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Game Theoretical Offshore Container Port Competition

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ABSTRACT

Container ports are indispensable parts of the container transport operations. In terms of container transport operations even better port services are desired to provide viability of reliable liner shipping service. Therefore, port competition to supply better port services is one of the natural consequences of the container transport evolution in the globalisation era. This thesis offers a port competition analysis as total transportation time and cost based between the container ports which serve to collided hinterlands with the integration of offshore container port system (OCPS) and ultra large container vessels (ULCV). An OCPS adaptation is assumed to create offshore container port related an inter-port container competition with other conventional container ports which can handle ULCVs. This OCPS is going to complicate competition game and conditions even much more between ports. The methodological approach of this study aims to develop a hybrid port competition analysis model to analyse port competition in terms of commercial and operational aspects. The model is divided to two different methodological stages. First proposed method is to apply total transportation time and cost based door-to-door container network analysis in order to determine the competitiveness of the given port alternatives. In this approach, according to total time and cost values, the weights of each competitive port are determined to define the position of ports in the competition in order to attract interest of the industrial customers. Operating costs, voyage costs, cargo handling costs and hinterland transportation cost, and also port construction costs are considered as main criteria to clarify the ports' position in the competition. Second method is to develop a game theoretical strategy concept to apply on the port competition regarding to lucrativeness and investment opportunity expectations of the port authorities. Integration and comparison of the both methodological approaches is going to provide valuable findings to analyse competitiveness level of container ports more accurately. Outcomes of this research may help for future business development strategies of port authorities, port operators, shipping liners and private and public port investors. This study is expected to provide a clear holistic comprehending about the underlying dynamics of the port competition for all counterparties involved in container transport operations.

ABBREVIATIONS

ADPC	: Abu Dhabi Ports Company
AGV	: Automated Guided Vehicle
APV	: Authority of the Port of Venice
BIC	: Bureau International des Conteneurs
CAPEX	: Capital Expenses
CO_2	: Carbon Dioxide
DPM	: Diesel Particulate Matter
ECA	: Emission Control Area
EPEC	: Equilibrium Problem with Equilibrium Constraints
EU	: European Union
FLNG	: Floating Liquefied Natural Gas
FOC	: First Order Condition
FPSO	: Floating Production Storage and Offloading
GDP	: Gross Domestic Product
GHG	: Greenhouse Gas
IMO	: International Maritime Organization
IT	: Information Technology
IWM	: International War Museum
JOC	: Journal of Commerce
LNG	: Liquefied Natural Gas
LOA	: Length Overall
LOOP	: Louisiana Offshore Oil Port
LSCI	: Liner Shipping Connectivