concept**,** is formulated as $F \,:\, \{s_1^\theta, \dots s_\mu^\theta, ,\pi_1^\theta, \dots, \pi_\tau^\theta\} \rightarrow s_\mu^{\theta^*}$. The strategy combination $s_\mu^{\theta^*}$ is the Nash equilibrium if no player has an incentive to deviate from his strategy given that the other players also do not deviate from their strategies. Formally Nash equilibrium best response function can be shown as follows (Bergemann, 2006):

$$\forall\theta, \forall\mu, \forall\tau \quad \pi_\tau^\theta \left(s_\mu^{\theta^*}, s_{-\mu}^{\theta}{}^*\right) \geq \pi_\tau^\theta \left(s_\mu^{\theta'}, s_{-\mu}^{\theta}{}^*\right), \forall s_\mu^\theta$$

Where; $s_{-\mu}^{\theta}{}^*$ is the Nash equilibrium best response strategies of the other

players $s_\mu^{\theta'}$ is any alternative strategy of player θ

(34)

Another way of expressing the inequality of Nash equilibrium can be given with the below formula (Zhang, 2014).

$$\forall\theta, \forall\mu, \forall\tau \quad \pi_\tau^\theta\left(s_\mu^{\theta^*}, s_{-\mu}^{\theta}{}^*\right) = argmax_{s_\mu^{\theta'}}\, \pi_\tau^\theta\left(s_\mu^{\theta'}, s_{-\mu}^{\theta}{}^*\right), \forall s_\mu^\theta$$

Where; $s_{-\mu}^{\theta}{}^*$ is the Nash equilibrium best response strategies of the

other players $s_\mu^{\theta'}$ is any alternative strategy of player θ

(35)

The above formula can also be considered as an optimisation problem. The Nash equilibrium defines that each player's best response strategy to other player's best Nash strategy is optimal solution of the game.

4.6. Bayesian-Nash Equilibrium of the Game with Incomplete Information

Many situations of the actual business cases do not contain perfectly completesymmetric market information for the players. In these cases, the Nash equilibrium requires an update of player's belief according to the widely applied probabilistic Bayes Theorem. The Bayesian-Nash equilibrium is indicated as the following equation (Zhang, 2014).

$$\Gamma^{\theta} = (N, (S_{\theta})_{\theta \in N}, (T_{\theta})_{\theta \in N}, (p_{\theta})_{\theta \in N}, (\pi_{\theta})_{\theta \in N})$$

Where;

$N = \{1,2,3,4\}$ is the set of the players and $\theta \in N$ is the player in the quadropoly game.

S_{θ} is set of strategy actions for each players

T_{θ} is set of possible types for each players

p_{θ} over $T_{\theta}$is probability function of the players

π_{θ} is payoffs of the players

(36)

Let $T_{-\theta}$ symbolise all possible combinations of types for all players except the player θ. The conditional probability of $p_{\theta}(t_{-\theta} \setminus t_{\theta})$, $t_{-\theta} \in T_{-\theta}$ indicates the belief of player θ about the other players type given that his type is t_{θ}. If we define the

Cartesian strategy action set $A = \prod_{\theta \in N} A_{\theta}$ and $T = \prod_{\theta \in N} T_{\theta}$ then the profit payoffs $\pi_{\theta}(\cdot)$ of the players can be defined over the set $A * T$. Let $\tilde{a} = (a_1, a_2, a_3, a_4)$ be a typical member of A and $\tilde{t} = (t_1, t_2, t_3, t_4)$ be a typical member of T. We can define the payoff function of the player θ as $\pi_{\theta} = (\tilde{a}, \tilde{t})$ by consideration of the player's action ($\tilde{a}$) and player's type ($\tilde{t}$). In addition, the players' actions are functions of their types which can be shown as $a_{\theta} = s(t_{\theta})$. In a four player game with incomplete information, the strategies $(s_1^*, s_2^*, s_3^*, s_4^*)$ are Bayesian-Nash pure strategy equilibrium if for each player θ with finite type t_{θ}, $s_{\theta}^*(t_{\theta})$ is the solution of below equation ($n = 4$).

$$max_{a_{\theta} \in A_{\theta}} \sum_{t_{-\theta} \in T_{-\theta}} \pi_{\theta}(s_{1*}(t_1), s_{2*}(t_2), \dots , s_{\theta *-1}(t_{\theta -1}), a_{\theta}, s_{\theta *+1}(t_{\theta +1}), \dots , s_{n*}(t_n); t) p_{\theta}(t_{\theta -1} \setminus t_{\theta})$$

(37)

In the case that types are infinite, the definition of the above equation could be reduced to:

$$\int \pi_\theta(s_\theta^*(t_\theta), s_{-\theta}(t_{-\theta}), t_\theta, t_{-\theta}) p_\theta(t_{-\theta} \backslash t_\theta) dt_{-\theta}$$

(38)

Therefore, for each player of the quadropoly with condition of $\forall a_\theta \in A_\theta, \forall t_\theta \in T_\theta$ ($\theta = 1,2,3,4$) , the Bayesian-Nash best response functions could be described as following ;

$$\forall a_\theta \in A_\theta, \forall t_\theta \in T_\theta, \int \pi_\theta(s_{\theta*}(t_\theta), s_{-\theta}(t_{-\theta}), t_\theta, t_{-\theta}) p_\theta(t_{-\theta} \backslash t_\theta) dt_{-\theta}$$

$$\geq \int \pi_\theta(a_\theta, s_{-\theta}(t_{-\theta}), t_\theta, t_{-\theta}) p_\theta(t_{-\theta} \backslash t_\theta) dt_{-\theta}$$

(39)

In adaptation of the Bayesian Nash equilibrium to Cournot competition model, which is given in section 4.2, the following profit functions of the players could be written.

$$\pi_1 = \int (a - b_1q_1(t_1) - b_2q_2(t_2) - b_3q_3(t_3) - b_4q_4(t_4) - c_1)q_1p_1(t_{-1} \backslash t_1)dt_{-1}$$

$$\pi_2 = \int (a - b_1q_1(t_1) - b_2q_2(t_2) - b_3q_3(t_3) - b_4q_4(t_4) - c_2)q_2p_2(t_{-2} \backslash t_2)dt_{-2}$$

$$\pi_3 = \int (a - b_1q_1(t_1) - b_2q_2(t_2) - b_3q_3(t_3) - b_4q_4(t_4) - c_3)q_3p_3(t_{-3} \backslash t_3)dt_{-3}$$

$$\pi_4 = \int (a - b_1q_1(t_1) - b_2q_2(t_2) - b_3q_3(t_3) - b_4q_4(t_4) - c_4)q_4p_4(t_{-4} \backslash t_4)dt_{-4}$$

(40)

In order to solve the system, derivatives of the player profits are written as equal to zero.

$$\frac{\partial \pi_1(Q)}{\partial q_1} = \int (a - 2b_1 q_1(t_1) - b_2 q_2(t_2) - b_3 q_3(t_3) - b_4 q_4(t_4) - c_1) q_1 p_1(t_{-1} \backslash t_1) dt_{-1} = 0$$

$$\frac{\partial \pi_2(Q)}{\partial q_2} = \int (a - b_1 q_1(t_1) - 2b_2 q_2(t_2) - b_3 q_3(t_3) - b_4 q_4(t_4) - c_2) q_2 p_2(t_{-2} \backslash t_2) dt_{-2} = 0$$

$$\frac{\partial \pi_3(Q)}{\partial q_3} = \int (a - b_1 q_1(t_1) - b_2 q_2(t_2) - 2b_3 q_3(t_3) - b_4 q_4(t_4) - c_3) q_3 p_3(t_{-3} \backslash t_3) dt_{-3} = 0$$

$$\frac{\partial \pi_4(Q)}{\partial q_4} = \int (a - b_1 q_1(t_1) - b_2 q_2(t_2) - b_3 q_3(t_3) - 2b_4 q_4(t_4) - c_4) q_4 p_4(t_{-4} \backslash t_4) dt_{-4} = 0$$

(41)

Solving the above equations give the following optimal capacity allocations in a game with incomplete information.

$$q_1^* = \frac{a - b_2 \widetilde{q_2} - b_3 \widetilde{q_3} - b_4 \widetilde{q_4} - c_1}{2b_1}$$

$$q_2^* = \frac{a - b_1 \widetilde{q_1} - b_3 \widetilde{q_3} - b_4 \widetilde{q_4} - c_2}{2b_2}$$

$$q_3^* = \frac{a - b_1 \widetilde{q_1} - b_2 \widetilde{q_2} - b_4 \widetilde{q_4} - c_3}{2b_3}$$

$$q_4^* = \frac{a - b_1 \widetilde{q_1} - b_2 \widetilde{q_2} - b_3 \widetilde{q_3} - c_4}{2b_4}$$

Where;

$$\tilde{q}_1 = \int q_1(t_1)\, p_1(t_{-1} \backslash t_1) dt_{-1}$$

$$\widetilde{q_2} = \int q_1(t_1)\, p_1(t_{-1} \backslash t_1) dt_{-1}$$

$$\tilde{q}_3 = \int q_3(t_3)\, p_3(t_{-3} \backslash t_3) dt_{-3}$$

$$\tilde{q}_4 = \int q_4(t_4)\, p_4(t_{-4} \backslash t_4) dt_{-4}$$

(42)

The above equations provide mathematical integration of the probabilistic Bayesian rule and optimal strategy solution of the Nash equilibrium. Therefore, it is possible to analyse outcomes of the games, based on the probability theory and type (symmetry) of the players, where information about the competitor's position are not complete/perfect.

5. DATA COLLECTION

In the following chapters of the thesis, a case-study based analysis approach is adapted to previously given theoretical background and methodological descriptions. Therefore, it is aimed to provide a depth insight to practical applications of the theoretical contributions of the study. Before start to analyse the selected cases, the data collection process is a fundamental research stage requiring to be mentioned in details. Furthermore, the data collection process reliability is very significant for robustness of the research to reflect the practical actuality and, accurate and validate the hypothetical predictions. In this chapter, the data collection processes of the case studies are explained under different technical categories, and the simplification of the data is mentioned in order to provide a better link between utilised data and results of the case studies.

In the study, for the purpose of analysis, various data collection methods and steps are utilised. It is possible to summarise these data collection methods in the following categories:

- Survey questionnaires (including marine transport and logistics experts, shipping liner and customer sides)
- Interviews (including a port expert and a bunker supply expert)
- Row data and published secondary data from reliable data sources
- Processes of recording data and observations
- Assumptions made and assumed data
- Ethical issues and legal procedures of data collection

5.1. Survey Questionnaires data and Interviews

The survey questionnaires and interviews are applied to container port and bunker supplier case parts of the study. Aims of these questionnaires and interviews are determined as applying the expert and customer opinions to get numerical outcomes regarding to their experiences and perspectives from the liner container shipping operations. Especially survey questionnaires and interviews are applied for the case study 2 given in chapter 7 and case study 3 given in chapter 8. Thus, it is achieved to include the opinions of people involved in the liner container shipping industry.

It is possible to numerically illustrate the outcomes of the data by applying different data normalisation scales. The data collected from survey questionnaires were normalised based on allocation of score values between 0-100 where 100 is the best and 0 is the worst performance that criteria are obtained. Therefore, all numerical outcomes of the survey questionnaires are presented in percentage form throughout the case studies of this thesis.

In data collection of the case study 1 given in chapter 7, survey and interview techniques are not required to utilise. In data collection for the case study 2, given in chapter 8, three different survey questionnaires are utilised. Due to Petlim port is not active at the moment; the related data is generated based on the predictions and assumptions of the participants and various previously published studies. The prediction and assumptions of the participants also is asked for the Candarli port which is another inactive state owned port not included to the analysis of the research presented. Firstly, an expert survey is designed on the Qualtrics software (Qualtrics, 2016) and distributed via e-mail to 6 formerly connected maritime transport and logistics experts. It is asked them to compare and weigh the criteria and sub-criteria of the hinterland customer perspective. Secondly, a customer survey is designed on the Qualtrics software and distributed to randomly selected and previously connected 12 freight forwarders and foreign trade experts in Izmir region. It is asked them to score performances of the port alternatives for each sub-criteria of the hinterland customer perspective. Thirdly, a brief shipping liner survey is designed on the Qualtrics software and distributed to three middle and senior level employees of the shipping liners in Turkey. It is asked them to compare and weigh the criteria and subcriteria of the shipping liner perspective to port services. The statistical summary of the survey questionnaire participants are given in the following table.

Table 5.1: Statistical summary of the survey questionnaire participants

Survey Type	Number of	Male	Female	Academics	Professional	Average
Expert	6	5	1	5	1	10 years
Customer	12	8	4	2	10	5 years
Shipping Liner	3	3	0	0	3	5 years

(Source: Own work)

An interview is also organised with a senior level employee of a port operator in Turkey. His knowledge, opinions, assumptions and experiences regarding the port operation and financial structure of the port operators are elaborated and utilised in the cost calculations of the port operators in case study 2 given in chapter 7. Another interview is also arranged with an experienced bunker supplier company manager in Turkey to reveal the cost elements of the bunker suppliers, which is difficult to find in academic publications, and adapt it to the developed future LNG bunkering scenario. During this interview also proportional weights of each cost element in the total cost are determined. Specific handling process of the different bunker types are mentioned by the bunker supplier company manager and his predictions about LNG bunkered liner container shipping is learned.

Both interviews are structured as 60 minutes via online face to face communication system software skype. The approximate time arrangements of the interviews are structured as following:

- Interview opening part : 5 minutes
- Providing information regarding the research:10 minutes
- Gathering information from the respondent: 40 minutes
- Interview closing part: 5 minutes

During the process of gathering information from the respondents, the following interview question principles are applied.

- Mostly open-ended questions are utilised
- Leading questions are avoided
- Issues in depths are probed
- The interviews are carried out fully in the framework of the research data requirements
- Minimum 80% of the total interview times are used by the participants

5.2. Raw and Published Data

Unfortunately due to the confidentiality of the financial and operational information of the liner container shipping counterparties, it was not possible to collect primarily operational and financial data from directly to liner container shipping counterparties. In addition, some commercial market data suppliers could not be utilised due to the funding limitations of this study. However, various limited free available secondary data sources were utilised throughout this research. Especially, the following main sources were utilised in case studies, and referenced throughout the text and reference list of this thesis:

- International Transport Forum (ITF)
- Alphaliner
- Drewry Maritime Research
- BP Statistical Review of World Energy
- The World Container Index

- OECD
- PR News Service
- United Nations Conference on Trade and Development
- Seaport Group
- DNV GL
- Lloyd Register
- Previous PhD and MSc Studies
- Publications of the Transport Ministry of Turkey
- Port Economics

5.3. Recording Data and Observations

This study considers “code of practice on investigations involving human beings” of the University of Strathclyde. Throughout the data collection process the requirements of “the data protection act (DPA) 1998” are satisfied completely. The following data protection principles are applied in this thesis:

- The data is considered fairly and lawfully
- The data is presented with a respect to confidentiality of individuals and actual company data
- All collected data is used only for the research purposes
- The data is protected from unauthorised access
- The data is processed according to data subject’s rights
- The data is used accurately in the research

The data recording process is structured according to section D of “code of practice on investigations involving human beings” of the University of Strathclyde. This section identifies following issues regarding the data recording:

- Data management and planning procedures
- Data security
- Data sharing
- Retention of data
- Disposal of data
- Departmental ethics committee data records
- Departmental ethics committee data monitoring

5.4. Ethical Issues

Research ethics requirements of the University of Strathclyde are strictly considered throughout data collection, analysis and presentation processes of this research. As a requirement of ethical part of the university's scientific research standards, the following issues were taken into account in the establishment of the survey questionnaires and interviews:

- The appropriate permission of people involved into this research regarding to confidentiality of the data and their individual and organisational identities were considered.
- Interviews and questionnaires were well structured in terms of diversity of the participants, and the words were chosen in order not to cause any physical or emotional harm to the participants.
- The research makes sure that data collection approach developed is fair enough and maintains the law of objectivity.
- Any person's thoughts or writings used at any stage of the data collection and case study development were acknowledged.

- ➢ In the case of anonymity, the subjects were informed about publication of this research.
- ➢ The participants were selected based on their best benefit to the requirements of the research and not because they were easy to collaborate.
- ➢ The observed data were presented and analysed accurately throughout this research.

6. CASE STUDY 1: SHIPPING LINER ALLIANCES' GAME

The first case study of this thesis is the numerical application of the previously developed methodology, as in chapter 4, on the shipping liner alliance structure in 2015. According to the generated base case scenario, there is an oligopolistic control of four fully competitive shipping alliances on a specific liner shipping trade route. In this scenario, the most competitive trade route is identified as the Asia-Europe trade route. As a main focus of the detailed numerical analysis, a typical Far- EastNorthern Europe liner shipping service loop and its market structure is utilised. In the cost calculations, ports of call and voyage schedules are assumed as identical for all competitors. Liner shipping services of the other standalone operators and slot charter agreements between competitor alliance members are excluded and their market impacts are disregarded. Therefore, a perfectly competitive market structure is demonstrated as assumed in the theory and a detailed numerical application of the methodology is enabled.

In this chapter, firstly, some background information of the liner shipping alliances and their historical transformations of the alliances are given. Secondly, the methodology is applied to a hypothetical Far East- North Europe liner service loop case study. Moreover, results of the case study are analysed and discussed for both complete and incomplete information states of the players. Furthermore, current and equilibrium point cash flow analysis of the shipping alliances are illustrated. Finally, an outline of the case study and recent developments in the shipping alliance formations are given, and some future predictions regarding the Far East- North Europe liner service are mentioned.

6.1. Quadropolistic Competition Analysis of the Shipping Alliances

The liner container shipping industry plays a critical role in the viability of the international trade. Therefore, the market behaviours and allocation of the liner shipping service capacities is a great interest of the global trade counterparties. Historically, the liner container shipping market was controlled by conference monopolies for a very long time until the anti-trust legal enforcements ended their cartels. During this period the shipping liners had been exempted from anti-trust legislations of the trade law, and freight rate fixing were allowed (UNCTAD, 2014). In 1990s the freight rate fixing was banned and the liner shipping conferences were replaced by the shipping alliances which have been established to respond the requirements of slot chartering, sharing capital investment risks, improvement of the network coverage, and support of strategic operational and management decisions among cooperative competitor container shipping liners (Shi and Voss, 2011).

The liner shipping alliances utilises strategic decision-makings and tactical planning of members in order to gain operational flexibility, sustainability and cost efficiency due to the shared utilisation service capabilities. The liner shipping alliances have experienced competitive developments and evolutions since 1995. In 1998, due to cross-alliance mergers and acquisitions, the form of shipping alliances changed and The New World Alliance replaced Global Alliance (Doi *et al.*, 2000). This trend extended to other alliances and continued until China's rejection of the Pioneer 3 shipping alliance network. Thus, the shipping liners were enforced to develop new perspectives for their strategic alliances. As shown in the following figure, in 2015 the shipping alliances were shaped as four competitors as a consequence of the rejection of the P3 alliance.

Figure 6.1: Historical development of the shipping alliances (Source: Notteboom, 2016)

The present market tolerance is a significant indicator of the optimal ship size determination. Therefore, optimal capacity deployment via optimal average ship size selection needs to maintain the market based perspective of the liner container shipping services. The liner container shipping alliances are established to provide better utilisation of the mega container vessels. However, the additional capacity investment of individual alliance members requires on their mega vessel newbuilding orders as well as the financial consequences of their capacity deployment decisionmaking rationales (Notteboom, 2004).

As aforementioned in chapter 2, the density of liner container shipping services mostly congregates on certain shipping routes, and generates major trade network markets. This density, in addition to transatlantic, transpacific and Far East-Europe trade, East-West trade is also considered as a separate market shared between the competitor alliances. The market supply shares of the alliances comparisons as per main route areas are given in figure 6.2.

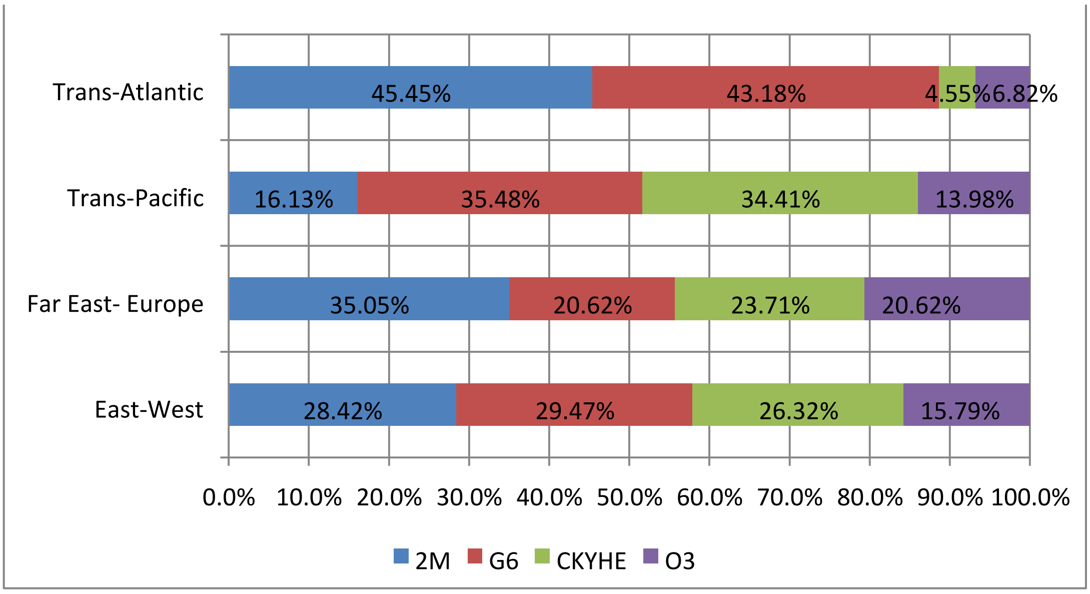


Figure 6.2: Market shares of the liner shipping alliance supply capacities

(Source: Own elaborations based on Alphaliner, 2015 data)

On the other hand, the following pie chart shows the weekly demand shares of the alliances for the Far East- Europe liner trade market.

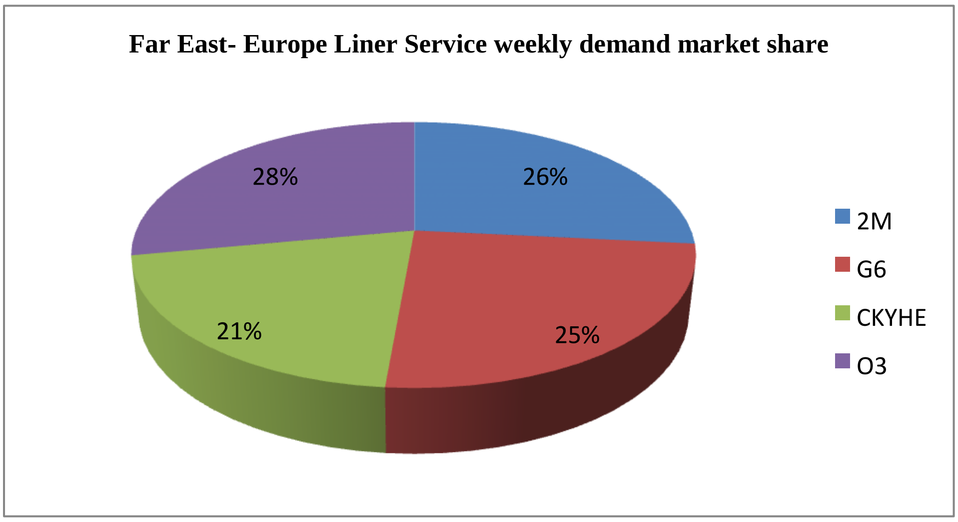


Figure 6.3: Market shares of the liner shipping alliance weekly demand for Far East-Europe Services

(Source: Own elaborations based on Alphaliner, 2015 data)

6.2. The Far East-Northern Europe Liner Service Loop

In this section, the methodology is applied to an idealised liner shipping service loop. Nevertheless, the approach of this case study assumes the liner shipping service of the global liner shipping alliances as identical with routes and port of calls and each alliance utilises a certain average ship size on the given liner shipping service route. The route consists of, including east bound and west bound, 13 voyages between 14 port of calls namely; Qingdao, Kwangyang, Busan, Shanghai, Yantian, Singapore, Algericas, Hamburg, Rotterdam, Le Havre, Algericas, Singapore, Yantian and Qingdao. Due to the Qingdao port being called at for a second time at the end of the round trip it is excluded from port of calls and the total port of calls for one round trip, and the number of port of calls is accepted as 13. The visual illustration of the identically assumed Far East- Northern Europe liner service loop is illustrated below.

Figure 6.4: Typical Far East-Northern Europe liner shipping service

For the given service loop, the current average freight rate is identified as $650/TEU based on 2015 Shanghai-Rotterdam and Rotterdam- Shanghai rates of the world container index data. Thus, the market slope values of the alliances are determined as $b_{2M} = 0.003248$, $b_{G6} = 0.003612$, $b_{CKYHE} = 0.002269$, $b_{O3} = 0.004404$, and the a value is given as 900. It is assumed that the round trip time of the service loops are the same for all shipping alliances and considered as 30 days for the West Bound and 40 days for the East Bound. The bunker prices are considered as constant annually and $200 per tonne. It is assumed that all shipping services have an annual 15 days (2 weeks) delay. The port charges are accepted as $15,000 for all port of call~~s~~ and all ship sizes. In addition, the voyage costs, the capital cost and the operational costs are calculated based on the deployed ship sizes. The annual additional costs of the players are considered approximately equal and as $500,000 ship/year.

The present market characteristic of the given liner container shipping service is shown in Table.6.1 including average ship sizes, weekly demands, capacity utilisation rates, and average profits per TEU.

Table 6.1: Properties of the liner shipping alliances for the service route

Properties	**2M**	**G6**	**CKYHE**	**O3**
Av. Ship Size 2015(TEU)	14,000	12,300	10,800	13,400
Weekly Demand (TEU)	11,167	10,400	8,667	11,750
Capacity Utilisation Rate	79.76%	84.55%	80.24%	87.68%
Round Trip (Days)	70	70	70	70
Number of Ships Utilised	10	10	10	10

(Source: Drewry, 2016)

6.3. Cash Flow Analysis of the Alliances for the Liner Service Loop

Before the establishment of a decision scenario and analysis of tactical behaviours of the alliances, in a particular liner shipping service loop, it is required to exhibit the situation of the market at the decision-making moment. According to calculations of the data at the decision-making period, the cost distributions per unit carried of the competitors are illustrated in the following figure.

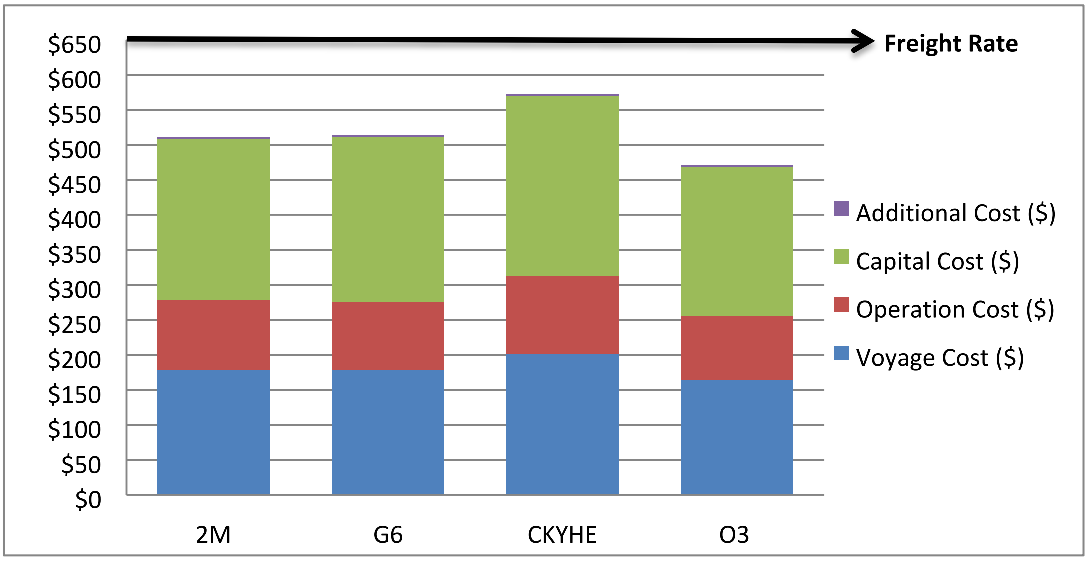
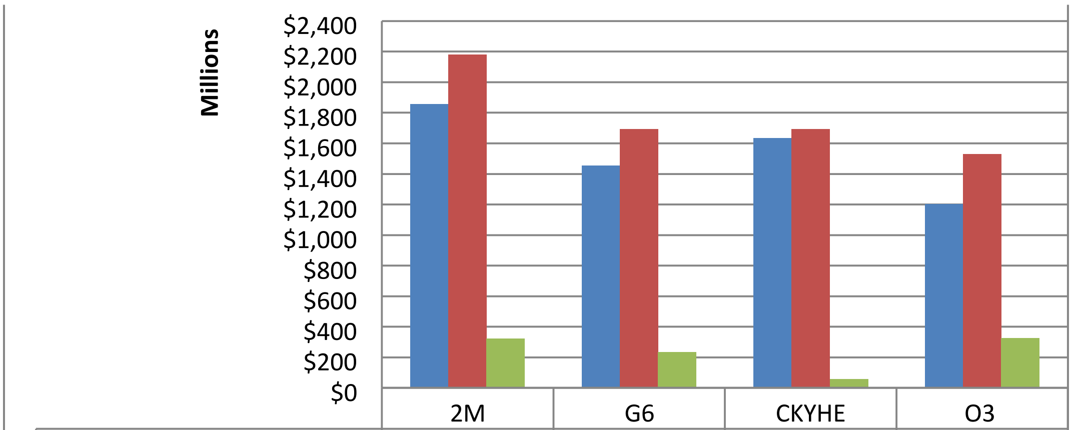


Figure 6.5: The cost per unit distributions of the alliances at decision-making moment
(Source: Own work)

Approximate cash flows of the competitor alliances according to the market situation in 2015 can be calculated by assuming the weekly demands, round trip days, number of ports of call, number of ships and average ship size identical with the given scenario. Due to the alliances obtaining a different number of identical liner service loops it is required to consider the sum of all loops together in order to find total cash flow of the Far East-Northern Europe liner container shipping market. Figure 6.6 shows the total revenue, cost and profits of the alliance for $650 freight rate per TEU.



	2M	G6	CKYHE	O3
Annual Cost for Services ($)	1855620000	1455920000	1633884000	1201424000
Annual Revenue for Services ($)	2179513418	1691512160	1691577218	1528866760
Annual profit for services ($)	323893418.2	235592160	57693218.16	327442760

Figure 6.6: Approximate total cash flow of all Far East-Europe services of the alliances in 2015
(Source: Own work)

One of the most significant indicators to assess investment and managerial performance of the shipping business is the profit-cost ratios, which are calculated and indicated in figure 6.7. According to the figure, O3 alliance performed best in 2015 in terms of high profit-cost ratio. On the other hand, CKYHE achieved only 3.53% profit-cost ratio and remained under the minimum requirement of feasibility.

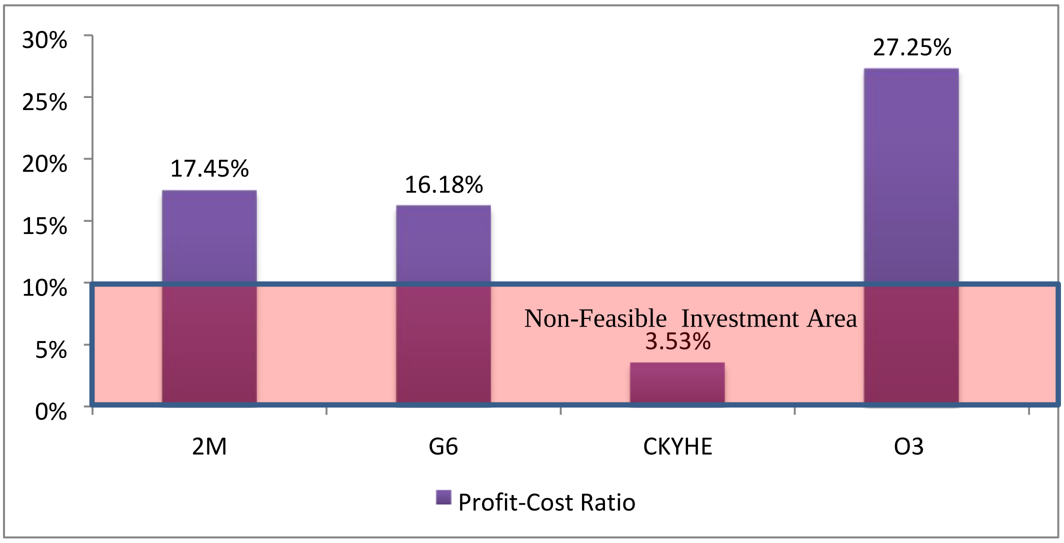


Figure 6.7: Profit-cost ratios of the alliances for East-Northern Europe liner trade market
(Source: Own work)

6.4. Scenario Building of the Shipping Liner Alliance Game

In order to analyse the competition state of the market, 2 years from present, a market scenario is generated. In this scenario, the bunker prices will climb up to $250 per tonne. It is assumed that the demand for each liner service will increase by 3.4% annually (UNCTAD, 2016). The round trip days, number of ships on the service, annual round trip per ship, number of port of calls, port charges, and annual additional costs are assumed as same as the present. It is proposed that CKYHE is the first rational player who needs to take a rational action regarding capacity deployment decision-making due to its lower profit. Then, the G6 is the second rational player and the 2M and O3 are adaptive players. It is assumed that the competition game is static and the players determine their best strategies by consideration of the tactical strategy behaviours of the competitor shipping alliances.

According to the given scenario each player has 2 available strategy options given below:

1- No average ship capacity increase on the current average ship capacity

2- 2000 TEU capacity increase on the existing average ship capacity

Therefore, the pure strategy combinations of the alliances for capacity deployment decision-making are given as follow:

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 1$$

$$(s^{CKYHE}_{No\ Increase}\ , s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 2$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 3$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 4$$

$$(SNoCKYHE\ Increase, S+G20006\quad TEU, S+2M2000\ TEU, SNoO3\ Increase) \coloneqq$$

$$Combination\ 5$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 6$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 7$$

$$(SNoCKYHE\ Increase, S+G20006\ TEU, S+2M2000\ TEU, S+O20003\ TEU) \coloneqq Combination\ 8$$

$$(S+CKYHE2000\ TEU, S+G20006\ TEU, S+2M2000\ TEU, S+O20003\ TEU) \coloneqq Combination\ 9$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 10$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 11$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 12$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 13$$

$$(S+CKYHE2000\ TEU, SNoG6\ Increase, S+2M2000\ TEU, SNoO3\ Increase) \coloneqq Combination\ 14$$

$$(s^{CKYHE}_{+2000\,TEU}, s^{G6}_{+2000\,TEU}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 15$$

$$(s^{CKYHE}_{+2000\,TEU}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 16$$

The Cournot-Nash complete information quadropoly game model is generated by an available commercial software called GamePlan 3.7 (Langlois, 2000) and is illustrated in figure 6.8. According to this model, the first two players chose rational strategies according to Nash pure strategy solution concept. The third and fourth players develop adaptive strategies according to the direction of the market situation. In figure 6.8, the players are shown with different colours. While CKYHE is shown in blue, G6 is depicted with red, 2M is shown in green and O3 with black. The game model of the case includes also the following elements:

- The name and order of the players, and their strategy options
- The decision node connections of the players
- The pay offs of the player for each strategy combinations

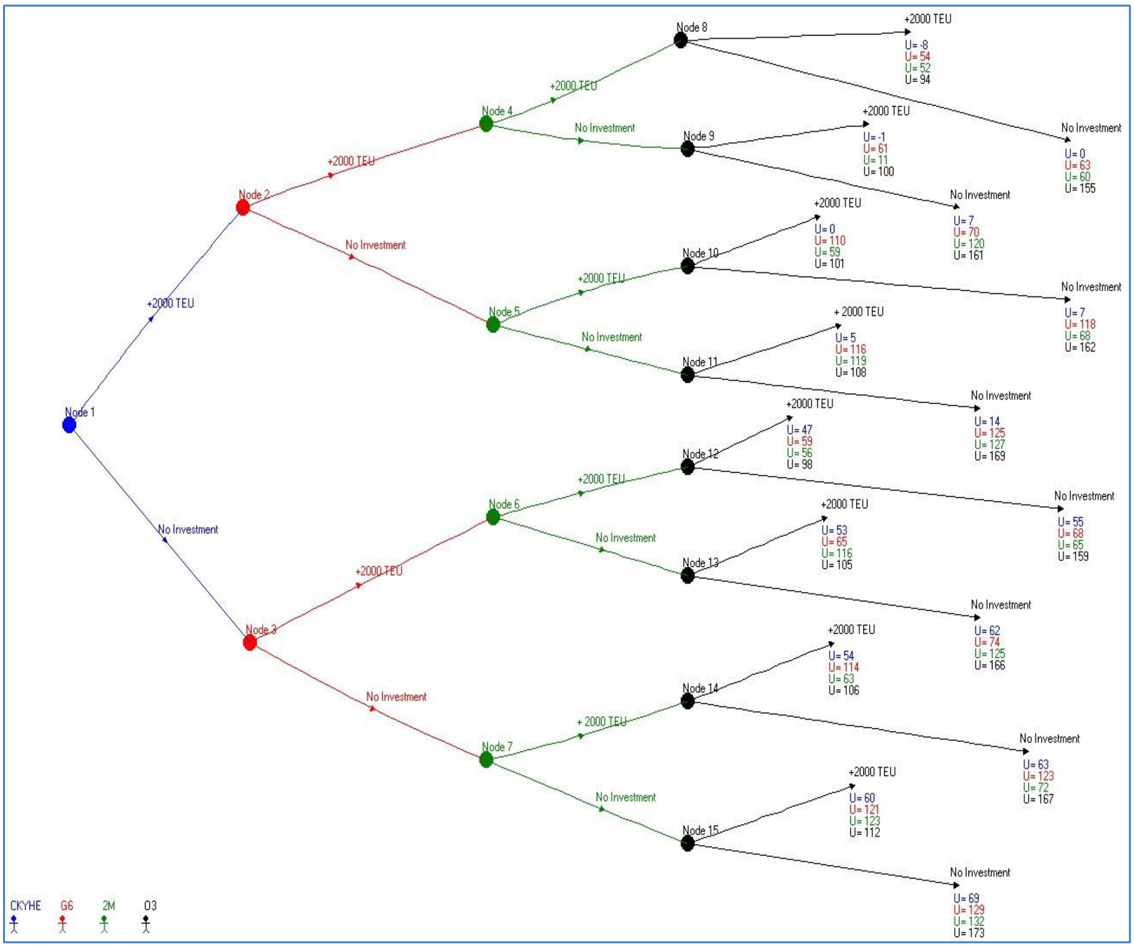


Figure 6.8: Game model of the case study 1 (Source: Own work)

6.5. Shipping Liner Alliance Game Results with Complete Information

The quadropolistic analysis of the capacity provides many results regarding tactical competition strategy outcomes. These results includes market freight rates, costs of TEU transported for all players, profit distribution of the players according to selected strategy combinations, Nash equilibrium and Bayesian-Nash equilibrium points of the strategy combinations. In addition, the results of the model provide annual cost elements, revenue, and profit comparisons of the competitor shipping alliances at the equilibrium point. Therefore, by applying the approach developed in this study, it will be possible to reach financial outcomes of the chosen competitive investment strategies.

In order to reach the desired results, all cost calculations are completed on MS EXCEL 2010 software. As aforementioned the Cournot game model is generated by utilisation of GamePlan 3.7. In addition, another freely available software called SGSolve (Abreu *et al.*, 2016) is utilised to better analyse tactical behaviours of the rational players. SGSolve is also applied to find Bayesian-Nash equilibrium of the incomplete game forms.

In figure 6.9, the changes of the freight rates of the market according to the chosen strategy combinations are given. It is also possible to understand revenue changes of the players from the freight rates. Based on the given freight rates, it is understood that capacity increases investment in the current market situation and further reduces the market freight rates and revenues of the liner container shipping alliances. While strategy combination 1 is providing the highest freight rates, strategy combination 9 provides the lowest freight rates and revenue.

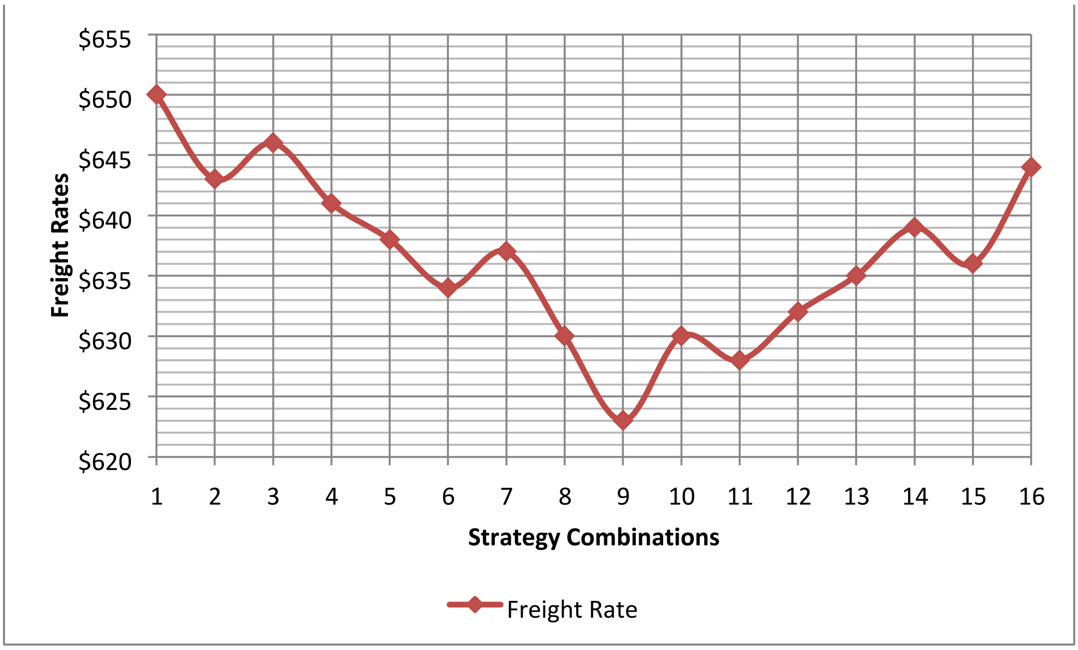


Figure 6.9: Freight rates according to decision strategy combinations (Source: Own work)

The methodology applied in this study calculates the changes to the costs per TEU transported of the alliances for each strategy combination. The cost per TEU changes of the alliances based on the strategy combinations which are given in figure 6.10. According to the determined cost behaviours, the CKYHE shipping alliance has a competitive cost disadvantage against other shipping alliances for all strategy combinations. On the other hand, for all players, whilst additional capacity decision increases the total costs, the decision of keeping the same capacity reduces the costs. Furthermore, due to the steady increase of the demand in seaborne trade, strategy combinations including investment decision mainly causes the increase of the cost per TEU transported.

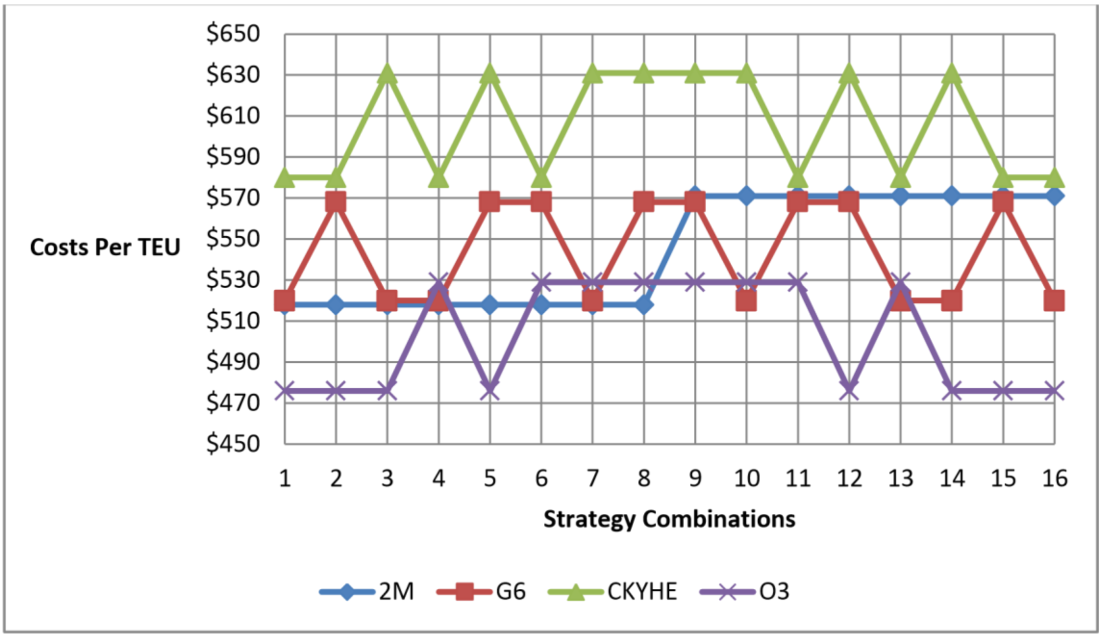


Figure 6.10: Costs per TEU transported according to strategy combinations (Source: Own work)

The most desirable results for the decision-makers was obtained from the Cournot competition game model analysis of this study and are presented in figure 6.11. The figure illustrates profit distribution of the shipping alliances as per each given strategy combinations. Furthermore, from the given figure, it is possible to see the peaks and troughs of the profit distributions for each shipping alliance. Moreover, the profit distribution figure indicates that whilst the highest profit is obtained by O3 alliance with 1st strategy combination, the lowest, and negative, profit is obtained by CKYHE alliance with 9th strategy combination. Therefore, it is possible to see the impacts of competitor behaviours on profit earning more clearly in the liner container shipping market.

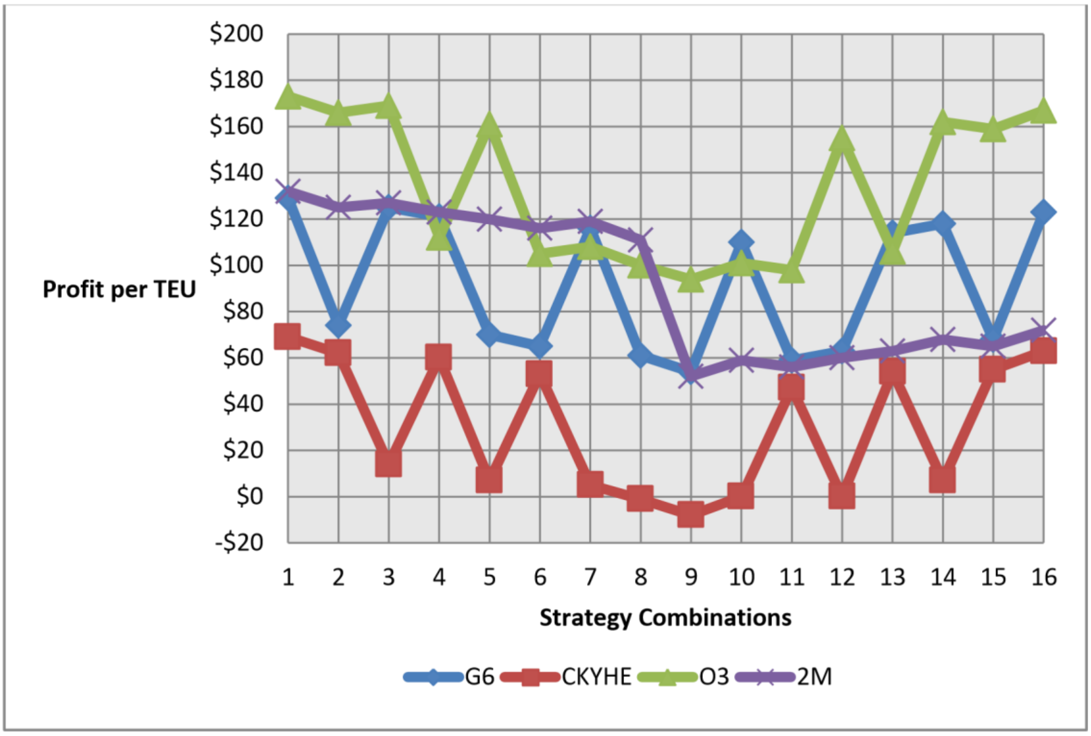


Figure 6.11: Profit distributions according to the strategy combinations of the alliances
(Source: Own work)

The GamePlan 3.7 software provides all pure and mixed solution sets which satisfies Nash equilibrium. Figure 6.12 provides the Nash equilibrium solution results of the game. The pure strategy solutions are normalised by assuming player 1 and player 2 as rational, and player 3 and 4 as adaptive. The strategy combination 1 is determined as the equilibrium point of the game which is illustrated with a complete straight line from the node of the player 1 to player 4. Also, the results on the GamePlan 3.7 software provides some detailed numerical outcomes of the tactical strategy selection of the alliances. The "p" symbols shown in figure 6.12 are the probabilities of each move at each game node. As a consequence of the utilisation of the Cournot-Nash pure strategy solution, p values found as only equal to 0 and 1. Another given symbol "e" is the expected pay offs of the strategy choices between decision nodes.

"E" represents the expected pay offs of each player at each node. "U" shows the zero sum utilities (pay offs) of each final strategy moves.

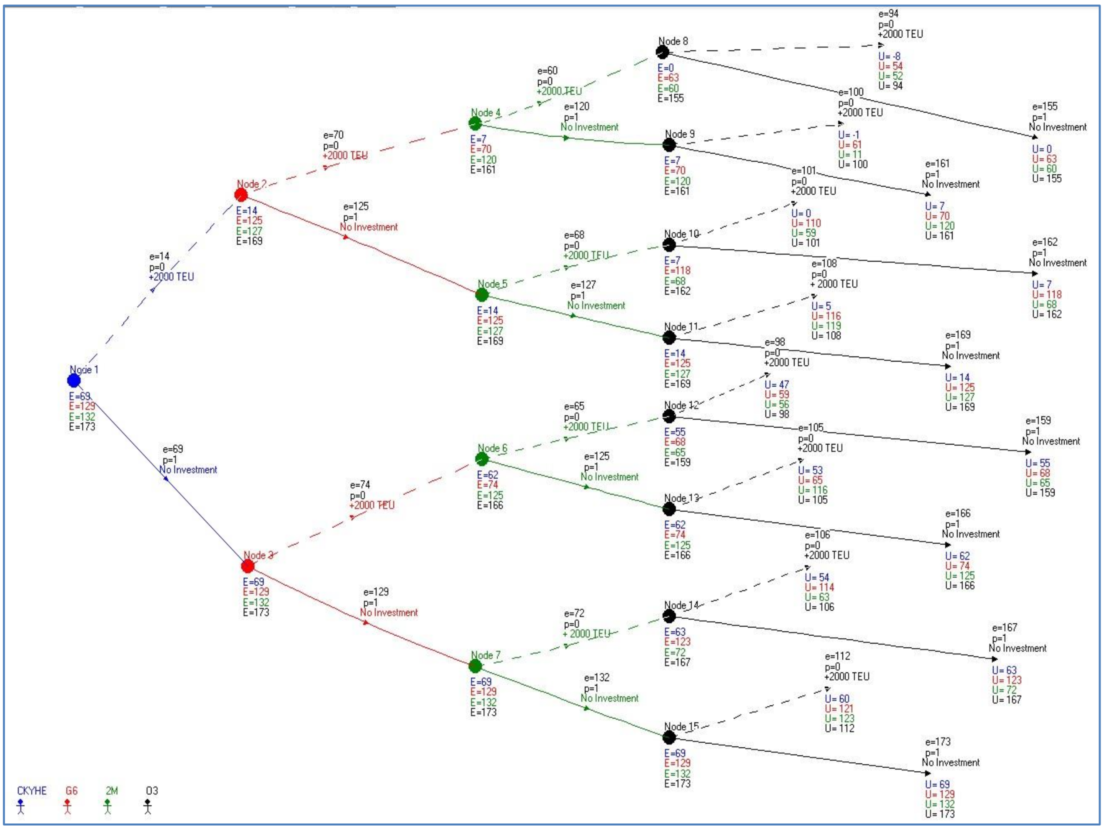


Figure 6.12: Nash Equilibrium solution of the quadropoly game (Source: Own work)

As aforementioned, in this study player 1 and player 2 are assumed as rational, and player 3 and player 4 are accepted as adaptive. In order to better explain tactical behaviours of players in a complete information case, CKYHE and G6 are identified as rational players needing to take action. Moreover, their strategy choice behaviours, according to different market conditions, could be analysed by the utilisation of SGSolver software. Therefore, in order to have a closer view of competition behaviours of player 1 and player 2, four different possible scenarios are generated by accepting competition strategy positions of player 3 and player 4 constant. The equilibrium points of each scenario are illustrated in the following figure. The equilibrium points of the scenarios are shown with star sign on the graphs.

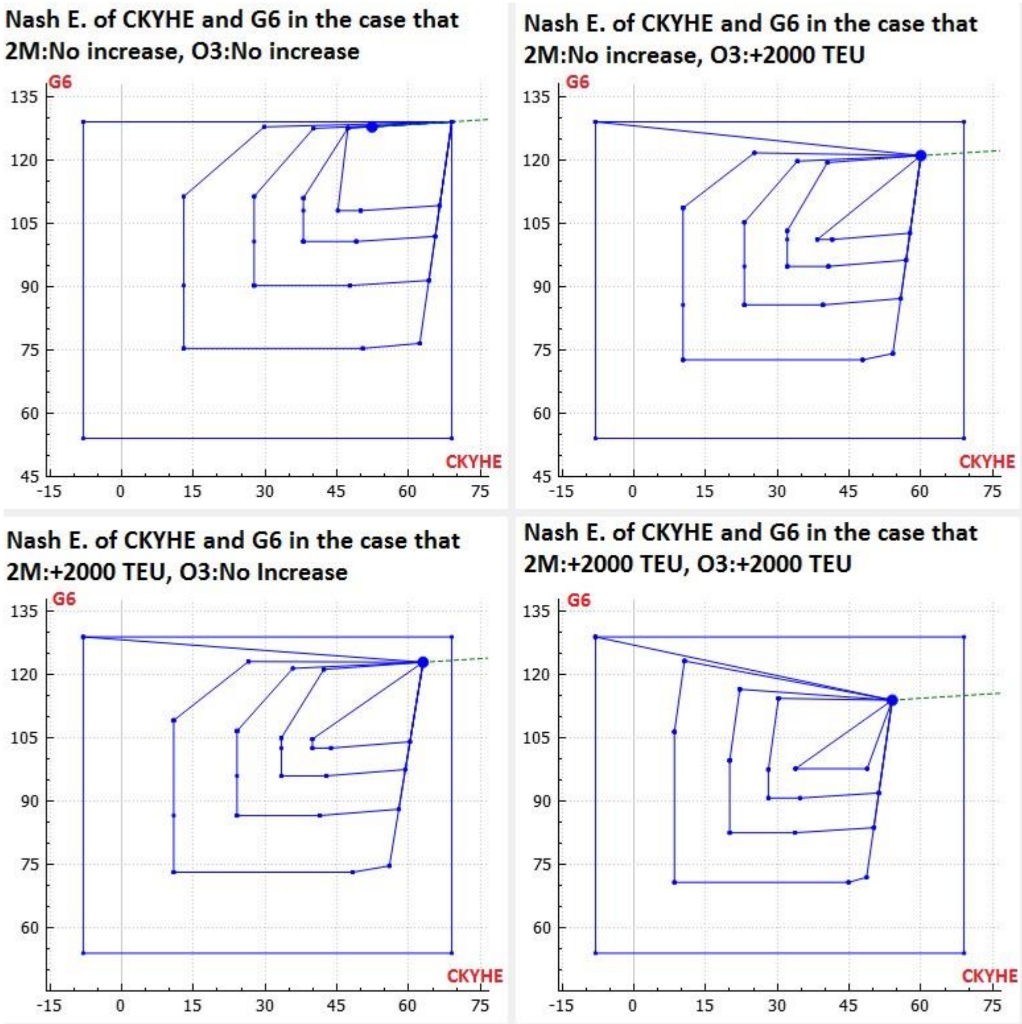


Figure 6.13: Tactical behaviour analysis and Nash equilibrium of the profits of rational players ($/TEU) (Source: Own work)

In holistic consideration of these four different cases, in order to find the Nash equilibrium point of the strategy combinations of the player one and two, SGSolver seeks the most feasible Nash equilibrium point. According to the given solution, the strategy combination that satisfies Nash equilibrium is determined as USD 69 and USD 129 which is strategy combination 1 and given in the following graph.

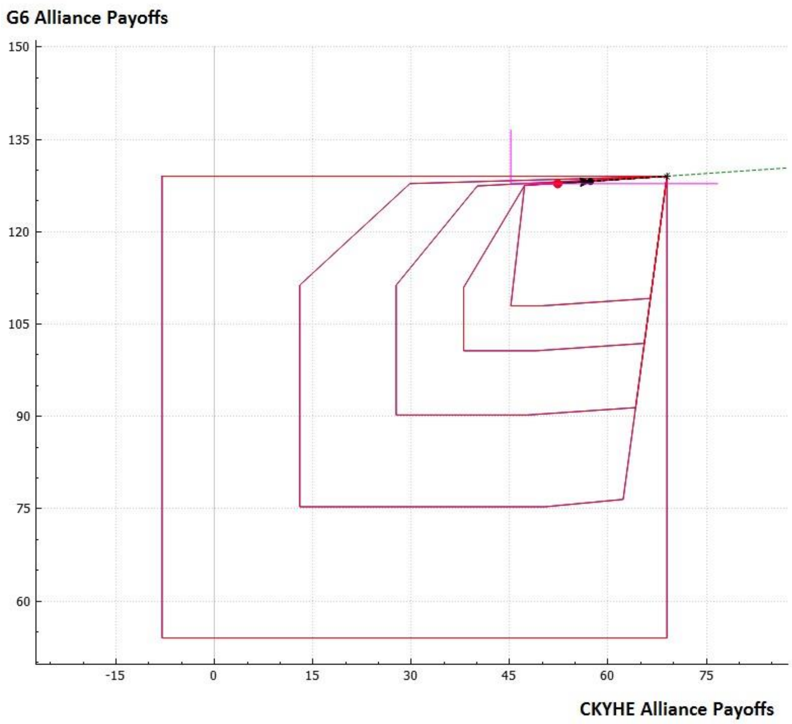


Figure 6.14: Nash equilibrium of the profits of rational players ($/TEU) (Source: Own work)

After the determination of the equilibrium point of the game by applying both GamePlan 3.7 and SGSolver softwares, the financial situations of the alliances are also comparatively analysed according to the equilibrium state as a part of this study. According to results given in figure 6.15 the O3 alliance is determined as the most competitive shipping alliance.

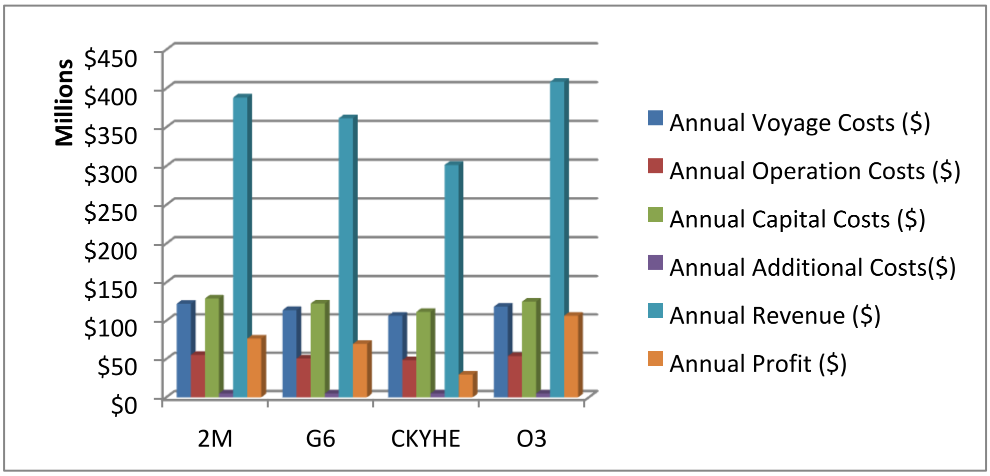


Figure 6.15: Costs, revenues, and profits of the alliances at Nash equilibrium state (Source: Own work)

6.6. The case of the incomplete information of the players

In the liner shipping business, although some annual financial reports and market analysis data exists in most decision-making cases, incomplete information is seen about the competitor behaviours reflecting the practical actuality. Therefore, competition forms of the shipping liner alliances are adapted to another part with incomplete information as well as complete information state in this thesis. Broadly, Bayesian theorem utilises the probabilistic approach in order to identify conditional probabilities of randomly selected probabilities of the players' strategy moves. In table 6.2, Bayes probabilities of the different strategy combinations are given by application of Bayesian conditional probability theorem on the randomly selected probabilities of each decision-making moves of each player.

Table 6.2: Bayes probabilities of the strategy combinations of shipping liner alliances' game

CKYHE	G6	2M	O3	Bayes Probabilities
+2000 TEU	+2000 TEU	+2000 TEU	+2000 TEU	0.15
+2000 TEU	+2000 TEU	+2000 TEU	No Increase	0.35
+2000 TEU	+2000 TEU	No Increase	+2000 TEU	0.25
+2000 TEU	+2000 TEU	No Increase	No Increase	0.25
+2000 TEU	No Increase	+2000 TEU	+2000 TEU	0.06
+2000 TEU	No Increase	+2000 TEU	No Increase	0.14
+2000 TEU	No Increase	No Increase	+2000 TEU	0.32
+2000 TEU	No Increase	No Increase	No Increase	0.48
No Increase	+2000 TEU	+2000 TEU	+2000 TEU	0.2
No Increase	+2000 TEU	+2000 TEU	No Increase	0.2
No Increase	+2000 TEU	No Increase	+2000 TEU	0.24
No Increase	+2000 TEU	No Increase	No Increase	0.36
No Increase	No Increase	+2000 TEU	+2000 TEU	0.03
No Increase	No Increase	+2000 TEU	No Increase	0.07
No Increase	No Increase	No Increase	+2000 TEU	0.18
No Increase	No Increase	No Increase	No Increase	0.72

(Source: Own work)

In the case of incompete information, 2M and O3 alliances are assumed as rational players of the game, and the form of game is applied to SGSolver software. As a consequence of the application of the strategy combinations, and bayesian probabilities of each combination, the following results are obtained for four different scenarios based on the strategic positions of the adaptive players.

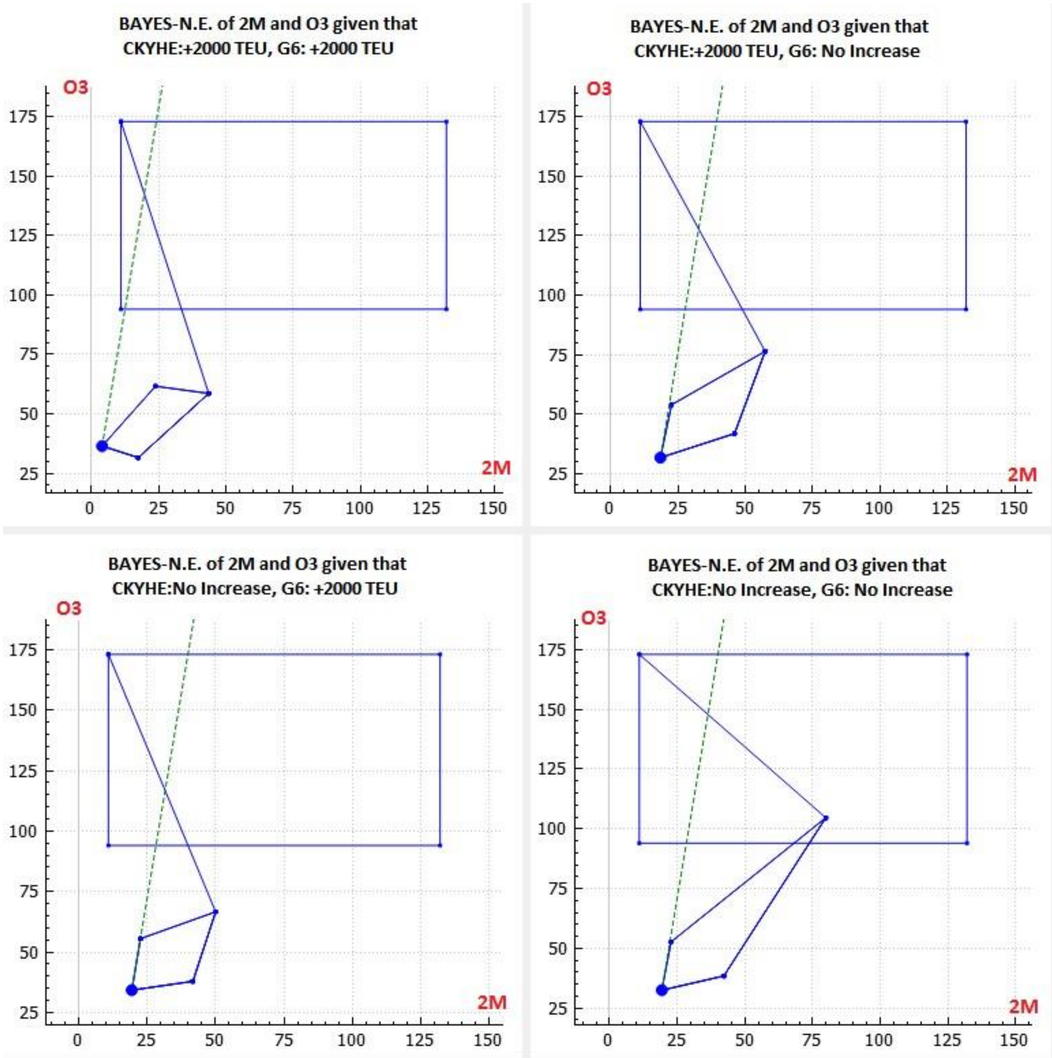


Figure 6.16: Equilibrium results of incomplete information game for each scenario ($/TEU)
(Source: Own work)

In holistic consideration of the obtained results, according to Bayesian-Nash equilibrium requirement, the solution of the game is determined USD 65 and USD 159 provided with the state of the strategy combination 15. According to strategy combination 15, 2M and G6 alliances should choose to enlarge average ship size on the liner service loop 2000 TEU, and CKYHE and O3 alliances should not increase their average ship size on the given Far East- Norther Europe liner service loop. In the following solution the black dashed line illustrates the solution link between probabilistic Bayesian region, shown with red colour, to the feasible decision region shown with blue colour.

Figure 6.17: Holistic Bayesian-Nash equilibrium result of incomplete information game ($/TEU)
(Source: Own work)

6.7. Outline of the Chapter

This chapter addressed the development of a game theoretical analysis tool for the liner container shipping alliance competition on a particular liner service loop. The case study integrated liner shipping company economics practices with capacity deployment related tactical decision-making concepts. In this section, it was clearly emphasised that the capacity deployment decision-making on a specific liner service loop should include the competitive behaviour of competitors. According to the obtained results, O3 shipping alliance was determined as the most competitive shipping alliance and CKYHE shipping alliance was found as the least competitive shipping alliance for the complete information state. On the other hand, in application of incomplete information methodology to two rational player's cases, it was again found that O3 shipping alliance is the most competitive.

7. CASE STUDY 2: PORT TERMINAL OPERATORS' GAME

In this chapter, the methodology is applied to a container port terminal operators' competition in Izmir, Turkey. Also an integration of the developed methodology to complex decision-making concepts is provided. Generally, non-existence of a holistic methodology in the port choice to combine hinterland perspective, shipping liner perspective and inter-port perspective requires the development of a new approach. While developing this novel approach in this chapter, it is applied to multicriteria decision-making and game theoretical strategy determination methodology of this study. The integrated methodology is hereafter referred to as Hybrid Port Competition Analysis Methodology (HPCAM). Briefly, HPCAM consists of the integration and comparison of the three different perspective analysis methods. In HPCAM, it is assumed that each perspective analysis method connects to the other one via their input-output interdependencies. The Izmir Province of Turkey is a geographically natural port region beside the Aegean Sea. The Izmir region is selected as the case study of this research due to its shared hinterland between the container port alternatives. Therefore, it may represent a good example of competitive port region in terms of the hinterland and shipping liners. Furthermore, none of the operators have a managerial link which allows applying a methodology designed to fully non-cooperative competition. Moreover, the methodology of this thesis is applied to capacity investment related inter-port competition to obtain final results of the holistic port competition analysis. Results for both complete and incomplete are presented in this chapter.

7.1.Four Player Port Competition Game in Izmir Province

Izmir has three active container ports and two planned port investments which will also serve the same hinterland in the near future. It has an especially significant export cargo capacity and it may be considered as an alternative port region to Piraeus, Istanbul, and Malta regarding the East Mediterranean-Black Sea region container transhipments. A basic illustration of the primary hinterland of the Izmir port region is given in figure 7.1 including a geographical area from Marmara Sea to the South coast of Anatolia, and all Aegean Sea coasts of Turkey. The Izmir port region also attracts the interest of customers from the west-middle Anatolia, including Eskisehir city and even the capital city Ankara.

Figure 7.1: Primary hinterland of Izmir port region (Source: Own work)

It is believed and expected that Izmir will be one of the main logistics centres of Europe by 2020 and will play an essential role for the East Mediterranean- Black Sea container transhipment (Colliers International, 2012). Therefore, logistics and port investments are rapidly increasing in the Izmir region. In 2016, the container ports of Izmir province will reach up to 2,800,000 TEU handling capacities but this number is reasonably over the demand for container handling (Esmer, 2013). The new port investments capacity distributions of the existing ports are shown in Table 7.1. In total 2,800,000 TEU capacities are planned to serve at the end of 2016 to meet the hinterland and transhipment demand.

Table 7.1: Handling capacities of container ports in Izmir

Container Port	Port	Existing
Candarli	Government/Private	-
Petlim	Private	1100,000*
Izmir Alsancak	Government	900,000
Nemport-Aliaga	Private	400,000
TCE EGE-Aliaga	Private	400,000

(Source: Esmer, 2013) (*: Predicted in 2017)

In the competition analysis of Izmir container ports HPCAM, shown in figure 7.2, is utilised as a starting milestone of the whole process. HPCAM maintains the port competitiveness from different views of the competition counterparties including shipping liner, customer and inter-port views.

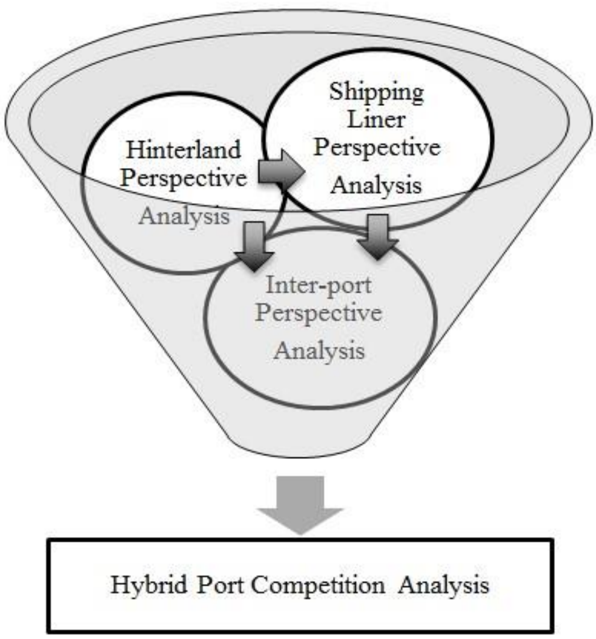


Figure 7.2: Hybrid port competition analysis process (Source: Own work)

7.2. Port Competition from the Hinterland Perspective

7.2.1 MAVA Modelling of the Hinterland Perspective

In HPCAM, first of all the value tree of the competitive port choice MAVA model is generated according to the perspective of hinterland. The main criteria are selected and simplified as cost, service quality, port service time, service line network and location based on the given literature review. Each main criterion is also divided to various sub-criteria which are shown in figure 7.3. Firstly, cost criterion is divided to inland transport cost, port charges, and clearance and storage costs criteria. Secondly, service quality sub-criteria are identified as a response to special cargo equipment requirements, port traffic congestion management and general port reputation. Thirdly, port service time is sub-categorised as truck waiting time, port handling and terminal operation time, and customs and warehouse time. Fourthly, service line network criterion is divided to main line and feeder network criteria. Lastly, location criterion is divided to intermodal connections and distance to industrial areas.

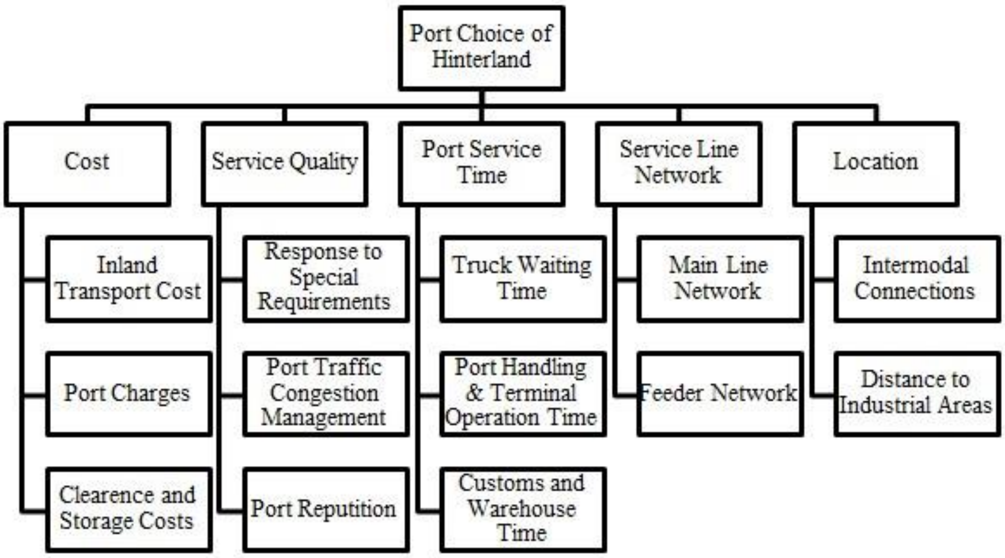


Figure 7.3: Criteria hierarchy of port choice decision from hinterland perspective (Source: Own work)

7.2.2 Elaborated Data for MAVA Model of the Hinterland Perspective

In this section, elaborated data of the survey questionnaires are presented. According to the results of the customer survey questionnaire, the performance scores of the port alternatives for each sub-criterion are determined as in table 7.2.

Table 7.2: Performance score distribution of the hinterland perspective criteria

Criteria	Izmir Alsancak	APM Petlim	Nemport-Aliaga	TCE EGE-Aliaga
I. Transport Cost	85%	76%	67.2%	71%
Port Charges	76.4%	68%	69%	67.2%
Clea. & Storage	74.6%	66.6%	67.2%	63.6%
S. Requirements	54.6%	82%	71%	71%
Port Congestion	49%	72%	74.6%	74.6%
Port Reputation	71%	80%	78.2%	76.4%
Truck Waiting T.	52.8%	76%	69%	67.2%
Port Handling T.	56.36%	80%	81.81%	80%
Cust. & Ware. T.	58.18%	73.33%	70%	74%
Main Network	70%	73.4%	76 %	70%
Feeder Network	78%	68.8%	74%	76%
Intermodal Con.	65%	61.81%	61.66%	61.66%
Distance to Indust.	89.09%	74.2%	74.2%	74.2%

(Source: Own work)

By consideration of the data obtained from the expert survey questionnaire, the global and local criteria weights of the hinterland perspective MAVA model are indicated in table 7.3. The local weights of sub-criteria may be defined as main criteria basis by the set of alternatives under consideration. The global weights are a more broad consideration of the criteria weights (Belton and Stewart, 2012). The data indicates that while cost is the most important main criteria, port charges is the most important sub-criterion in the model.

Table 7.3: Criteria weights of the hinterland perspective

Main Port Choice Criteria-Hinterland	**Global weight [%] 100**	**Local weight [%] 100**
Cost	42.28	42.28
Service Line Networks	25.29	25.29
Location	14.6	14.6
Port Service Time	9.67	9.67
Service Quality	8.16	8.16
Sub-Criteria of Port Choice-Hinterland	**Global weight [%] 100**	**Local weight [%] 100**
Port Charges	26.42	62.5
Main Line Network	21.07	83.33
Intermodal Connection	10.95	75
Inland Transport Cost	10.08	23.85
Clearance and Storage Charges	5.77	13.65
Customs and Warehouse Time	5.29	54.69
Port Congestion	4.56	55.84
Feeder Network	4.21	16.67
Distance to Industry	3.65	25
Handling Time	3.33	34.46
Special Requirements	2.61	31.96
Truck Waiting Time	1.05	10.86
Port Reputation	1	12.2

(Source: Own work)

7.2.3 *Results of the Hinterland Perspective*

The MAVA model of the hinterland perspective is established in a specialist decision-making software tool called MakeItRational (MakeItRational, 2016), and obtained data is entered to the model. After running the model, the following alternative utility percentages were obtained.

Table 7.4: Alternative utility results of the hinterland perspective

Alternative	Utility	Network	Time	Location	Service Quality	Cost
Izmir Alsancak	25.26	6.2	1.96	3.87	1.53	11.71
APM Petlim	25.10	6.3	2.6	3.54	2.19	10.43
Nemport Aliaga	26.62	6.7	2.53	3.98	2.38	11.01
TCE EGE-Aliaga	24.56	6.1	2.59	3.54	2.11	10.12

(Source: Own work)

The results given in table 7.4 illustrate that APM Petlim port has the highest utility percentage from the perspective of a hinterland decision-maker such as freight forwarder. According to the perspective of hinterland, Izmir alsancak and NemportAliaga ports have the best location, most competitive cost, and best network accessibility to other ports. In terms of service quality, Nemport-Aliaga and APM Petlim have the highest utilities. In addition, APM Petlim and TCE EGE-Aliaga obtain best performance regarding the port service time.

7.3. Port Competition from the Shipping Liner Perspective

7.3.1 MAVA model of the Shipping Liner Perspective

Another port choice perspective in container shipping operations is the perspective of the shipping liners. In this research, the value tree of competitive port choice model from the perspective of shipping liner is established based on the studies of Malchow and Kanafani (2004), Chang *et al.(* 2008), Hoshino (2010) and Tongzon and Sawant (2007). The selected criteria is simplified as a draft of the ports, port costs to shipping liner, average port time of a container ship, port characteristics (hub port, state or private, global consolidated port etc.), and customer satisfaction. The customer satisfaction is assumed as the interdependency agent of the perspective of shipping liner in order to gain results of the perspective of hinterland. The value tree of the port choice according to the perspective of shipping liner is given in figure 7.4.

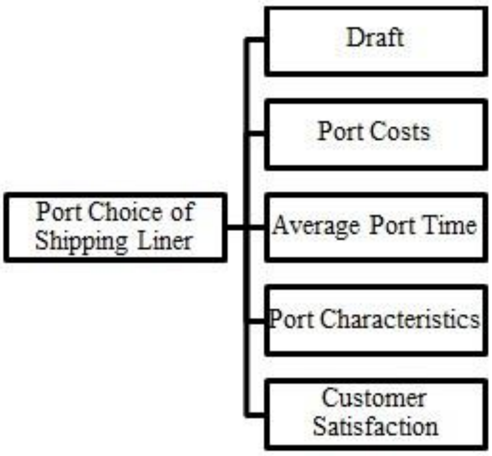


Figure 7.4: Criteria hierarchy of port choice model from perspective of the shipping liners

(Source: Own work)

7.3.2 Integration of the Methods with Interdependencies

In HPCAM of this study, MAVA and game theory methodologies are interconnected via interdependency of models. According to the methodological assumption of this study, alternative utilities of the hinterland perspective MAVA model is used as a source of the score for customer satisfaction criteria of the shipping liner perspective. Thus, interconnection of the MAVA model is provided. In addition, alternative utilities of the shipping liner perspective MAVA model utilised to order rational players in a non-cooperative zero sum game concept and interconnection. Therefore, it is assumed that the container port alternative with the lowest utility has a priority in strategy game.

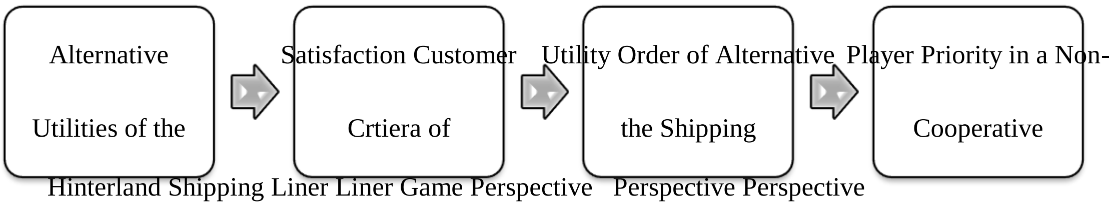


Figure 7.5: Interdependencies of the HPCAM for Integration

(Source: Own work)

By assistance of the data obtained from the available data from port websites and the study of Yuksel & Belde (2010), the performance scores of the port alternatives for each sub-criterion is determined as in table 7.5. Customer satisfaction data refers to hinterland perspective alternative utility results which are presented in the results section.

Table 7.5: Performance score distribution of the shipping liner perspective criteria

Criteria	Izmir Alsancak	APM Petlim	Nemport-Aliaga	TCE EGE-Aliaga
Draft	59%	73%	100%	91%
Port Costs	76%	69%	70%	69%
Average Port Time	70%	90%	80%	80%
Port Characteristics	80%	95%	80%	85%
Customer Satisfaction	94.95%	89.86%	90.13%	88.18%

(Source: Own work)

Based on the outcomes of the shipping liner survey questionnaire, the global and local criteria weights of the shipping liner perspective MAVA model are calculated and indicated in table 7.6. According to the given criteria weights, while the port characteristics is the most significant criteria for port choice of the shipping liner the port costs is the least significant criteria. Basically, the results show that the ports are able to serve container transhipment, and larger ships are more preferable choices for the shipping liners.

Table 7.6: Criteria weights of the shipping liner perspective

Main Port Choice Criteria-Shipping liner Perspective	**Global weight [%]**	**Local weight**
Port Characteristics	34.36	34.36
Draft	23.96	23.96
Average Port Time	18.16	18.16
Customer Satisfaction	12.85	12.85
Port Costs	10.66	10.66

(Source: Own work)

7.3.3 Results of Shipping Liner Perspective

The MAVA model of the shipping liner perspective is also developed on MakeItRational software, and obtained data from questionnaires and other sources are entered to the model. After running the model, the alternative utility percentages found are illustrated in table 7.7.

Table 7.7: Alternative utility results of the shipping liner perspective

Alternative	Utility (%)	Port Characteristics	Average Port Time	Customer Satisfaction	Draft	Port Cost

Petlim	25.90	9.89	5.10	3.14	5.46	2.59
Nemport-Aliaga	25.89	8.07	3.59	3.15	7.49	2.62
TCE EGE-Aliaga	25.57	8.58	3.59	3.10	6.82	2.58
Izmir Alsancak	22.64	8.07	3.14	3.32	4.42	2.85

(Source: Own work)

According to the results shown in the above table, APM Petlim and Nemport-Aliaga container terminals are determined as the most competitive ports from the perspectives of the shipping liners. The global port operator APM's Petlim port investment in Izmir obtains the highest score for the port characteristics, and average port time criteria. The results reveal that Izmir Alsancak port has a limited port draft and its business is under risk due to the ship size enlargement trend. In addition, while Izmir Alsancak port is the most competitive port from the hinterland perspective, it is the least competitive port from the shipping liner perspective.

7.4. Game Theoretical Analysis of the Inter-Port Competition

7.4.1 Scenario Building for the Inter-Port Competition

The methodology developed in chapter 4 is adapted to the second case study of this thesis, and applied to a numerical example of port competition. Nash and BayesianNash pure strategy solutions are applied to the problem in order to find the equilibrium points in their market. For the given port region, the current average port price rate that market can tolerate is given as $350/TEU based on the 2016 market prices. Thus, the market slope values of the port operators are considered as

$b_{Alsancak} = 0.0000378$, $b_{Petlim} = 0.0000443$, $b_{Nemport} = 0.000106$, $b_{TCE\ EGE} = 0.0001032$, and the a value is given as 517. Based on the 2016 data, 2017 cost calculations of port operators per TEU according to different cost groups are shown in the graph below.

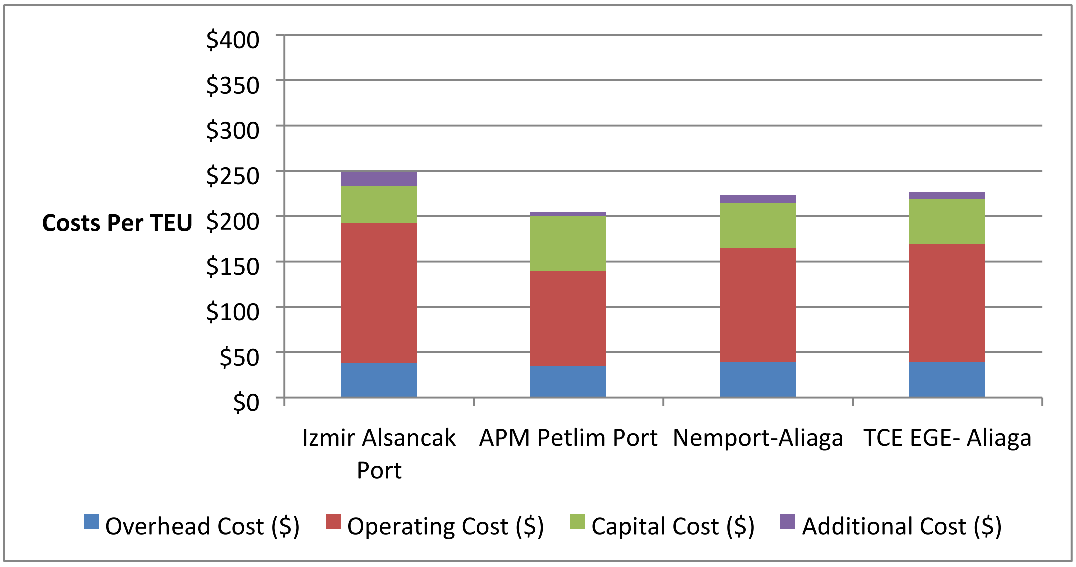


Figure 7.6: Cost structure of the port operators in Izmir per TEU handled (Source: Own work)

It is assumed that the competition game is static, fully non-cooperative and the players determine their best strategies by consideration of the tactical strategy behaviours of the competitors. Due to the APM Petlim port would serve to customers with full handling capacity in 2017, the years between the years of 2017-2025 is analysed in order apply the methodology of the study and determine the impacts of the capacity allocations on the financial situation. The demand is assumed to be steadily increasing 3.5% p.a. between the years of 2017-2025.

As a part of the case study, a scenario is built base on the idea of increasing port handling capacities around 100,000 TEU per container ports for the period of 20172025. According to the given scenario each player has 2 available strategy options given below:

1- No port handling capacity increase and keep the expected position at 2017

2- Decision to generate 100,000 TEU additional capacities at 2025

Therefore, the pure strategy combinations of the port operators in Izmir port region may be shown as following:

$$(S_{No Alsancak\ Increase}, S_{No Petlim\ Increase}, S_{No Nemport\ Increase}, S_{No TCE\ Increase\ EGE}) \coloneqq Combination\ 1$$

$$(S_{No Alsancak\ Increase}, S_{+Petlim 100000\ TEU}, S_{No Nemport\ Increase}, S_{No TCE\ Increase\ EGE}) \coloneqq Combination\ 2$$

$$(S_{No Alsancak\ Increase}, S_{No Petlim\ Increase}, S_{+Nemport 100000\ TEU}, S_{No TCE\ Increase\ EGE}) \coloneqq Combination\ 3$$

$$(S_{No Alsancak\ Increase}, S_{No Petlim\ Increase}, S_{No Nemport\ Increase}, S_{+TCE 100000\ EGE\ TEU}) \coloneqq Combination\ 4$$

$(SNoAlsancak\ Increase, S{+}Petlim100000\ TEU, S{+}Nemport100000\ TEU, SNoTCE\ Increase\ EGE) \coloneqq Combination\ 5$

$(SNoAlsancak\ Increase, S{+}Petlim100000\ TEU, SNoNemport\ Increase, S{+}TCE100000\ EGE\ TEU) \coloneqq Combination\ 6$

$(SNoAlsancak\ Increase, SNoPetlim\ Increase, S{+}Nemport100000\ TEU, S{+}TCE100000\ EGE\ TEU) \coloneqq Combination\ 7$

$(SNoAlsancak\ Increase, S{+}Petlim100000\ TEU, S{+}Nemport100000\ TEU, S{+}TCE100000\ EGE\ TEU) \coloneqq Combination\ 8$

$(S{+}Alsancak100000\ TEU, S{+}Petlim100000\ TEU, S{+}Nemp100000ort\ TEU, S{+}TCE100000\ EGE\ TEU) \coloneqq Combination\ 9$

$$\left(s^{Alsancak}_{+100000\ TEU}, s^{Petlim}_{No\ Increase}, s^{Nemport}_{+100000\ TEU}, s^{TCE\ EGE}_{+100000\ TEU}\right) \coloneqq Combination\ 10$$

$(S{+}Alsancak100000\ TEU, S{+}Petlim100000\ TEU, SNoNemport\ Increase, S{+}TCE100000\ EGE\ TEU) \coloneqq Combination\ 11$

$$\left(s^{Alsancak}_{+100000\ TEU}, s^{Petlim}_{+100000\ TEU}, s^{Nemport}_{+100000\ TEU}, s^{TCE\ EGE}_{No\ Increase}\right) \coloneqq Combination\ 12$$

$$\left(s^{Alsancak}_{+100000\ TEU}, s^{Petlim}_{No\ Increase}, s^{Nemport}_{No\ Increase}, s^{TCE\ EGE}_{+100000\ TEU}\right) \coloneqq Combination\ 13$$

$$\left(s^{Alsancak}_{+100000\ TEU}, s^{Petlim}_{No\ Increase}, s^{Nemport}_{+100000\ TEU}, s^{TCE\ EGE}_{No\ Increase}\right) \coloneqq Combination\ 14$$

$(S{+}Alsancak100000\ TEU, S{+}Petlim100000\ TEU, SNoNemport\ Increase, SNoTCE\ Increase\ EGE) \coloneqq Combination\ 15$

$(S{+}Alsancak100000\ TEU, SNoPetlim\ Increase, SNoNemport\ Increase, SNoTCE\ Increase\ EGE) \coloneqq Combination\ 16$

After determination of the available strategy options and strategy combinations and calculation of their numerical consequences, the Cournot competition model of the game is generated on GamePlan 3.7 software and given in the following figure. In the game model while Izmir Alsancak and TCE EGE- Aliaga ports are considered as rational players, Nemport-Aliaga and APM Petlim ports are considered as adaptive players. The Cournot game model of the case not only includes the players' tactical strategy links and connections with complete information but also the pay offs of each players for each strategy combination.

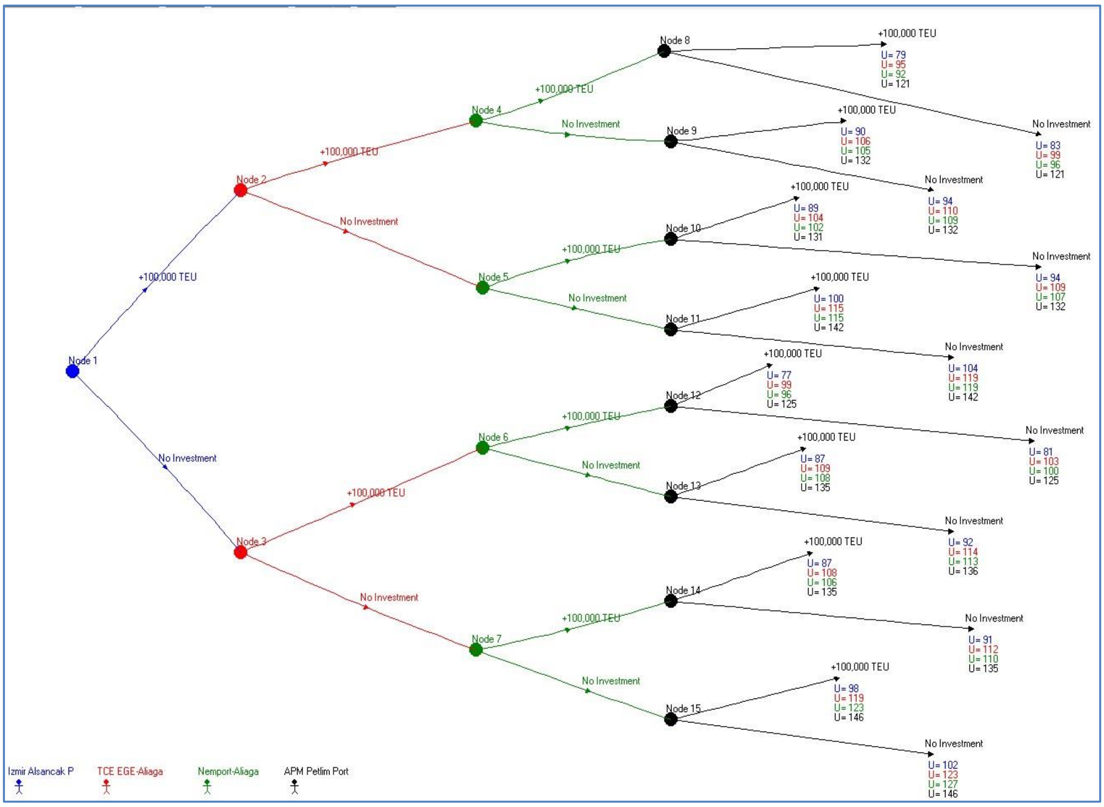


Figure 7.7: The Cournot competition game model of port competition
(Source: Own work)

According to the calculations, the costs per TEUs of the players over strategy combinations are given in figure 7.8. As clearly seen in the figure, for all strategy combinations, whilst Izmir Alsancak port has the highest costs per TEU handled on its terminals, APM Petlim port obtains the best cost advantage in terms of competitiveness.

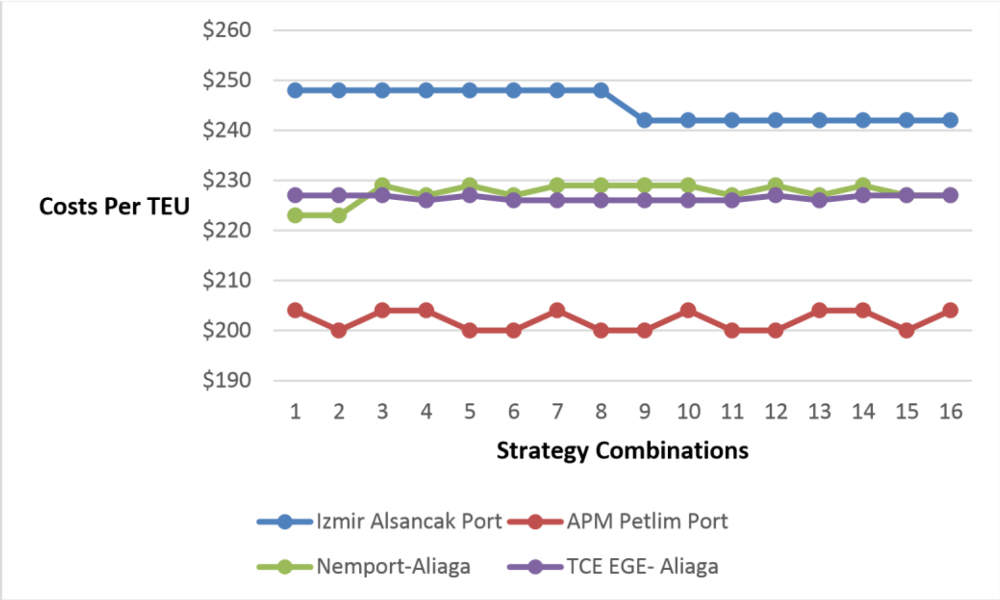


Figure 7.8: Costs of the port operators over strategy combinations (Source: Own work)

One of the key points of the methodology applied to the case study is the determination of the port prices according to strategy combinations of the players. The changing of the total port prices per TEU is calculated according to the methodology of this study and illustrated in figure 7.9. According to the model given the strategy combination 1 provides the highest port prices per TEU with $350 and total annual revenue. On the other hand, strategy combination 9, where all players select to increase container handling capacities of their terminals, the port prices per TEU with $321 provides the lowest total annual revenue.

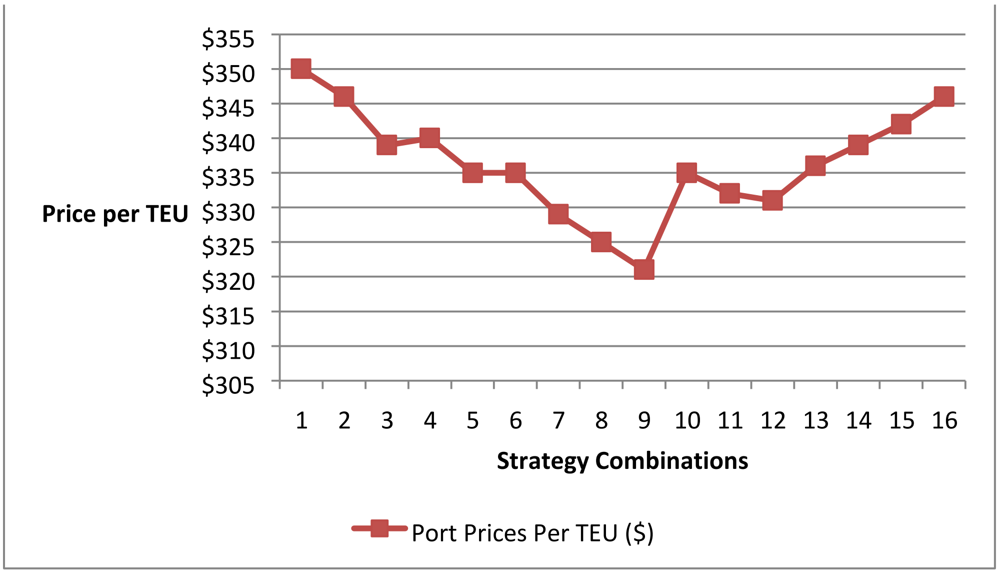


Figure 7.9: Port prices per TEU according to strategy combinations (Source: Own work)

Another significant result of the methodology applied to the case study is the determination of the profits gained according to strategy combinations of the players. The profit distributions per TEU of the players are given in the following figure. According to the figure, for all strategy combinations, while APM Petlim gains the highest profit, Izmir Alsancak gains the lowest profit.

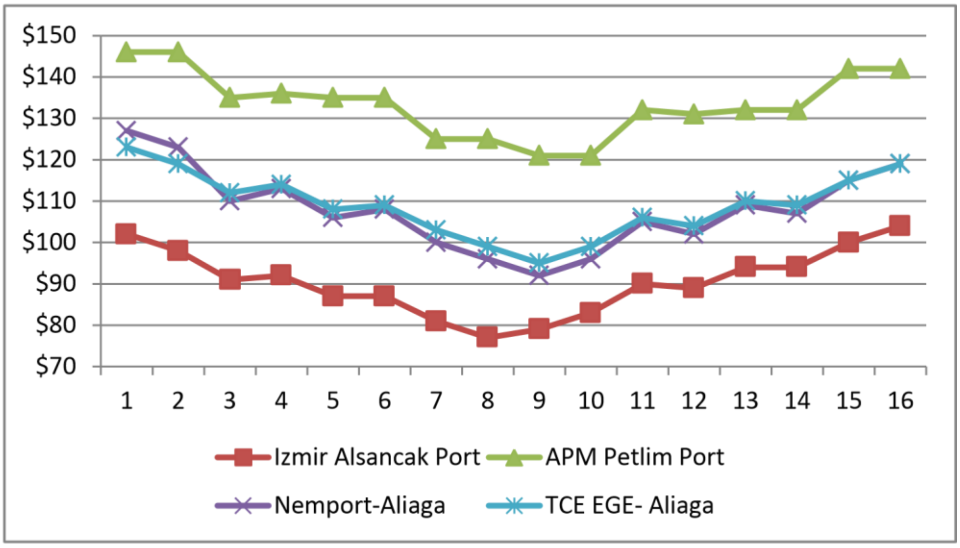


Figure 7.10: Profit distribution per TEU according to strategy combinations (Source: Own work)

7.4.2 *Results of Inter-Port Competition with Nash Equilibrium*

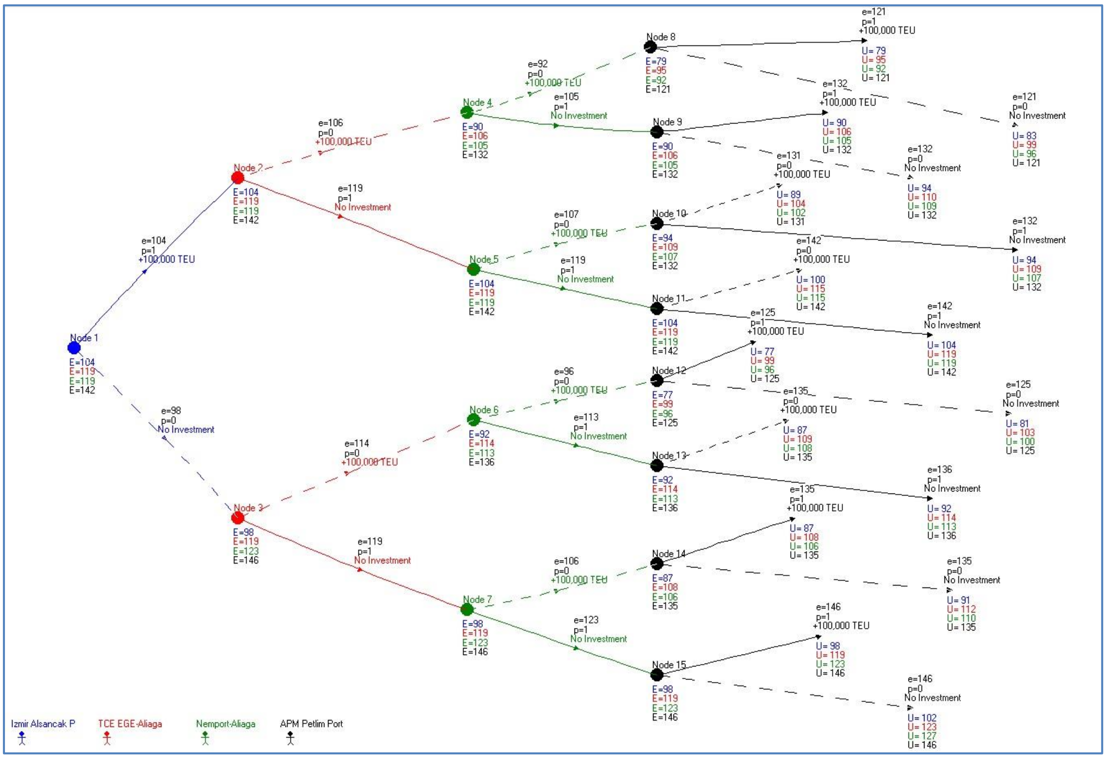
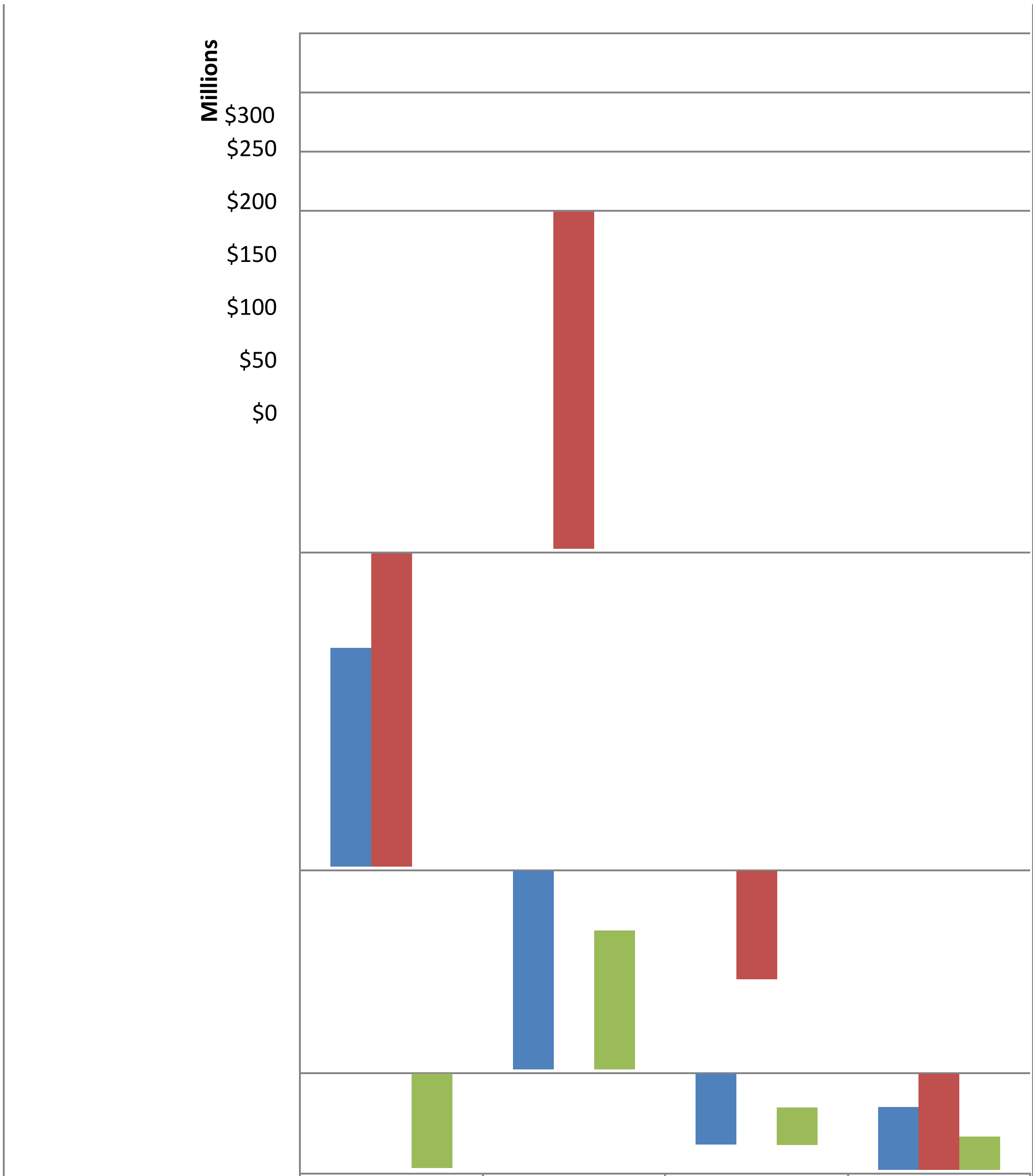


Figure 7.11: Nash equilibrium solution of the inter-port competition with complete information (Source: Own work)

In Figure 7.11, the blue colour represents rational moves of the first player; Izmir Alsancak Port, the red colour represents rational moves of the second player;

TCEGE-Aliaga port, the green colour represents adaptive moves of the third player; Nemport-Aliaga, and the black colour represents adaptive moves of the fourth player; APM Petlim,. The straight lines in the solution indicate rational strategies for the players at each node and the dashed lines indicate irrational moves for the players at each node. Complete straight lines between nodes of different players indicate the pure strategy solution of the game. In addition, the given results contain various numerical details about the game strategy choice of the players. The strategy combination 16 where only Izmir Alsancak port allows increasing its capacity 100,000 TEU is found as the solution of the game. As a consequence of the financial analysis of the equilibrium point, annual costs, revenue, and profits of the players are found as in the following graph.



	Izmir Alsancak Port	APM Petlim Port	NemportAliaga	TCE EGEAliaga
Annual Costs ($)	207133850	188040264	67256014	59782947
Annual Revenue($)	296826230	319659231	102747634	91330961
Annual Profit ($)	89692380	131618967	35491620	31548014

Figure 7.12: Costs, revenues, and profits of the players at equilibrium point (Source: Own work)

As it seen in the graph, APM Petlim is expected to have the biggest share of the hinterland in 2025. It is assumed that Izmir Alsancak and TCE EGE Aliaga Ports are rational players who need to take a capacity related action, and APM Petlim and Nemport-Aliaga Ports are adaptive players. Therefore, the problem is also applied to the SGSolver software providing Nash equilibrium points of the rational players according to four different scenarios based on adaptive players' tactical strategy positions in the capacity related competition. The results of the SGSolver application are given in the following graph.

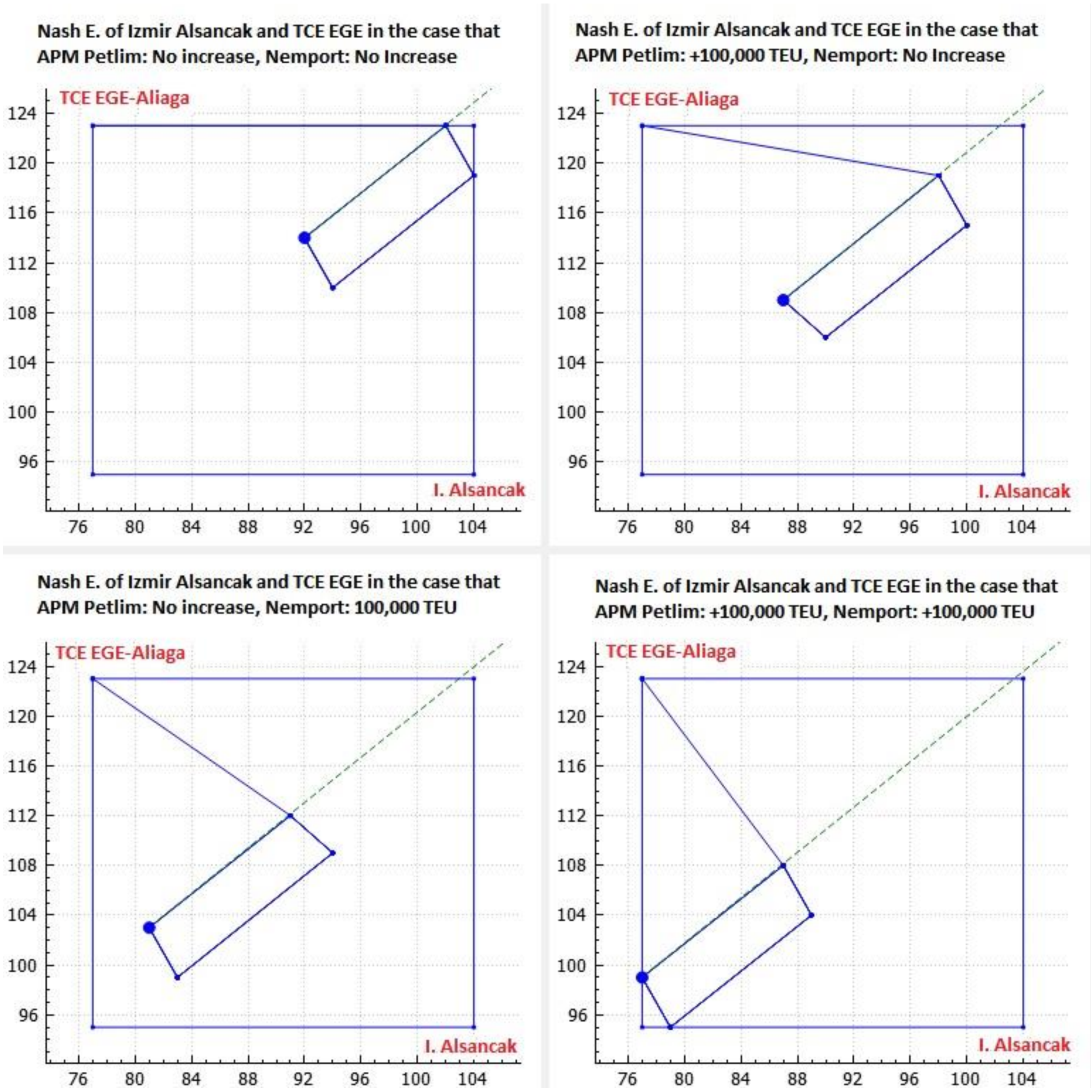


Figure 7.13: Nash equilibrium of rational players according to different scenarios (Source: Own work)

In the above graph for the first scenario which APM Petlim: No increase and Nemport: No increase has (No increase, No increase) ($ 102, $123) as equilibrium point. For the second scenario which APM Petlim: +100,000 TEU and Nemport: No increase has

(No increase, No increase) ($ 98, $119) as equilibrium point. For the third scenario which APM Petlim: No increase and Nemport: +100,000 TEU has (No increase, No increase) ($ 91, $112) as equilibrium point. For the fourth scenario which APM Petlim: +100,000 and Nemport: +100,000 TEU has (No increase, No increase) ($ 87, $108) as equilibrium point. From a holistic perspective to all equilibrium points, the second scenario which APM Petlim: +100,000 TEU and Nemport: No increase has (No increase, No increase) ($ 98, $119) as Nash equilibrium of the game. As a result of this analysis it is clearly found that rational players Izmir Alsancak and TCE EGE-Aliaga ports will not increase their capacities in any case.

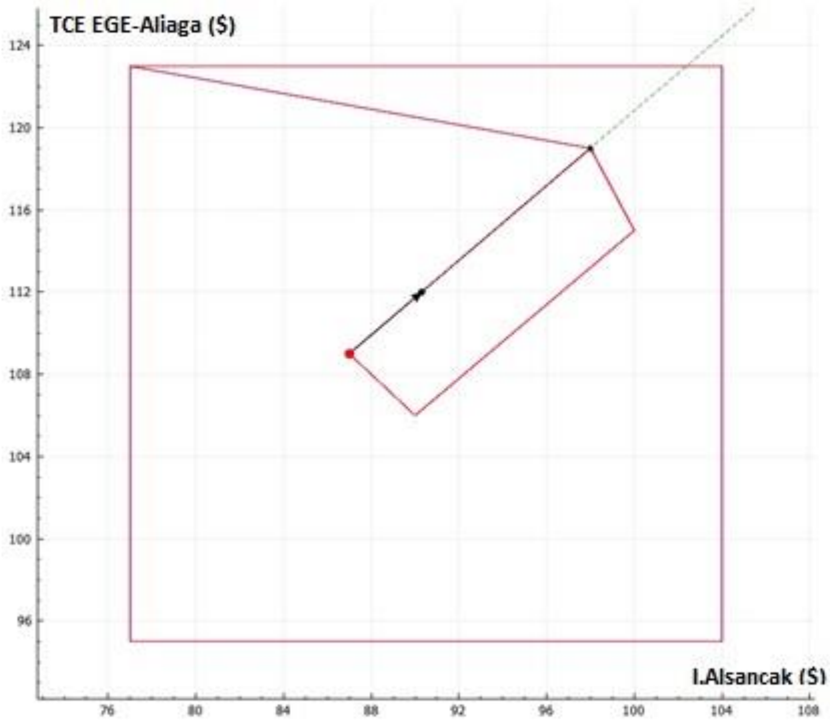


Figure 7.14: Nash equilibrium of the game according to holistic consideration ($/TEU)
(Source: Own work)

7.4.3 Results of Inter-Port Competition with Bayesian-Nash Equilibrium

In a collided hinterland case incomplete information regarding the capacity investment related strategy selections will less likely to occur in practice due to the transition of the information in the hinterland. However, competition forms of the shipping liner alliances are adapted to another part with incomplete information as well as complete information state in this thesis in order to include all possible situations. Bayesian theorem probabilities are utilised to determine competition outcomes under incomplete information state. In table 7.8, Bayes probabilities of the different strategy combinations of port operators are illustrated. The same randomly selected and calculated Bayes probabilities are utilised with the previous case study.

Table 7.8: Bayes probabilities of the strategy combinations of port operator's game

Izmir Alsancak	TCEGE-Aliaga	Nemport-Aliaga	APM Petlim	Bayes Probabilities
+100000 TEU	+100000 TEU	+100000 TEU	+100000 TEU	0.15
+100000 TEU	+100000 TEU	+100000 TEU	No Increase	0.35
+100000 TEU	+100000 TEU	No Increase	+100000 TEU	0.25
+100000 TEU	+100000 TEU	No Increase	No Increase	0.25
+100000 TEU	No Increase	+100000 TEU	+100000 TEU	0.06
+100000 TEU	No Increase	+100000 TEU	No Increase	0.14
+100000 TEU	No Increase	No Increase	+100000 TEU	0.32
+100000 TEU	No Increase	No Increase	No Increase	0.48
No Increase	+100000 TEU	+100000 TEU	+100000 TEU	0.2
No Increase	+100000 TEU	+100000 TEU	No Increase	0.2
No Increase	+100000 TEU	No Increase	+100000 TEU	0.24
No Increase	+100000 TEU	No Increase	No Increase	0.36
No Increase	No Increase	+100000 TEU	+100000 TEU	0.03
No Increase	No Increase	+100000 TEU	No Increase	0.07

No Increase	No Increase	No Increase	+100000 TEU	0.18
No Increase	No Increase	No Increase	No Increase	0.72

(Source: Own work)

In the case of incompete information of the players about the strategy choice of competitiors, once again, Izmir Alsancak and TCE EGE-Aliaga port are assumed as rational players of the game, given bayes probabilities are utilised in model, and the new form of competition is applied to SGSolver software. As a consequence of the used probabilities and strategy combination pay offs following four scenario equilibriums are generated.

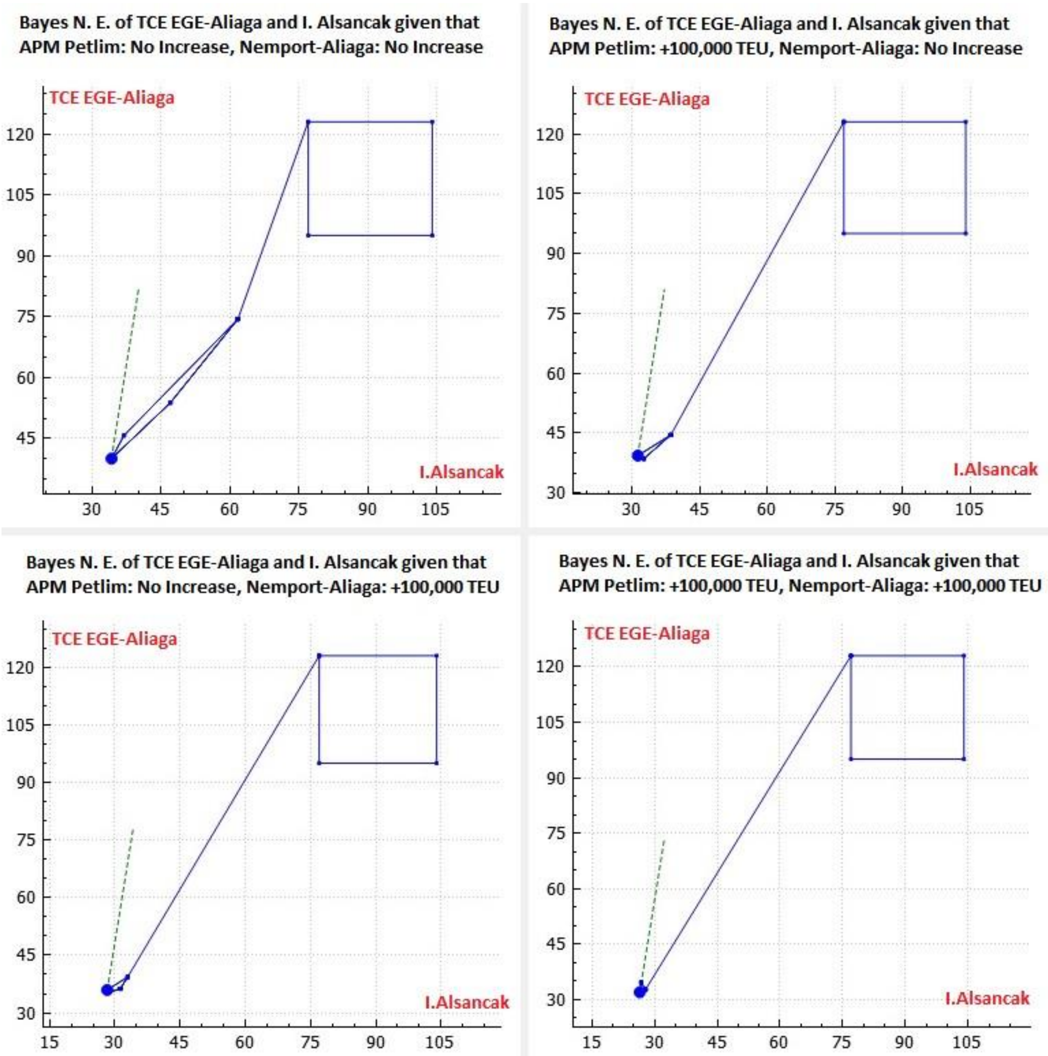


Figure 7.15: Bayesian N. Equilibrium results of incomplete information game for each scenario ($)
(Source: Own work)

In addition, SGsolver software provides best equilibrium solution among the equilibriums of the four different scenarios. In consideration of the equilibrium points in given incomplete game of port operators in Izmir, the final solution is found as ($77, $99) as a consequence of strategy combination 8 which requires no capacity increase of Izmir Alsancak port and +100,000 TEU capacity investment of the other port operators. The equilibrium point is shown with a star sign in figure 7.16.

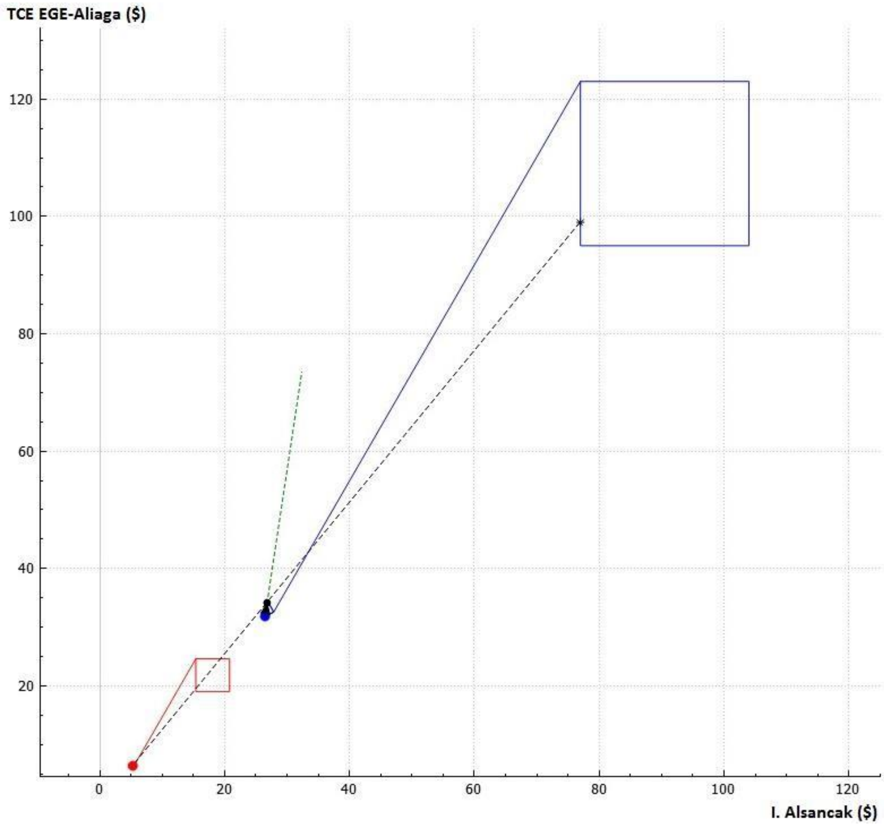


Figure 7.16: Holistic Bayesian-Nash equilibrium result of incomplete information game ($/TEU) (Source: Own work)

7.5. Outline of the Chapter

In this chapter, the aim was to illustrate numerical application and practicability of the generated methodology. Throughout this chapter, a novel port competition analysis methodology was presented and tested on an appropriate case study determined as Izmir port region. In the case study, an integration of different port competition analysis perspectives was provided by applying multi-criteria decisionmaking and game theory approach. For the game theory part of the analysis, the methodology developed in the chapter 4 was utilised for both complete and incomplete information cases. In both complete and incomplete information cases APM Petlim port was found as the most competitive port. The outcome of this chapter provides significant assistance to strategy development departments of the port operators in order to measure their competitiveness level by considering complex port performance criteria and tactical behaviours of the competitors.

8. CASE STUDY 3: LNG BUNKER SUPPLIERS' GAME

This chapter develops a futuristic scenario for the LNG bunkering decisions and LNG bunkering competitions of the liner container shipping industry. In the chapter, an optimistic motivation about the utilisation of the LNG as a primary marine fuel in middle long term is applied due to its suitability to emission regulations and its more stable product price volatility. Throughout the chapter, recent developments in LNG fuelled shipping are mentioned and the challenges and opportunities of the LNG fuelled liner container shipping are analysed in depth. Moreover, a multi-objective bunkering network optimisation framework of the shipping liners regarding the bunkering point selection is developed. Time and cost minimisation of the bunkering network is aimed in order to optimise bunkering point choice decisions. Hereupon, objective functions and typical constraints of the multi-objective minimisation problem are given. Furthermore, the methodology developed in chapter 4 is applied to a predicted future LNG bunker suppliers' competition scenario. Competition of four North Western Europe bunkering supply points with high LNG bunkering potential are selected for numerical application. Results for both complete and incomplete information cases of the players are presented and discussed. Competiveness of the LNG bunker suppliers are analysed and capacity investment decision equilibrium points are determined.

8.1. LNG Bunker for the Liner Container Shipping

8.1.1 Motivation for the LNG Bunkering

Utilisation of the LNG as a primarily marine fuel is a considerably new type of bunkering application containing many discussions and safety based concerns. At the moment, LNG fuelled shipping and bunkering business have only small scale practical applications for a limited number of ships on the North-western Europe ECA (Emission Control Area). Safety records of these bunkering applications are dominating positive motivation on the LNG bunkering, although there is a lack of regulative standardisation existing for bunkering operations. It is highly expected and believed that LNG may become one of the major alternatives to Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO) once sustainable LNG bunkering supply systems are established with all the required facilities and sources throughout ECAs and the wider coastal geographies. It is commonly predicted that in around one decade, or even sooner, LNG fuel will be sufficient for relatively small scale shipping LNG bunkering supply system on all ECAs, but worldwide applications still requires time (ECORYS, 2012).

In contrast, ship-owners from main shipping service sectors, especially deep sea container shipping lines, are very keen to invest newly developed more efficient- cost reductive green marine technologies in their new-build orders such as LNG fuelled ships due to CO_2, NO_x, SO_x, PM, Energy Efficiency regulative enforcement of regulatory bodies and high bunker prices with low ocean freight earnings under tough competition conditions. LNG seems like not only a more environmentally friendly fuel option for container ships but also a cost efficient solution to minimise the cost of bunkering needs of ship operators which mostly cost over 50% of the total operation expenses for many ship types (Buxton, 1985). It may be possible to be compatible with environmental regulations by using HFO+ scrubber+ and/or SCR mix, LNG or MGO options for deep sea container ships. Currently, LNG has a price advantage compared to MGO and HFO solution. LNG is not only the most sustainable solution for container shipping but it also meets majority of bunker performance expectations of liner shipping operators in sufficient level.

LNG bunker may be transferred to the ships by on shore supply (shore to ship bunkering), on shore mobile supply (truck to ship bunkering) or offshore supply (ship to ship bunkering) (Skramstad, 2013). For deep sea container shipping, due to time saving strategies, it is commonly desired to be injected to bunkering during port cargo operation time. Despite this desire, lack of availability for the first years of LNG bunker utilisation will require more focus on different operational solutions including the optimisation of bunkering station choice between liner service ports and bunkering points positioning out of ordinary liner service.

8.1.2 Challenges of LNG Bunkering

Although very positive opinions and comments have been made regarding LNG bunkering, it still contains some conjectural, systemic, operational, technical and safety challenges which have yet to be overcome. It is possible to summarise the key outlines of these challenges as following:

Systemic Challenges: Macro-scaled challenges are the most difficult challenges to overcome for business entrepreneurs to achieve micro level aims. Political instabilities, war risk, financial crisis, price volatility of natural gas and possible further regulative enforcements on the environment can be considered as major systemic challenges that LNG bunkering would face. Overcoming systemic challenges is directly related to adaptive capabilities of micro systems.

Operational Challenges: The main operational concerns arising about LNG bunkering are, availability of LNG bunkering facilities on ports of call and sustainable supply of LNG to bunkering stations. Apart from these challenges, new generation strategic shipping alliances on deep sea container shipping liner service with recently built giant ships are another operational challenge for prompting LNG fuelled ship orders from ship-owners.

Technical Challenges: LNG bunker with same amount of weight as HFO obtained requires around 80% more fuel tank volume on board (Bagniewski, 2013). Therefore, a design with sufficient volume of LNG tanks is a significant technical challenge. For existing ships, replacement of the LNG fuel system should be done appropriately according to ship stability and operational characteristics of the ship.

Safety Challenges: Safety is the main concern about LNG bunkering. Cold material handling capability of relevant ship structures, asphyxiation risk of people involved in bunkering, dependent on facts occurring at moment of LNG spill pool fire, vapour cloud fire, explosions, rapid phase transition (RPT) may be considered as safety challenges which should be prevented by more technological improvement and especially by training of crews and bunkering employees (Jonsdottir, 2013).

Conjectural Challenges: Adaptation LNG to ships by retrofitting or new-building and LNG bunkering supply for ships requires expensive technology investments. Broadly speaking, LNG fuelled ship investments are approximately 15-20 % more expensive than HFO+MGO fuelled ships. Also, it contains educational and technological adaptation costs for companies. Companies want to be sure from proposed conjectures and supply and demand balance of LNG bunker. Thus, gas providers and bunker suppliers are unwilling to invest in the necessary infrastructure for LNG bunkering until there is sufficient demand to supply commercial shipping with LNG fuel. Moreover, ship-owners will lose their interest on LNG fuelled ships if they don't see any development regarding the supply of LNG bunker on main shipping routes. (Lloyd Register, 2012).

8.1.3 Opportunities of LNG Bunkering

Alongside these challenges, utilisation of LNG as a ship fuel source also includes many opportunities such as compliance with emission regulations, price advantages, increasing global availability of natural gas and proposed or planned investment decisions. Opportunities of LNG bunkering are given as follows.

Environmental Opportunities: LNG does not cause any sort of marine pollution even if it spills to the sea and related coastal marine environment. Therefore, LNG bunkering brings huge benefits to prevent bunker based marine disasters threatening marine ecological life. Similarly, LNG is a clean fuel option to reduce ship sourced greenhouse gas emissions. LNG reduces CO_2, NO_x, SO_x, PM emissions in a significant level and very compatible with ECA and IMO emission regulations. In comparison to heavy fuel types, LNG reduces SO_x emission over 98%, NO_x emission around 85%, CO_2 emission up to 25 % and PM emission more than 90%
(Vandebroek & Berghmans, 2012). Methane slip is the weakest point of LNG's environmental performance which is not under any regulative enforcement yet. But development of engine technologies reduced it noticeably compared to the first LNG fuelling applications. In the future, by development of more advanced engine technologies it would be possible to prevent methane slip risk.

Economic Opportunities: LNG emission comparison with other fuel types is indicated in the previous section. At the moment LNG has a very competitive price advantage and more price stability to react price volatility factors compared to other fuel types. It is expected that in the future by increase on shale gas exploration natural gas prices will be even more competitive in comparison to oil prices. Fig. 8.1 indicates price comparison of average global LNG (Rotterdam, Hamburg and Japan average), average global HFO and MGO prices equal to 1 barrel.

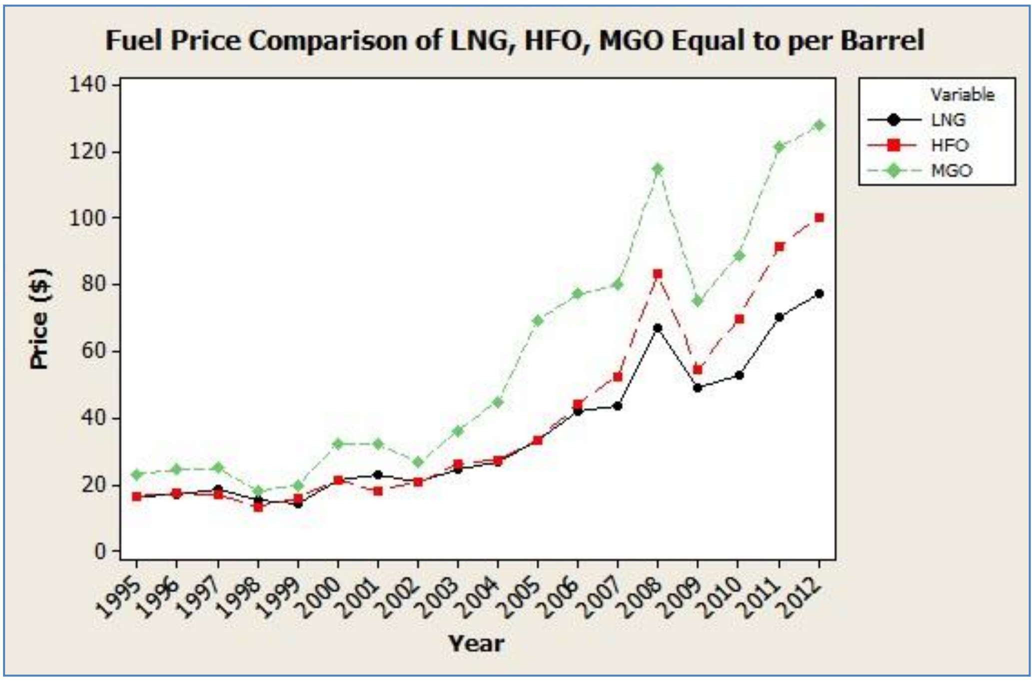


Figure 8.1: Annual average bunker price comparison equal to one barrel oil's thermal energy content (1 barrel=0.136 Metric Tonnes) (Data Source: Adapted from BP, 2014)

Global Availability of LNG Trade Opportunity

Lack of availability of LNG bunkering stations on main liner shipping routes is the basic reason of hesitation for LNG fuelled ship investment decisions taken by deep sea container liner shipping operators. A robust LNG bunkering supply chain recently only exists in the Scandinavia region. Although lack of application infrastructure of LNG bunkering globally, utilisation of LNG and LNG trade are increasing, and therefore availability of natural gas worldwide is rising. Storage of LNG in importer countries is the main problem of availability of Natural gas in LNG form. Importer countries mostly obtain degasification facilities and don't have a supply chain of liquefied natural gas. In these countries bunkering facilities and sustainable supply chain of LNG to bunkering points requires serious investments and robust investment planning. The following map indicates existing (blue), planned (green) and proposed (grey) LNG bunker station investments worldwide.

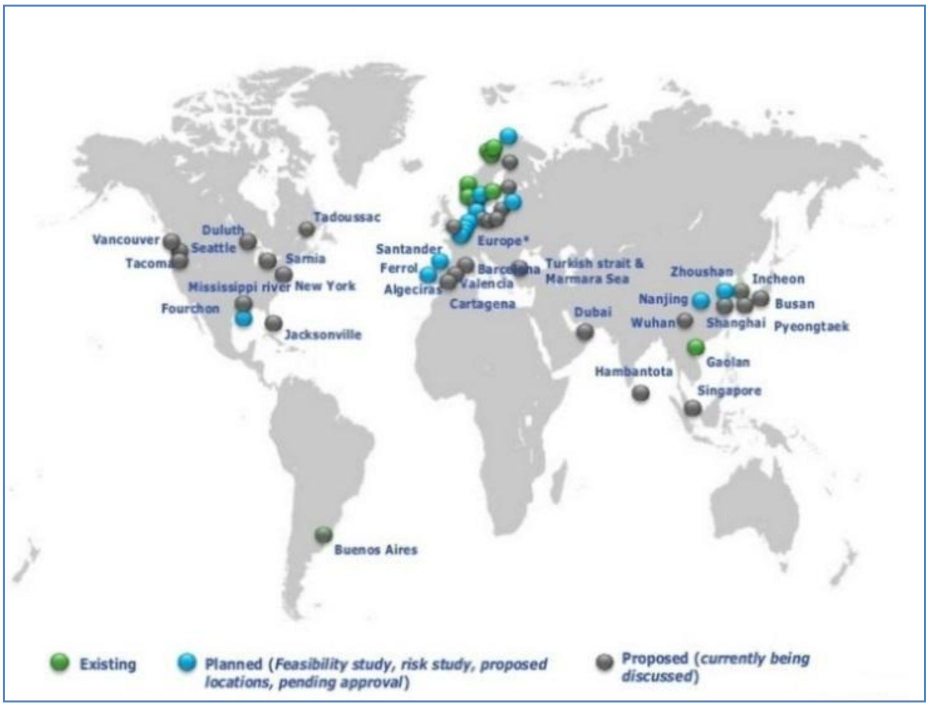


Figure 8.2: Existing, Planned and Proposed LNG bunkering points (Source: DNV GL, 2014)

In table 8.1 it is possible to see approaches of the top 10 bunkering points of LNG bunkering investments, which appears promising. Rotterdam and Antwerp ports have already planned their LNG bunkering investments. Port of Singapore, United Arab Emirates ports and Busan port are also proposing to invest in LNG bunkering. Although Hong Kong and Gibraltar have not proposed LNG bunkering facility yet, planned and proposed other ports in China and Spain could handle LNG bunkering needs in the future.

Table 8.1: Top 10 bunkering points for shipping world

Port Name	Throughout (1000t)	Market Share	LNG Bunkering Facility
Singapore	34,000,000	38%	Proposed
Rotterdam	13,000,000	15%	Planned
Fujairah	9,500,000	11%	Proposed
Antwerp	6,180,000	7%	Planned

Hong Kong	5,429,000	6%	-
Gibraltar	5,407,000	6%	-
Busan	4,559,000	5%	Proposed
West Africa	4,100,000	5%	-
Tokyo Bay	3,494,000	4%	-
Iran	3,135,000	3%	-

(Source: Aagesen, 2013, DNV GL, 2014)

Port consolidation Opportunity: Marine container transport system has characteristic dynamics such as port consolidation. Ship operator Maersk and many others are also global port operators of container terminals. Utilisation of LNG decision by ship operators may increase availability of LNG bunker in container terminals due to consolidation of port services.

8.1.4 System Adaptation to LNG Bunkering

It is applied a system approach to help holistic understanding of complex adaptive behaviours of marine container transport system to LNG bunkering trend. It is aimed to clarify what LNG bunkering would bring for container shipping and how deep sea liner container shipping network would adapt to utilisation of LNG as ship fuel source from an operational strategy perspective. If reasons underlying utilisation of LNG as a bunkering source for deep sea container shipping are analysed, it will be noticed that high fuel prices, coercive emission regulations, capacity oversupply due to enlargement of ship size, development of efficient LNG fuel only engine technology, increasing exploration of natural gas are main milestones of LNG bunkering. Utilisation of LNG as a bunker for deep sea liner container shipping has some adaptive outputs and self-organisational requirements such as crew and bunkering employee training, generating of safety standards, designing of larger fuel tanks, investments of LNG fuelled ship and LNG bunkering facilities and liner service network design to benefits from LNG fuel efficiently with a minimum effects on liner service schedules. The following figure indicates inputs and outputs of LNG fuelled container shipping.

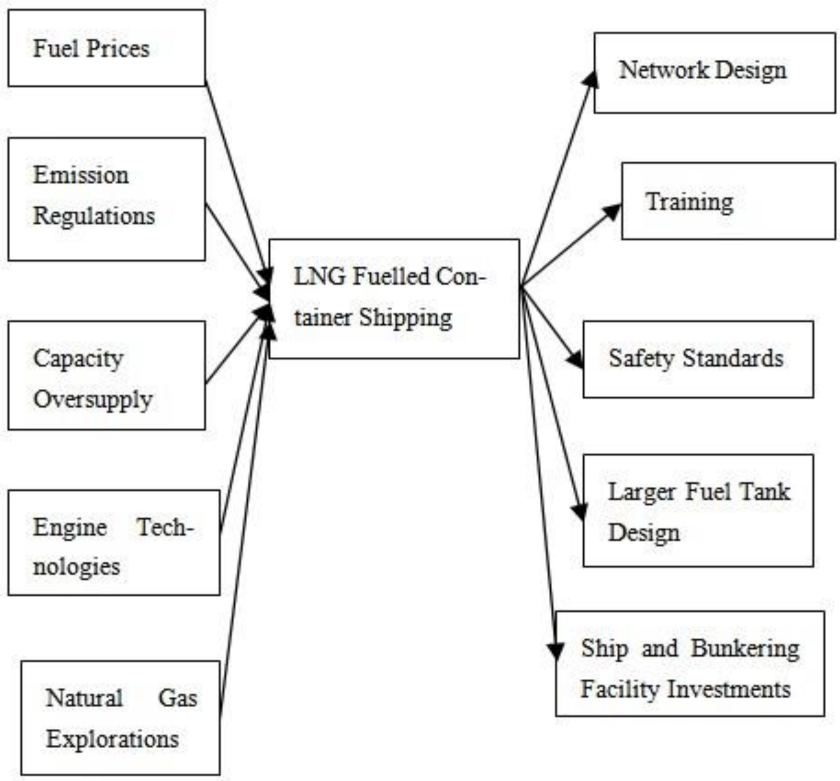


Figure 8.3: Inputs and outputs of self-organisation of liner shipping to LNG Bunkering
(Source: Own work)

8.2. LNG Bunker Supplier Choice Modelling of Shipping Liners

Generally speaking, shipping liners intend to develop strategies to minimise time wasting and costs, and maximise profit and operational efficiency. Decision variables of the bunkering point selection problems can be learned from operational experiences through adaptive learning loop of shipping management. Bunkering dynamics of LNG for deep sea container ships will also be learned via practical experience. Due to the global LNG bunker supply chain not yet existing, in the LNG bunkering point choice models of the shipping liners, some assumptions are made about the future. It is predicted that some ports of call will not own LNG bunkering facilities in the first years of shifting to LNG but some other ports which are not part of ordinary liner service or some floating LNG bunker suppliers will supply LNG bunker to deep sea liner container ships with different bunker prices of different geographical regions.

Based on assumptions, it will be possible to design a framework for the bunkering point selection problem of shipping liners providing time and cost minimisation of LNG bunkering operations. This framework also aims at maximisation of fleet capacity utilisation and maximisation of supply to transport demands with further considerations. It is also possible to mathematically model this framework within a multi-objective optimisation form for a particular liner service loop (Aymelek *et al.*, 2014). Figure 8.4 illustrates the logico-mathematical steps of the LNG bunkering choice model of the shipping liners.

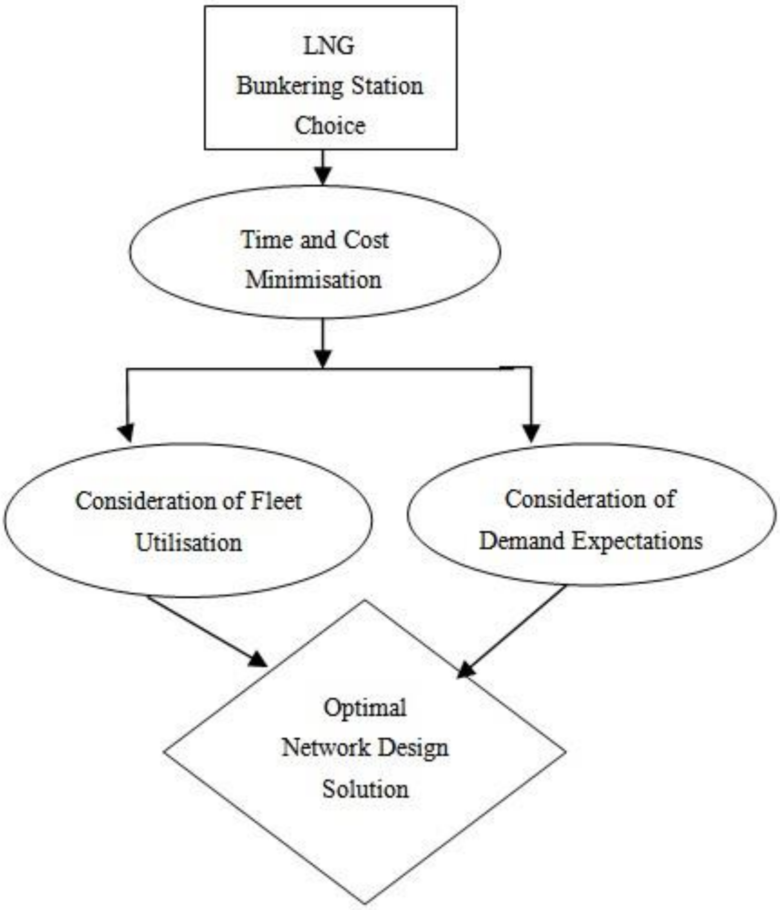


Figure 8.4: Logico-Mathematical stages of LNG bunkering station choice of shipping liners
(Source: Own work)

8.3. Scenario Building for the LNG Bunkering Supply Competition

The North-Western Europe region is one of the most popular bunkering areas for shipping. In order to establish a numerical application of the methodology given in chapter 4, four potential bunker supply points of North West Europe are selected as a case study. In this section, four fully competing bunkering points of the region are selected as a case of predicted future LNG bunkering scenario. The bunkering points are determined as Rotterdam, Antwerp, Hamburg, and Bremen. It is predicted that all will have LNG bunkering facilities and its supply chain by 2025. In the scenario it is also assumed that the regional LNG prices are affected by capacity deployment of the competitor suppliers. Predicted LNG bunkering capacities and demands of each bunker supply points in 2025 is shown in table 8.2. Assumed capacities and demands are given in MGOe MT (Absolute Marine Gas Oil Metric Ton) unit representing the amount of LNG equalling to energy content of 1 metric ton MGO.

Table 8.2: Predicted LNG bunkering capacities and demands of the bunkering points

North West Europe Bunkering Point	Capacity 2025 (MGOe MT)	Demand 2025 (MGOe MT)	Demand 2030 (MGOe MT)
Rotterdam	120,000	80,000	117,546
Antwerp	80,000	40,000	58,773
Hamburg	60,000	30,000	44,079
Bremen	50,000	25,000	36,733

(Source: Own work)

For the given bunkering region, the beginning average bunker price rate is assumed as \$310/MGOe MT based on the current market prices. Thus, the market slope values of the port operators are calculated as $b_{Bremen} = 0.000307$, $b_{Hamburg} = 0.000283$, $b_{Antwerp} = 0.000242$, $b_{Rotterdam} = 0.000307$, and the a value is found as 382. According to assumed cost data of the players in 2025, the related costs per unit of competitor bunker suppliers are found as shown in the following graph.

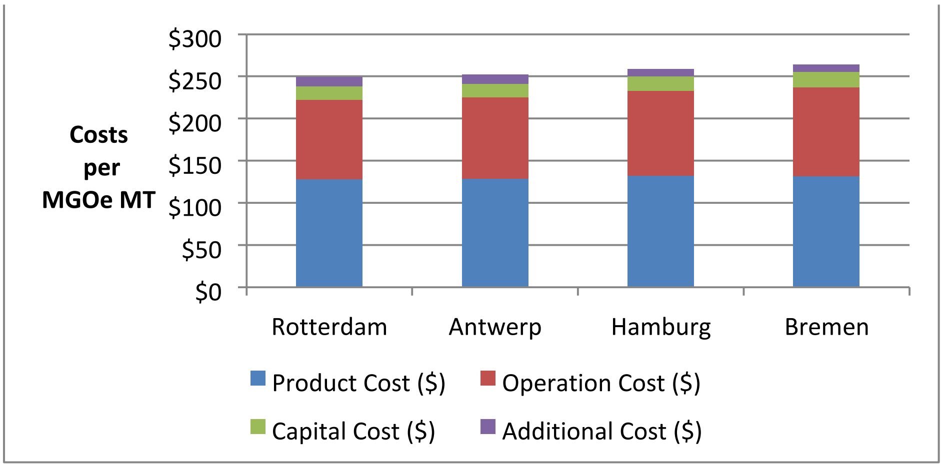
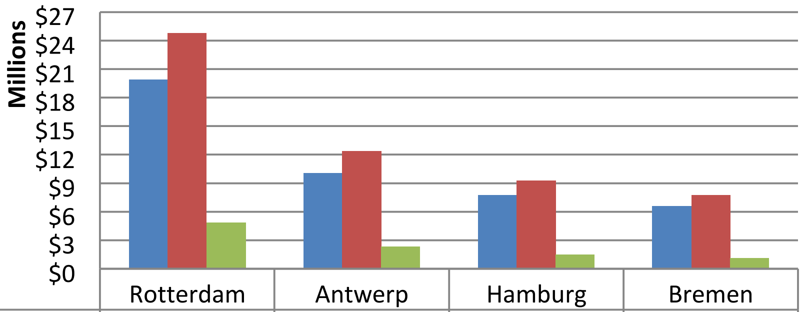


Figure 8.5: Cost structure of the LNG bunkering points (Source: Own work)

Figure 8.6 compares the financial situation of the bunker suppliers according to the 2025 scenario. In the financial analysis of the situation before capacity deployment decision-making process, Rotterdam is given as the biggest market player with the highest annual revenue and profit. On the other hand, Bremen is illustrated as the smallest market player in terms of annual cost, revenue and profit.



	Rotterdam	Antwerp	Hamburg	Bremen
Annual Costs (\$)	19920000	10080000	7770000	6600000
Annual Revenue(\$)	24802400	12401200	9300900	7750750
Annual Profit (\$)	4882400	2321200	1530900	1150750

Figure 8.6: Annual financial situation of the players in 2025 according to the scenario (Source: Own work)

As a part of this case study, a capacity deployment decision-making scenario is generated. The decision-making question includes additional supply capacities of the players for 20,000 MGOe MT by 2030. In terms of the simplification of the calculations and result analysis, 2 available strategy options in the capacity deployment related decision-making process are identified as following:

1- No bunkering supply capacity increase by 2030

2- Decision to provide 200,000 MGOe MT additional LNG bunkering supply capacities by 2030.

To establish a tactical decision-making analysis concept, the strategy combinations of the competitors are utilised. Based on the available strategy options of the LNG bunker suppliers, strategy combinations of the capacity deployment game may be obtained. As aforementioned 2 strategy options for each player creates 16 pure strategy combinations. The pure strategy combinations of the bunker suppliers are given as following:

$$\left(s_{No\ Increase}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.\,1$$

$$\left(s_{No\ Increase}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.\,2$$

$$\left(s_{No\ Increase}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.\,3$$

$$\left(SNoRotterdam\ Increase, SNoHamburg\ Increase, SNoAntwerp\ Increase, S{+}Bremen20{,}000\ MGOe\ MT\right) \coloneqq Comb.\,4$$

$$\left(s_{NoRotterdam\ Increase}, s_{+Hamburg20{,}000\ MGOe\ MT}, s_{+Antwerp20{,}000\ MGOe\ MT}, s_{NoBremen\ Increase}\right) \coloneqq Comb.\,5$$

$$\left(s_{No\ Increase}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.\,6$$

$$\left(s_{No\ Increase}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.7$$

$$\left(s_{No\ Increase}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.8$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.9$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.10$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.11$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.12$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{+20{,}000\ MGOe\ MT}^{Bremen}\right) \coloneqq Comb.13$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{+20{,}000\ MGOe\ MT}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.14$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{+20{,}000\ MGOe\ MT}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.15$$

$$\left(s_{+20{,}000\ MGOe\ MT}^{Rotterdam}, s_{No\ Increase}^{Hamburg}, s_{No\ Increase}^{Antwerp}, s_{No\ Increase}^{Bremen}\right) \coloneqq Comb.16$$

After determination of the available strategy options, strategy combinations of the players, and calculation of their numerical consequences, the Cournot competition model of the LNG bunkering supply game is generated on GamePlan 3.7 software. In the game model shown in figure 8.7, Bremen is given as player 1 with blue, Hamburg is presented as player 2 with red, Antwerp is given as player 3 with green, and Rotterdam is shown as player 4 with black. Decision hierarchy of players and pay offs of each strategy combinations are also illustrated.

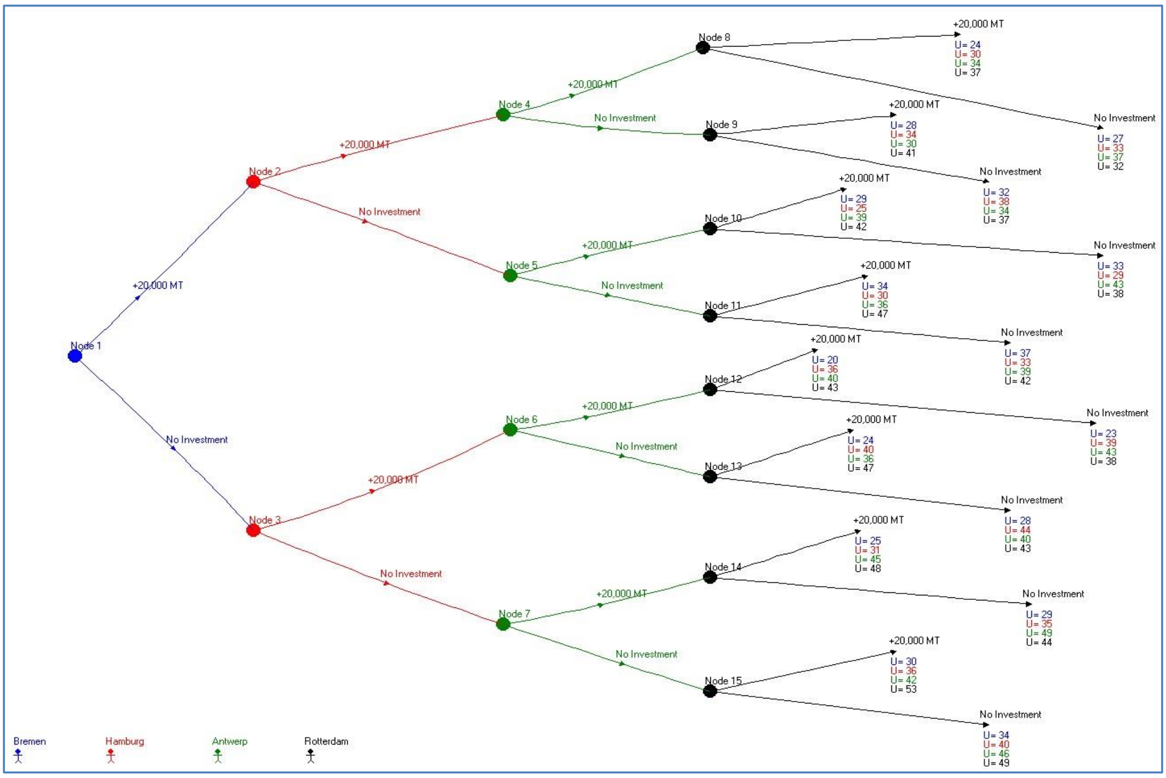


Figure 8.7: Cournot model of the LNG bunker supplier's game (Source: Own work)

The graph below per unit changes of the bunkering points according to risen strategy combinations. According to given cost results, the cost per MGOe MT of the LNG changes between 253 and 276. In addition, it is clearly shown that 20,000 MGOe MT additional capacity investment decision of Rotterdam is the dominant strategy of the Rotterdam in terms of obtaining the lowest cost.

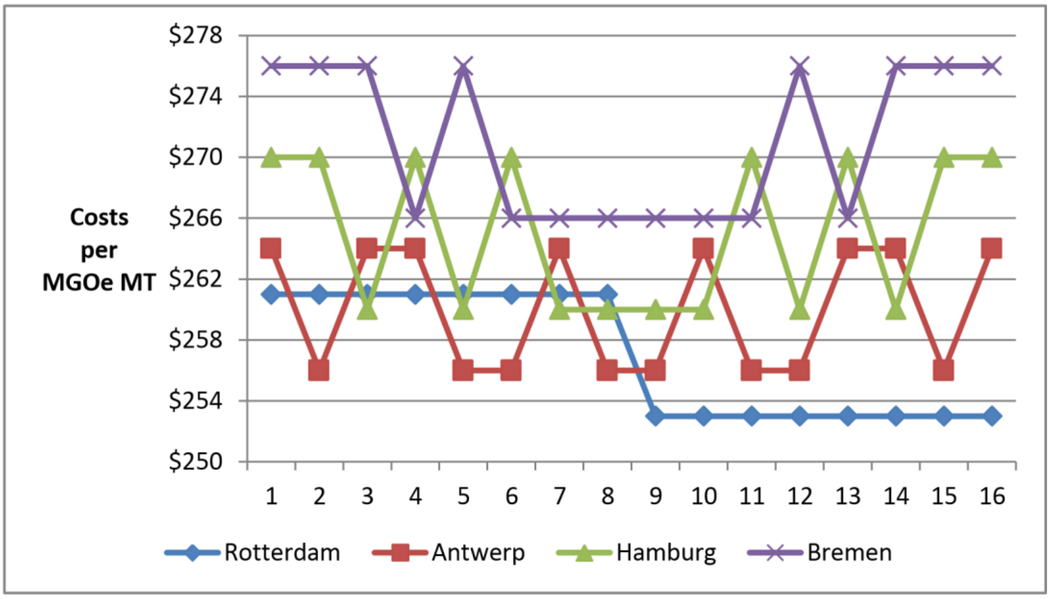


Figure 8.8: Cost per unit of the bunker points according to strategy combinations (Source: Own work)

The regional market price changes according to the relationship between price and supply capacities. In the model market constants and market slopes of the bunker suppliers are assumed as the same over 2025-2030 time periods at the decisionmaking moment. In each given strategy combinations, the market prices of the LNG bunker unit are calculated and presented in figure 8.9. According the figure 8.9, whilst strategy combination 1 is providing the highest market price with $310 MGOe MT, combination 9 provides the lowest regional market price with $290 MGOe MT.

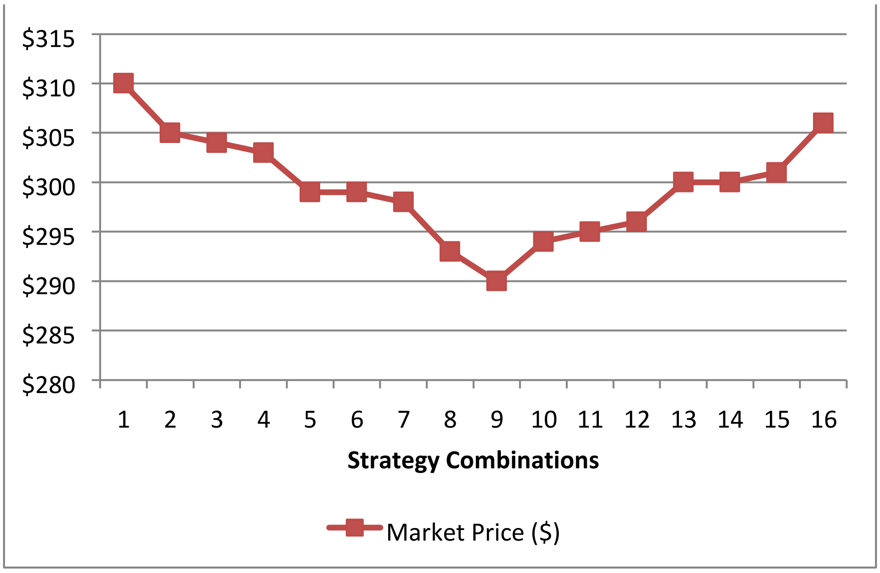


Figure 8.9: The market price of the LNG bunker according to strategy combinations (Source: Own work)

According to previously given costs and market prices, profits per MGOe MT of the bunker supplier points are calculated and illustrated in the following graph. It is clearly seen that Rotterdam has the highest profit with $53 per MGOe MT where the strategy combination 16 takes place. On the other hand, Bremen has the lowest profit with $20 where strategy combination 12 exists.

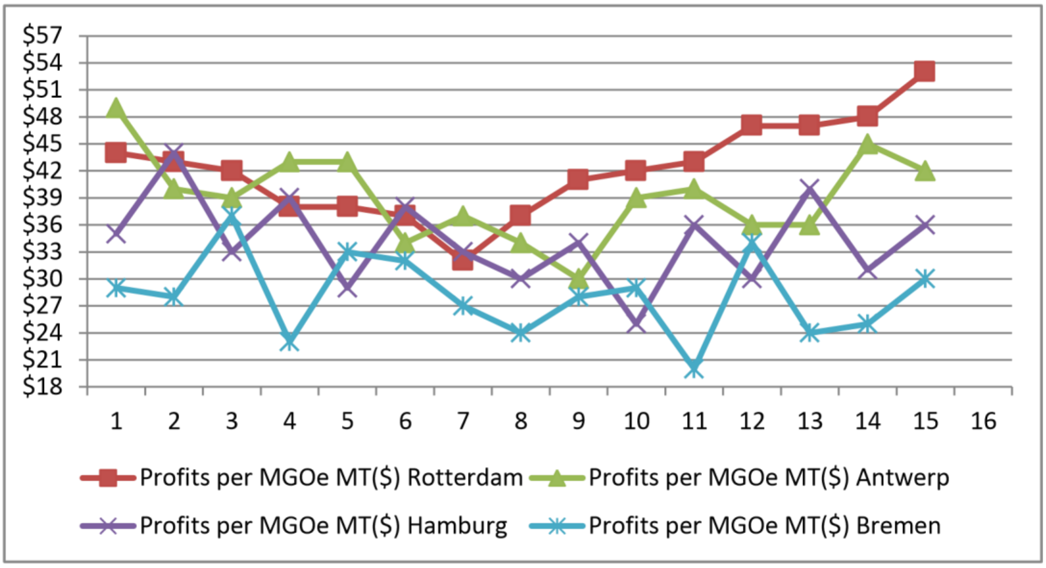


Figure 8.10: Profits per unit of the bunker points according to strategy combinations (Source: Own work)

8.4. Results of the LNG Bunkering Suppliers' Game with Complete Information

In the analysis of the results, firstly, the complete (perfect) information case of all players are applied. Therefore, the Cournot competition model of the game is run in the GamePlan 3.7. According to the solution given by GamePlan 3.7 shown in figure 8.11, the strategy combination 9 is determined as Nash equilibrium point of the LNG bunker supplier's competition game.

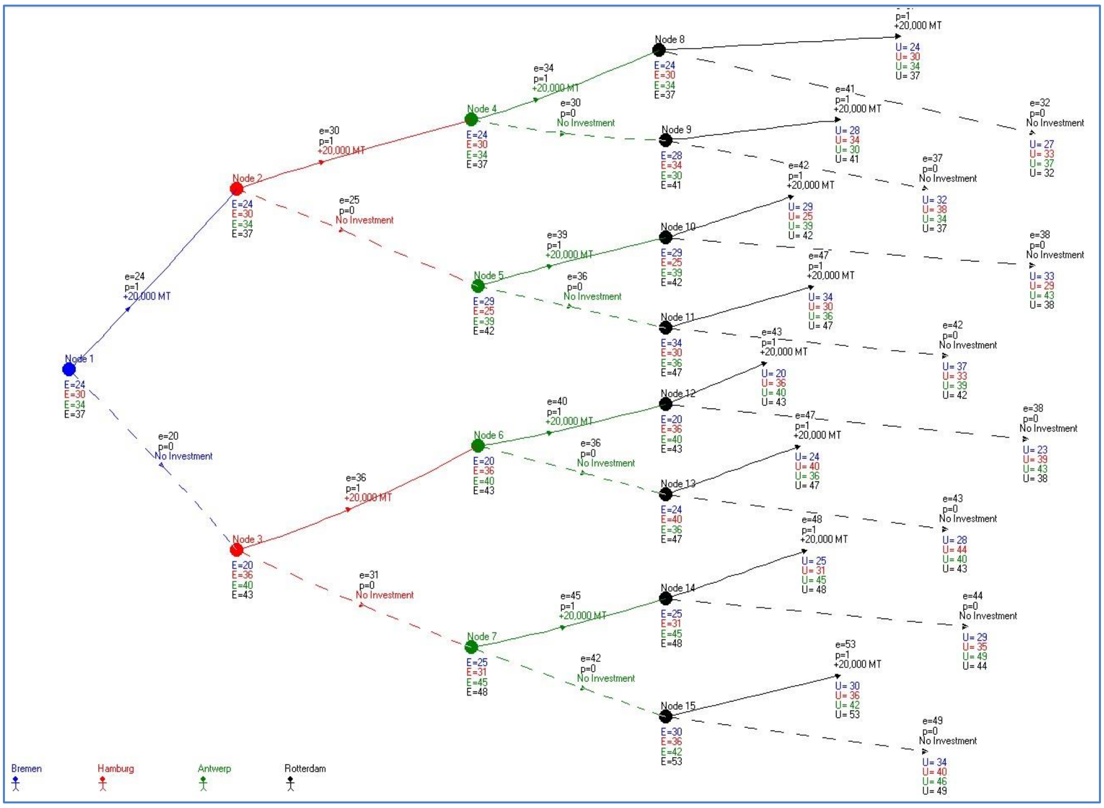
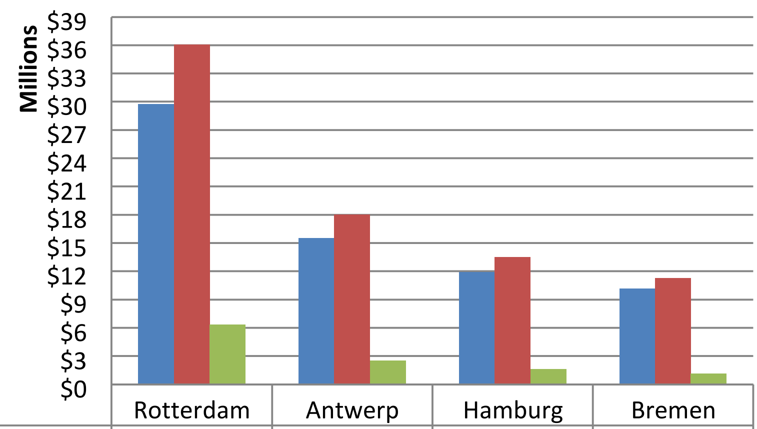


Figure 8.11: Nash equilibrium of the LNG bunker supplier's competition game

In calculations of the profits of the players for all strategy combinations, the annual costs, annual revenue and annual profits are also found. Figure 8.12 shows annual costs, annual revenue and annual profits of the players at Nash equilibrium point which is previously specified as strategy combination 9.



	Rotterdam	Antwerp	Hamburg	Bremen
Annual Costs ($)	29739138	15516072	11901330	10138308
Annual Revenue($)	36045480.9	18022740.45	13516825.35	11264174.45
Annual Profit ($)	6306342.9	2506668.45	1615495.35	1125866.45

Figure 8.12: Annual financial payoffs of the player at Nash equilibrium point (Source: Own work)

In this case study also a close view of decision behaviour is established. In order to analyse game theoretical decision-making of the bunker suppliers, two players are defined as rational players and two players are identified as adaptive players. This definition is intended to analyse decision-making process between two rational players. Bremen and Hamburg are identified as rational players. Antwerp and Rotterdam are identified as adaptive players. The player profit pay offs are applied to SGSolver software. Figure 8.13 illustrates Nash equilibriums for four different scenarios. The first scenario is the case that both Rotterdam and Antwerp are investing 20,000 MGOe MT additional capacities. The second scenario is the case that Rotterdam is not considering any investment, and Antwerp is investing 20,000 MGOe MT additional capacity. The third scenario is the case that Rotterdam is investing 20,000 MGOe MT additional capacity, and Antwerp is not investing any additional capacity. Finally, the fourth scenario is both adaptive players decide to not invest for any additional capacities. The equilibrium points are highlighted with points intersected by a green dash line.

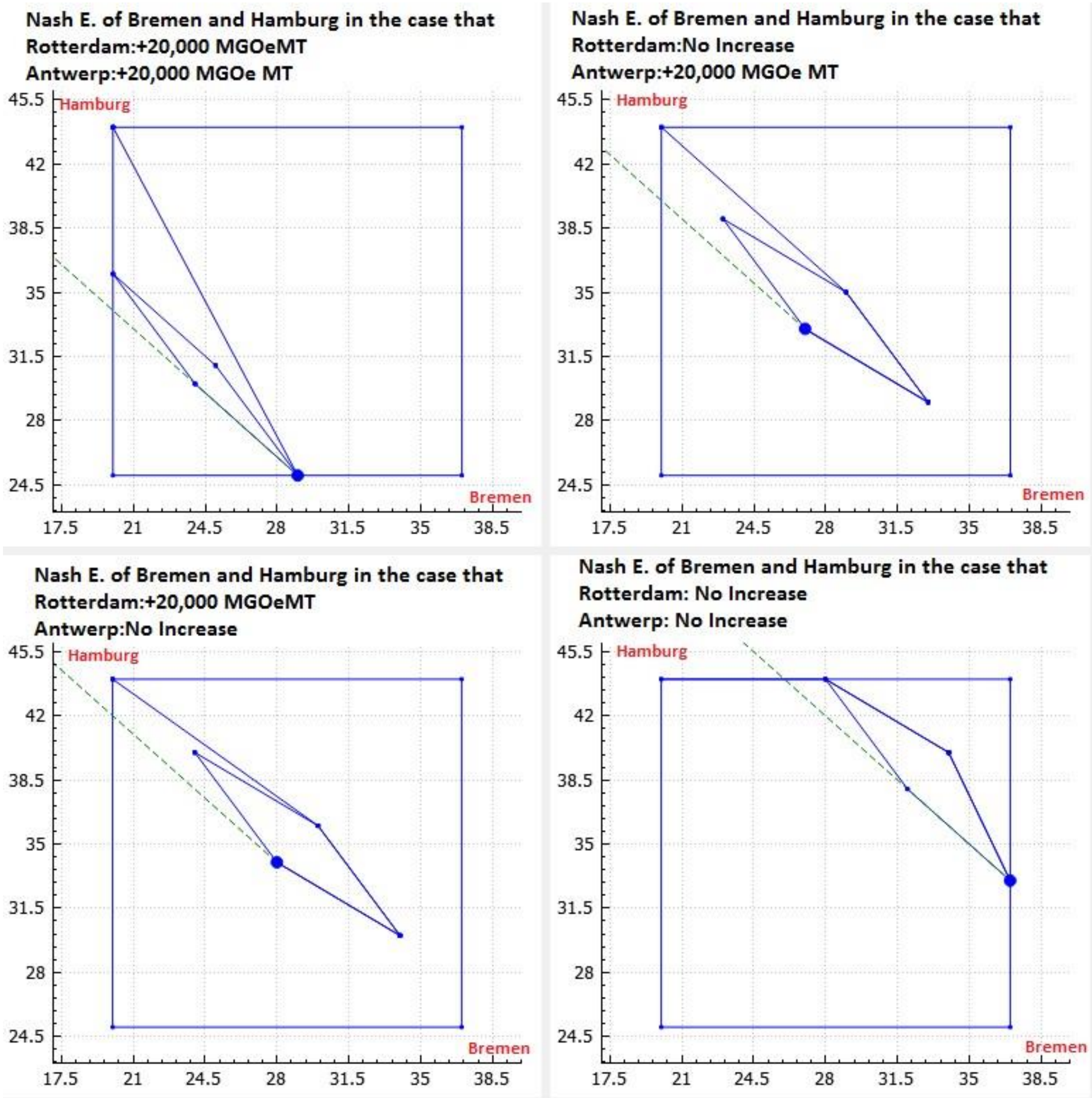


Figure 8.13: Nash equilibrium of rational players' profits for four different scenarios ($/MGOe MT) (Source: Own work)

In a holistic assessment of the four Nash equilibrium points obtained from four different scenarios by considering outcomes of adaptive players as well, the equilibrium point of the fourth scenario is found as Nash equilibrium. In figure 8.14 solution of the game is illustrated with a star intersected by a dash green line. Therefore, the Nash equilibrium point of the two rational players found as ($32, $38) representing the strategy combination 9.

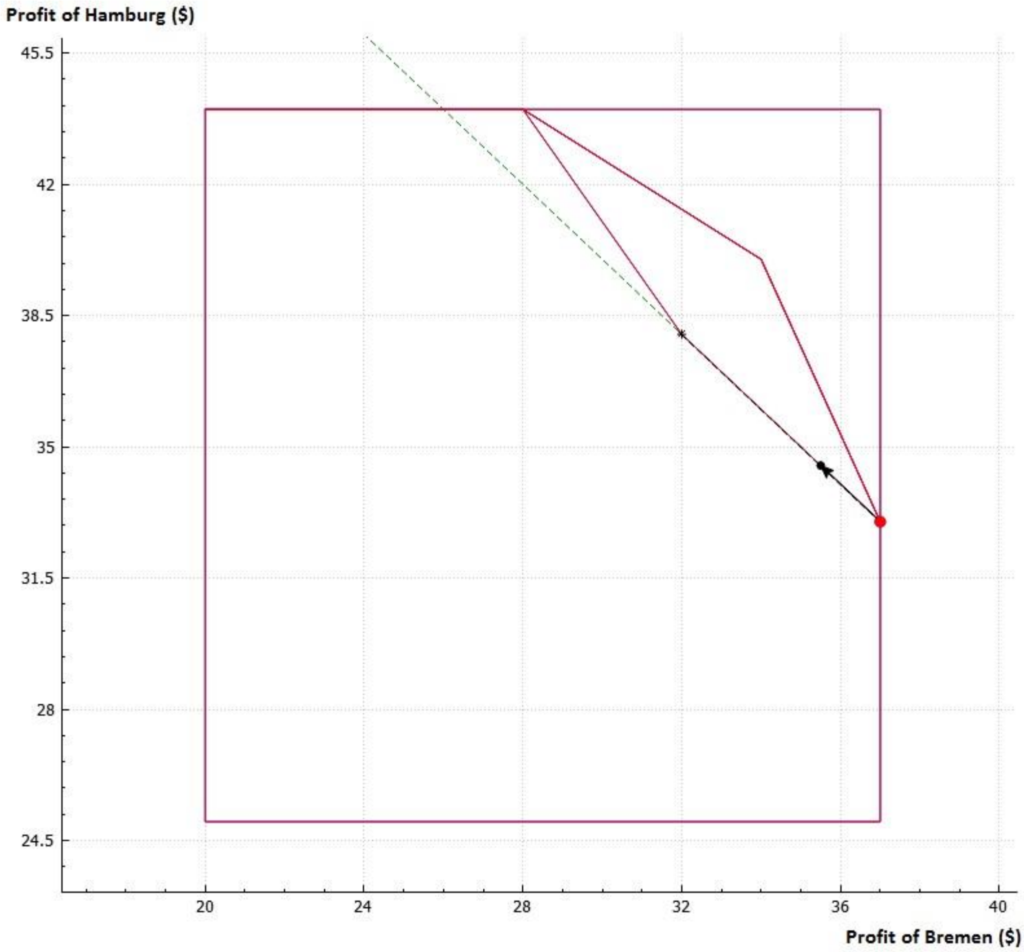


Figure 8.14: Nash equilibrium of rational players' profits ($/MGOe MT)
(Source: Own work)

8.5. LNG Bunkering Suppliers' Game with Incomplete Information

Another way of analysing the LNG bunker suppliers' competition is considering information related to capacity deployment decision as incomplete/imperfect. In order to apply on Bayesian-Nash Cournot competition model, the following Bayesian probabilities are utilised.

Table 8.3: Bayesian probabilities of the strategy combinations for the incomplete information game

Bremen	Hamburg	Antwerp	Rotterdam	B.P.
+20000 MGOe MT	+20000 MGOeMT	+20000 MGOeMT	+20000 MGOeMT	0.15
+20000 MGOeMT	+20000 MGOeMT	+20000 MGOeMT	No Increase	0.35
+20000 MGOeMT	+20000 MGOeMT	No Increase	+20000 MGOeMT	0.25
+20000 MGOeMT	+20000 MGOeMT	No Increase	No Increase	0.25
+20000 MGOeMT	No Increase	+20000 MGOeMT	+20000 MGOeMT	0.06
+20000 MGOeMT	No Increase	+20000 MGOeMT	No Increase	0.14
+20000 MGOeMT	No Increase	No Increase	+20000 MGOeMT	0.32
+20000 MGOeMT	No Increase	No Increase	No Increase	0.48
No Increase	+20000 MGOeMT	+20000 MGOeMT	+20000 MGOeMT	0.2
No Increase	+20000 MGOeMT	+20000 MGOeMT	No Increase	0.2
No Increase	+20000 MGOeMT	No Increase	+20000 MGOeMT	0.24
No Increase	+20000 MGOeMT	No Increase	No Increase	0.36
No Increase	No Increase	+20000 MGOeMT	+20000 MGOeMT	0.03

No Increase	No Increase	+20000 MGOeMT	No Increase	0.07
No Increase	No Increase	No Increase	+20000 MGOeMT	0.18
No Increase	No Increase	No Increase	No Increase	0.72

(Source: Own work)

In the Bayesian-Nash Cournot competition model, again Bremen and Hamburg bunkering points are identified as rational players; the remaining players are defined as adaptive players. Figure 8.15 illustrates the Bayesian-Nash equilibrium points of rational player's profits according to the given four different scenarios. A dashed green line is illustrated as the geometrical connection from Bayesian Nash solutions to feasible solution region.

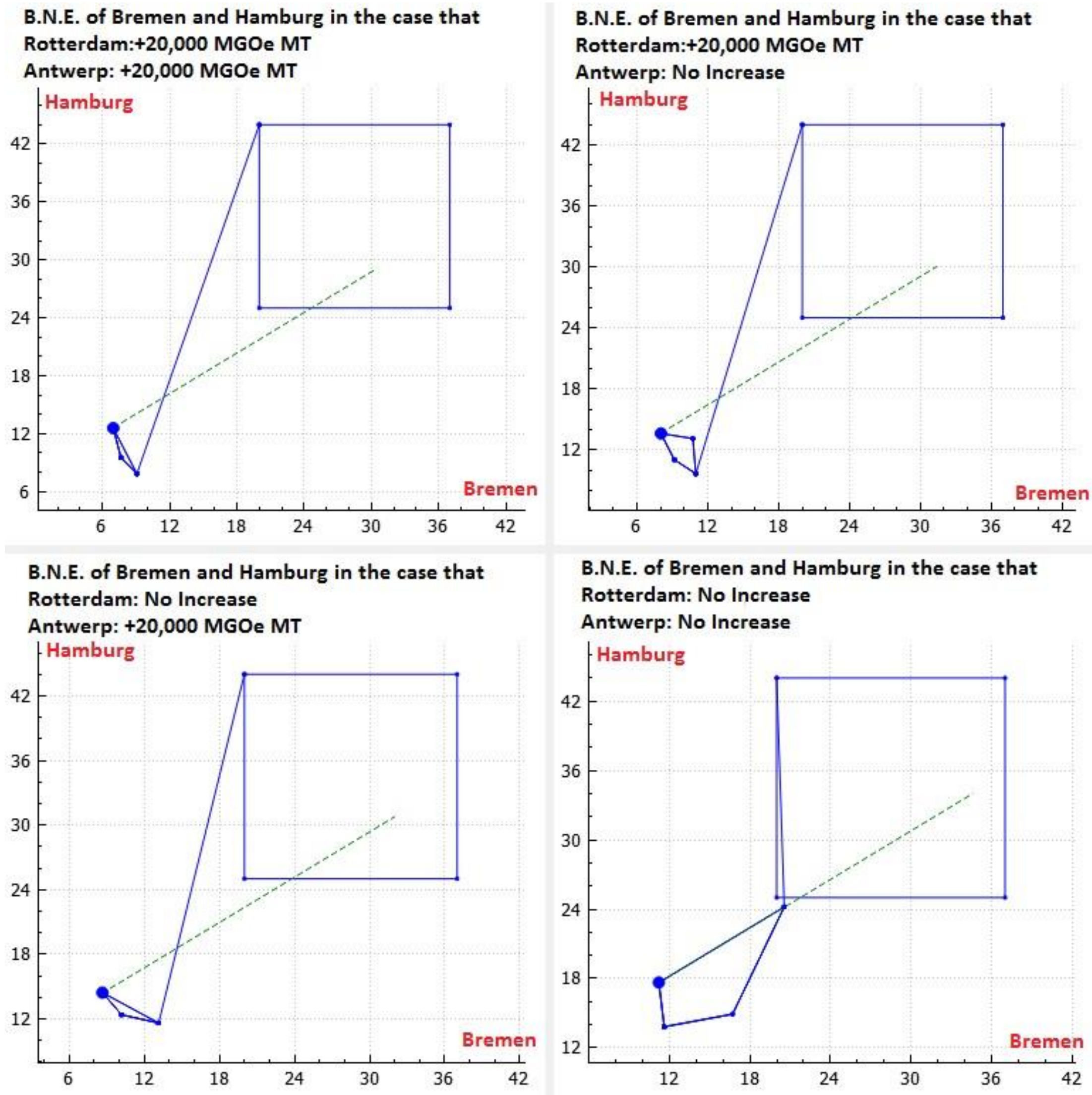


Figure 8.15: Bayesian Nash equilibrium of rational players' profits ($/MGOe MT)
(Source: Own work)

In figure 8.16 the final equilibrium point of the Bayesian-Nash Cournot game of the LNG bunker suppliers are presented. According to the figure, strategy combination 1 is found as the Bayesian-Nash solution of the game.

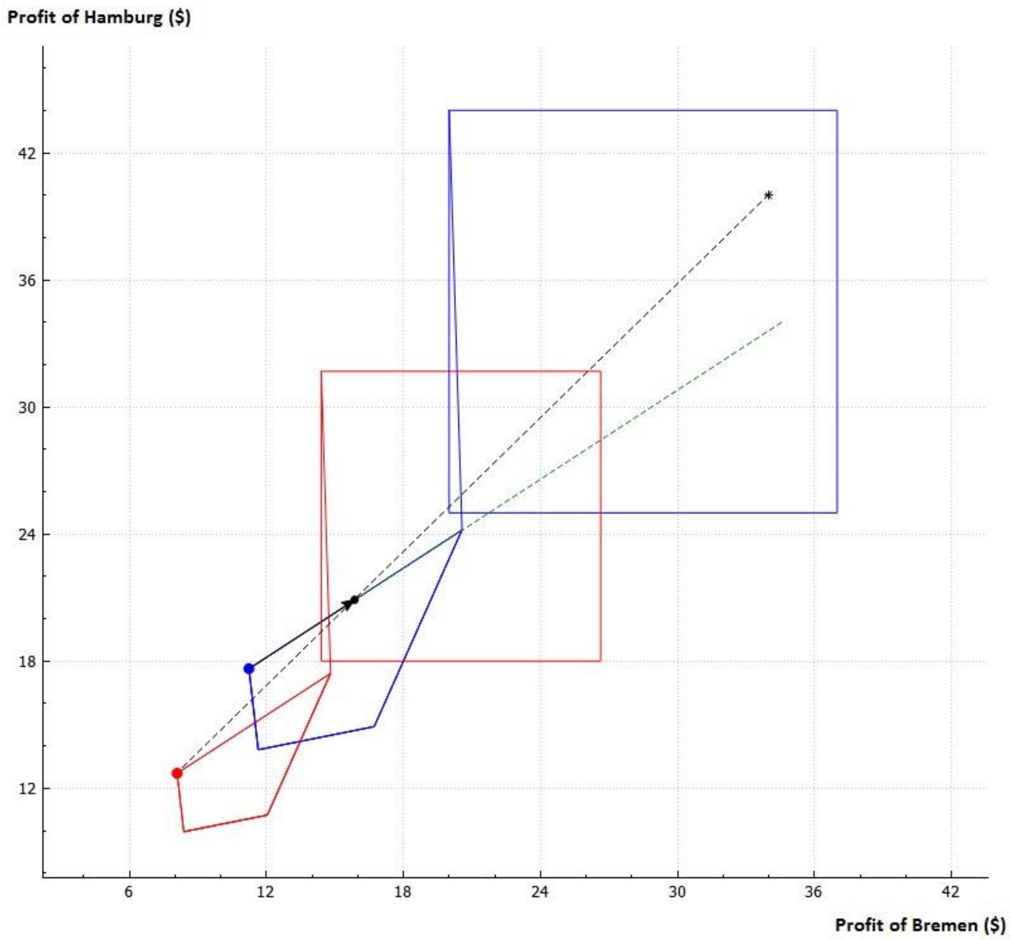


Figure 8.16: the final equilibrium point of the Bayesian-Nash Cournot game ($/MGOe MT)
(Source: Own work)

8.6. Outline of the Chapter

Throughout this chapter, the motivation for the LNG bunkering business was mentioned, and the LNG was considered as a promising future marine fuel for the liner container shipping industry. Systemic, operational, technical, safety, and conjectural challenges of the LNG fuelled liner container shipping were investigated. Opportunities including price, emission, global availability and port consolidation were outlined. System adaptation of the liner container shipping system to the LNG bunkering trend were analysed in depth. The outcomes of system adaptation were determined as network design, training of bunkering and ship crews, new safety standards, larger fuel tank design of container ships, and LNG bunkering supply chain. In addition, it was emphasised that in first application of the LNG bunkering, due to lack of availability of LNG bunker, it was required to develop bunkering network optimisation strategies. Therefore, a theoretical multi-objective optimisation concept of LNG bunkering was briefly mentioned. Moreover, numerical analysis of the methodology was carried out with North West Europe bunkering supply case scenario. Consequences of the tactical decision of the bunker suppliers regarding the capacity investment were analysed. Costs per units and profit per units of the competitors were calculated, and market prices of the bunkering region that shipping liners could tolerate were presented. The equilibrium points of both complete and incomplete information cases were found and illustrated.

9. CONCLUSION & RECOMMENDATIONS

In recent years, a series of studies have been conducted to develop competition analysis models and methods for the liner container shipping. The research structure and presentation of this thesis was shaped with a motivation of contributing to existing academic knowledge in the literature by developing a novel theoretical approach. However, more significantly, by developing a better practically applicable and logico-mathematically well-structured liner container shipping competition analysis concept, it was also achieved to respond to the requirements of the liner shipping industry. Throughout the thesis the developed methodology was applied to three different cases of each competition platforms of the liner container shipping. The outcomes of the methodological application were numerically illustrated and their support to decision-making processes was clearly indicated. In the study a significant number of outcomes and numerical results were obtained. The results illustrated in the case studies took into account the managerial decision-making priorities of the liner container shipping industry.

In this chapter of the study, firstly, the research objectives of the thesis are reviewed to make sure that the research effort and numerical illustrations satisfy the objectives of the research. Secondly, all limitations regarding the methodology, data, case studies and results are clearly emphasised. Moreover, innovations of the research in the research field are expressed. Furthermore, concluding remarks of the study is given. Finally, various recommendations are made regarding the further development of the study and future research directions of the field are mentioned.

9.1. Review of the Research Objectives

The aim of this research was to develop a competition analysis methodology which could contribute existing academic literature, and capacity planning related decisionmaking process of the liner container shipping industry. This study identified the hierarchy of the liner container shipping in value chain and determined the most significant three competition platform of the liner container shipping. The study attempted to enlighten the unknowns of the capacity deployment decisions of the competitors in certain liner container shipping markets. Therefore, an integrated methodology consisting of Cournot competition model, company economics, capacity investment decision-making, Nash and Bayesian-Nash equilibrium solutions were established.

In this study many outputs were generated in terms of satisfying the previously determined research objectives. The research achievements identified in the following bullet points, which are in line with the research objectives given in chapter 1:

- Market shares of the liner shipping alliances on specific liner shipping routes were presented. A specific focus on the Far East- Northern Europe liner shipping service was given in order to understand market behaviours.
- A competition analysis framework of the shipping liner alliance competition was established. The cash flow of the alliances for the initial state and equilibrium state was found. A very strong mathematical integration between shipping company economics and capacity planning related decision-making were created.
- A holistic port competition analysis methodology was developed and applied on a port competition case in Izmir Turkey. In this analysis, Multi Attribute Value Analysis methodology was utilised as well as game theoretical analysis. Therefore, for both shipping liner and hinterland perspective performances of the ports were presented by utilisation of the data collected.
- Challenges and opportunities of possible utilisation of the LNG bunker for the liner container shipping were briefly well summarised. Transition from conventional bunkering sources to the LNG bunker was justified with the requirements of the industry.
- Decision logic of the shipping liners regarding the bunker supplier choice was presented. Significance of the time and cost minimisation were clearly explained.

- A novel game theoretical analysis approach was developed and applied for all competition platform cases of the liner container shipping. Firstly, Far- East Northern Europe liner service loop was utilised as a case study of the shipping liner alliance competition. Secondly, Izmir province of Turkey was selected as a case study of the port competition with shared hinterland market. Thirdly, North Western Europe bunkering points were selected as a case study of the LNG bunkering supply competition.

9.2. Limitations of the Research

This study contains some restrictions and assumptions in order to establish a methodological framework providing numerical results to analyse liner container shipping competition. Major limitations of the thesis are given with the following statements:

- The methodology developed in this study only analyses the consequences of the capacity deployment decision-making of the liner container shipping counterparties in a particular market competition.
- In terms of simplification of the model, it was accepted that the market price was only affected by capacities supplied to the market. Impacts of the other factors on freight mechanism were disregarded.
- During the research process a large amount of data were generated. Only limited number of outcomes could be illustrated. However, the research outcomes shown were selected based on the decision-making requirements of the industry.
- In methodology and case studies, four player-games with two homogenous available strategy moves of the players were considered as constant in terms of simplification of the analysis. However, in reality the number of players and available strategy option may contain larger numbers.
- The study was only applied for practical incomplete and complete information game cases in the form of Cournot competition game model. Other competition models of the economics literature were excluded.
- In shipping liner competition, the liner service loops of the alliances were assumed as identical. However, in practical reality there are small differences between service loops of the alliances.
- Data collected in port competition case reflects subjective assessment of the survey participants. Therefore, the results may differ based on the selected statistical sample.
- It is assumed that LNG would be a significant bunkering fuel source for the liner container shipping in long-middle term. However, current fleet of the liner container shipping industry are not suitable to burn this bunker and retrofitting cost is relatively high. Therefore, it is considered that only new buildings will have the capability of the LNG fuel.
- The data utilised in the bunker suppliers' game reflects subjective comments of the interviewee and some assumptions based on the current HFO and MGO markets.

9.3. Innovations of the Research

- A clear link between academic knowledge generated and decision-making process of the liner container shipping industry counterparties was demonstrated. In development of the methodology both academic and industrial knowledge were combined.
- The competition platforms of the liner container shipping industry, for the four market player state, was analysed systematically.
- In port competition analysis, integration of different perspectives including hinterland, shipping liner and inter-port perspectives was created via utilisation of input-output interdependencies. Therefore, it was attempted to generate a

hybrid port competition analysis methodology to contribute to existing academic literature with an innovative approach.

- A very first application of LNG bunkering for the liner container shipping was analysed in depth. A system approach was utilised in order to understand inputs and outputs of the LNG bunkering trend for the liner container shipping.
- Impacts of the capacity deployment of the liner container shipping counterparties on the market price were illustrated with numerical application of the developed methodology.
- Cost and profit changes of the liner container shipping counterparties according to strategy combinations in market were illustrated by integration of the company economics and game theory decision-making behaviours.
- Both complete and incomplete cases of four player games were considered in this study in order to contribute different state of the decision-making processes.

9.4. Discussion & Concluding Remarks

In summary, this study has emphasised significance of the liner container shipping for globalisation and it has attempted to analyse the competition among industrial players with an innovative approach. The study has identified that competition in the liner container shipping industry was not only appeared in shipping liner alliance competition platform but also in port competition, and bunker supplier competition platforms. Therefore, a special research attention was given to all platforms in this research. The study was provided a clear insight to the competition dynamics of different branches of the liner container shipping industry. More specifically, influence of the capacity investment decisions on the market price was revealed. The outcomes of this study showed that strategic capacity planning was essential for the cost saving of the liner container shipping counterparties in a perfect competition environment.

The theoretical discussion of this study was argued practical applicability of a novel non-cooperative four player game theory on the liner container shipping competition. This theory was established based on a successful methodological integration of Cournot competition theory, shipping company economics, Nash equilibrium and Bayesian-Nash solution concepts. The theory was applied on the three different case studies of the determined liner container shipping competition platforms. Therefore, the practicability of the methodology for all different branches of the liner container shipping industry was proven.

In the first case study, a shipping liner competition case, which is a trend research subject, is analysed. The outcomes of this research reveal that redesigning of the liner container shipping alliances is influenced by the financial performance of the alliance structures. Another factor is economy of scale of the larger ship investments due to its direct link with financial indicators. Shipping alliances established based on efficient utilisation of the ship capacities. However, the results of this study suggest that larger ship investment decisions need to consider growth of the demand in a particular market to minimise negative influence on the freight rates. In the markets where demand growth is slow, profitability of the large ships are limited. Thus, it is not a correct approach to only consider economy of scale at the large ship investment decision. Holistic consideration of the market by consideration of the decisions of the competitors is vital to predict the market influence of the decisions.

In the second case study, a port competition case in Turkey is analysed holistically including shipping liner, hinterland and inter port perspectives. Therefore, a better port competitiveness assessment regarding to port performance is obtained. This part of the study suggested a new form of port competition analysis which considers the shipping liner's port choice dynamics as well as satisfaction of the hinterland from port services provided. Therefore, a capacity investment decision-making should be planned to maximise the outcomes of the

In the final case study, a futuristic LNG bunkering supply competition case is analysed. The LNG is a promising marine fuel for the liner container shipping industry in terms of its emission and price. However, applicability of the LNG bunkering will be limited for the near and middle future due to its lack of availability and expensive technological applicability. Thus, LNG bunkering supply capacities should be planned strategically by the bunker suppliers. However, in a future scenario, where LNG bunkering supply competition may be seen as though, the game theoretical methodology developed in this study has a high applicability and provide a useful decision-making rationale for the bunkering suppliers.

Taken together the results of the three case studies suggests that the non-cooperative four player game theory competition analysis developed in this research is applicable for all competition platforms of the liner container shipping. In addition, it also can be utilised together with different tools such as system approach and multi criteria decision analysis and can provide more meaningful results for the industry. To conclude, this research extends our knowledge on applicability of non-cooperative game theoretical decision-making models in the liner container shipping industry and integrates shipping economics and behavioural models.

9.5. Recommendations for the Future Research

More research is required to better understand the practical implementation of the game theory approaches on liner shipping competition analysis cases. This could include both qualitative and quantitative research efforts. Especially, there is an increasing demand of the industry for the research including competitor behaviours in the future capacity planning related decisions. Therefore, special attention is required to analyse competitor behaviours in liner container shipping competition platforms. However, it is possible to extend the application of the methodological outcomes for the other competition platforms of the value chain for the future.

This study attempted to clarify the decision uncertainties of the liner container shipping counterparties and developed a four player game theory competition analysis method which could be utilised for both complete and incomplete information cases. The developed game theoretical research approach of this thesis could be improved in several ways by following further research directions:

- With a closer collaboration with industrial counterparties, it will be possible to determine all single cost elements of the liner shipping counterparties more accurately in a particular geographical area. And their real share in the cost structure of the company can be revealed.
- In this thesis the results are obtained by a long mathematical calculation process and utilisation of different software applications. The future research should focus on the development of integrated software by utilisation of advanced computer software programming languages such as Java or C++. Therefore, application in practice would be simplified and the outcomes of this study would be commercialised.
- A similar approach could be developed to apply to the competition of the other branches of the shipping industry.
- In this thesis only cost reduction with capacity deployment decision-making was included in analysis. In the future it may be extended to other competitive decision-making issues such as differentiation with marketing strategies.

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APPENDICES

Appendix A- An Example of Survey Questionnaire Forms

This survey has been designed by researchers at the University of Strathclyde to gather feedback from Maritime Logistics Experts regarding to most appropriate port selection for both Import and Export Operations in Izmir.

The aim of the survey is to obtain subjective data, from experts, about weighing of different decision making criteria to utilise on a multi-criteria decision analysis model.

If you have any questions or comment about this survey please don't hesitate to contact us.

Thank you very much in advance!

Murat Aymelek
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Please answer the following questions about yourself

Which of the following academics degree you hold?

- ☐ PhD
- ☐ Master
- ☐ Bachelor
- ☐ Other

How would you describe your organisation/company?

- ○ Freight Forwarder
- ○ Inland Transport Company
- ○ Academics
- ○ Customs Broker
- ○ Other (Please specify)

Please comparatively scale the following criteria and sub-criteria according to you think which holds how much importance compared to other one in the port choice in Izmir Province of Turkey

The 5 main criteria are determined based on the location, foreland, cost, service speed and service quality of port alternatives of Izmir region

Scale -
1 - Equally important
2- Between 1 and 3
3 - Slightly more important
4- Between 3 and 5
5- Moderately more important
6- Between 5 and 7
7 - Very Important compared to other criterion
8- Between 7 and 9
9 - Extremely important compared to other criterion

For Example, in the first question, if you think that location is slightly more important than service time then you would select the number 3 towards location.
If you think that time is extremely more important compared location, then you would select number 9 towards service time.

Please comparatively scale the importance of each main criteria in port selection. Location should be understand as geopraphical position of the ports. Service time is the time requires from ship's arrival to delivery to customer. Cost is sum of all arising costs which customers have to pay. Service network is foreland connection of ports to other ports via liner transport networks. Service quality represents quality of services given to customers by port terminals.

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Time
Location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Cost
Location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Network
Location	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Quality
Service Time	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Cost
Service Time	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Network
Service Time	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Quality
Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Network
Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Quality
Service Network	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Service Quality

Please comparatively scale the importance of each sub-criteria of cost criterion

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Port Charges	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Inland Transport Charges
Port Charges	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Customs & Storage Charges
Inland Transport Charges	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Customs & Storage Charges

Please comparatively scale the importance of each sub-criteria of service time criterion

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
HandlingTime	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Truck waiting time
Handling Time	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Customs & Warehouse Time
Customs & Warehouse Time	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Truck waiting time

Please comparatively scale the importance of each sub-criteria of sevice quality criterion

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Special Requirements	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Port Congestion
Special Requirements	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Reputition
Port Congestion	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Reputition

Please comparatively scale the importance of each sub-criteria of port network criterion

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Feeder Network	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Main Line Network

Please comparatively scale the importance of each sub-criteria of Location criterion

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Intermodal Connection	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Distance to Industry

Thank you for completing the survey, your feedback is invaluable to us.

Appendix B- Excel Calculations of the Initial States

Shipping Alliance Competition Initial State Calculation

	A	B	C	D	E
1	Topic	2M	G6	CHYKE	O3
2	Voyage Cost ($)	1995000	1860000	1743000	1932000
3	Operation Cost ($)	1108800	1013520	972000	1077360
4	Capital Cost ($)	2581600	2450160	2231280	2497760
5	Total Cost ($)	5685400	5323680	4946280	5507120
6	Additional Costs per ship($)	100000	100000	100000	100000
7	Annual Additional Cost per ship($)	500000	500000	500000	500000
8					
9	Port Time (Days)	25	25	25	25
10	Voyage Time (Days)	45	45	45	45
11	Round Trip (Days)	70	70	70	70
12	Days in a year	365	365	365	365
13	Annual Delays (Days)	15	15	15	15
14	Service Days	350	350	350	350
15	Weeks	50	50	50	50
16	Number of Trips	5	5	5	5
17	Number of Port calls in a round trip	13	13	13	13
18	Number of Ships	10	10	10	10
19	Annual Additional Cost per service loop($)	2500000	2500000	2500000	2500000
20					
21	Annual Cost Per Service loop ($)	286770000	268684000	249814000	277856000
22					
23	Cost Per TEU ($)	513.602579	516.7	576.4716742	472.946383
24					
25	Freight per TEU ($)	650.5816	650.5816	650.5816	650.5816
26	Average Capacity TEU	14000	12300	10800	13400
27	Weekly Demand TEU	11167	10400	8667	11750
28	b slope	0.003248	0.003612	0.002269	0.004404
29	a market constant	824	824	824	824
30	Daily Bunker Consumption (ton)	200	185	172	193
31	Annual Operation Cost ($) per TEU transported	396	412	450	402
32	Annual capital cost of a ship ($)	922	996	1033	932
33	Bunker price ($/ton)	200	200	200	200
34	Port Charges ($) per port of call	15000	15000	15000	15000
35					
36	Profit per TEU($)	136.979021	133.8816	74.10992583	177.635217

Holistic Port Competition Initial State Calculation

	A	B	C	D	E
1	Topic	Izmir Alsancak Port	APM Petlim Port	Nemport-Aliaga	TCE EGE- Aliaga
2	Overhead Cost ($)	38	35	40	40
3	Operating Cost ($)	155	105	125	129
4	Capital Cost ($)	40	60	50	50
5	Additional Cost ($)	15	4	8	8
6	Total Cost ($)	248	204	223	227
7	Overhead Costs				
8	Concession Cost ($)	5	10	10	10
9	Staff Cost ($)	20	10	15	15
10	Office Cost ($)	8	10	10	10
11	Other Overhead Cost ($)	5	5	5	5
12	Operational Costs				
13	Labour Cost ($)	130	90	106	110
14	Energy Consumption Cost ($)	15	10	12	12
15	Maintenance and Repair Cost ($)	10	5	7	7
16	Capital Costs				
17	Equipment Asset Cost ($)	30	50	40	40
18	Misc. Capital Cost ($)	10	10	10	10
19	Additional Cost				
20	Insurance Cost ($)	5	2	4	4
21	Extraordinary Cost ($)	10	2	4	4
22	Total Port Price per TEU ($)	350.57	350.57	350.57	350.57
23	Port Annual Handling Capacity TEU	900000	1100000	400000	400000
24	Annual Demand TEU	650000	700000	225000	200000
25	b slope	0.0000378	0.0000443	0.000106	0.0001032
26	a market constant	517	517	517	517
27	Desired Port Price per TEU ($)	350	350	350	350
28	Profit per TEU($)	102.57	146.57	127.57	123.57
29	Annual Costs ($)	161200000	142800000	50175000	45400000
30	Annual Revenue($)	227870500	245399000	78878250	70114000
31	Annual Profit ($)	66670500	102599000	28703250	24714000

LNG Bunker Suppliers' Competition Initial State Calculation

	A	B	C	D	E
1	Topic	Rotterdam	Antwerp	Hamburg	Bremen
2	Product Cost ($)	128	129	132	132
3	Operation Cost ($)	94	96	101	105
4	Capital Cost ($)	16	16	17	18
5	Additional Cost ($)	11	11	9	9
6	Total Cost ($)	249	252	259	264
7	Product Costs				
8	Product Price Index ($)	120	120	122	122
9	Product Logistics Cost ($)	8	9	10	10
10	Regional Product Tax Rate ($)	0	0	0	0
11	Operational Costs				
12	Storage Cost ($)	9	9	10	10
13	Heating-Cooling Cost ($)	40	40	42	43
14	Barging Cost ($)	5	5	5	6
15	Administration Cost ($)	3	3	3	3
16	Labour Cost ($)	37	39	41	43
17	Capital Costs				
18	Equipment Asset Cost ($)	13	13	13	14
19	Misc. Capital Cost ($)	3	3	4	4
20	Additional Cost				
21	Insurance Cost ($)	4	4	3	3
22	Inspection and Survey Cost ($)	7	7	6	6
23	Absolute MGO (LNG-MGOe) price ($)	310.03	310.03	310.03	310.03
24	Capacity MGOe MT	120000	80000	60000	50000
25	Annual Demand MGOe MT	80000	40000	30000	25000
26	b slope	0.000169	0.000242	0.000283	0.000307
27	a market constant	382	382	382	382
28	Desired bunker Price per MGOe MT ($)	310	310	310	310
29	Profit per MGOe MT($)	61.03	58.03	51.03	46.03
30	Annual Costs ($)	19920000	10080000	7770000	6600000
31	Annual Revenue($)	24802400	12401200	9300900	7750750
32	Annual Profit ($)	4882400	2321200	1530900	1150750

Appendix C- Excel Calculations of the Equilibrium Points

Shipping Alliance Competition Nash Equilibrium Point Calculation

	A	B	C	D	E
1	Topic	2M	G6	CHYKE	O3
2	Voyage Cost ($)	2445000	2276250	2130000	2366250
3	Operation Cost ($)	1108800	1013520	972000	1077360
4	Capital Cost ($)	2581600	2450160	2231280	2497760
5	Total Cost ($)	6135400	5739930	5333280	5941370
6	Additional Costs per ship($)	100000	100000	100000	100000
7	Annual Additional Cost per ship($)	500000	500000	500000	500000
8					
9	Port Time (Days)	25	25	25	25
10	Voyage Time (Days)	45	45	45	45
11	Round Trip (Days)	70	70	70	70
12	Days in a year	365	365	365	365
13	Annual Delays (Days)	15	15	15	15
14	Service Days	350	350	350	350
15	Weeks	50	50	50	50
16	Number of Trips	5	5	5	5
17	Number of Port calls in a round trip	13	13	13	13
18	Number of Ships	10	10	10	10
19	Annual Additional Cost per service loop($)	2500000	2500000	2500000	2500000
20					
21	Annual Cost Per Service loop ($)	309270000	289496500	269164000	299568500
22					
23	Cost Per TEU ($)	518.0720901	520.7135708	580.9477784	476.9218241
24					
25	Freight per TEU ($)	650.5816	650.5816	650.5816	650.5816
26	Average Capacity TEU	14000	12300	10800	13400
27	Weekly Demand TEU	11939.26505	11119.2224	9266.375052	12562.583
28	b slope	0.003248	0.003612	0.002269	0.004404
29	a market constant	824	824	824	824
30	Daily Bunker Consumption (ton)	200	185	172	193
31	Annual Operation Cost ($) per TEU transported	396	412	450	402
32	Annual capital cost of a ship ($)	922	996	1033	932
33	Bunker price ($/ton)	250	250	250	250
34	Port Charges ($) per port of call	15000	15000	15000	15000
35					
36	Profit per TEU($)	132.5095099	129.8680292	69.63382163	173.6597759

Holistic Port Competition Nash Equilibrium Point Calculation

	A	B	C	D	E
1	Topic	Izmir Alsancak Port	APM Petlim Port	Nemport-Aliaga	TCE EGE- Aliaga
2	Overhead Cost ($)	35	35	40	40
3	Operating Cost ($)	145	105	129	129
4	Capital Cost ($)	46	60	50	50
5	Additional Cost ($)	16	4	8	8
6	Total Cost ($)	242	204	227	227
7	Overhead Costs				
8	Concession Cost ($)	5	10	10	10
9	Staff Cost ($)	18	10	15	15
10	Office Cost ($)	7	10	10	10
11	Other Overhead Cost ($)	5	5	5	5
12	Operational Costs				
13	Labour Cost ($)	121	90	110	110
14	Energy Consumption Cost ($)	14	10	12	12
15	Maintenance and Repair Cost ($)	10	5	7	7
16	Capital Costs				
17	Equipment Asset Cost ($)	35	50	40	40
18	Misc. Capital Cost ($)	11	10	10	10
19	Additional Cost				
20	Insurance Cost ($)	5	2	4	4
21	Extraordinary Cost ($)	11	2	4	4
22	Total Port Price per TEU ($)	346.79	346.79	346.79	346.79
23	Port Annual Handling Capacity TEU	1000000	1100000	400000	400000
24	Annual Demand TEU	855925	921766	296282	263361
25	b slope	0.0000378	0.0000443	0.000106	0.0001032
26	a market constant	517	517	517	517
27	Initial Port Price per TEU ($)	350	350	350	350
28	Profit per TEU($)	104.79	142.79	119.79	119.79
29	Annual Costs ($)	207133850	188040264	67256014	59782947
30	Annual Revenue($)	296826230.8	319659231.1	102747634.8	91330961.19
31	Annual Profit ($)	89692380.75	131618967.1	35491620.78	31548014.19

LNG Bunker suppliers' Competition Nash Equilibrium Point Calculation

	A	B	C	D	E
1	Topic	Rotterdam	Antwerp	Hamburg	Bremen
2	Product Cost ($)	138	139	142	142
3	Operaton Cost ($)	89	98	102	107
4	Capital Cost ($)	15	16	17	18
5	Additional Cost ($)	11	11	9	9
6	Total Cost ($)	253	264	270	276
7	Product Costs				
8	Product Price Index ($)	130	130	132	132
9	Product Logistics Cost ($)	8	9	10	10
10	Regional Product Tax Rate ($)	0	0	0	0
11	Operational Costs				
12	Storage Cost ($)	7	9	10	10
13	Heating-Cooling Cost ($)	37	42	43	45
14	Barging Cost ($)	5	5	5	6
15	Administration Cost ($)	3	3	3	3
16	Labour Cost ($)	37	39	41	43
17	Capital Costs				
18	Equipment Asset Cost ($)	12	13	13	14
19	Misc. Capital Cost ($)	3	3	4	4
20	Additional Cost				
21	Insurance Cost ($)	4	4	3	3
22	Inspection and Survey Cost ($)	7	7	6	6
23	Absolute MGO (LNG-MGOe) price ($)	306.65	306.65	306.65	306.65
24	Capacity MGOe MT	140000	80000	60000	50000
25	Annual Demand MGOe MT	117546	58773	44079	36733
26	b slope	0.000169	0.000242	0.000283	0.000307
27	a market constant	382	382	382	382
28	Desired bunker Price per MGOe MT ($)	310	310	310	310
29	Profit per MGOe MT($)	53.65	42.65	36.65	30.65
30	Annual Costs ($)	29739138	15516072	11901330	10138308
31	Annual Revenue($)	36045480.9	18022740.45	13516825.35	11264174.45
32	Annual Profit ($)	6306342.9	2506668.45	1615495.35	1125866.45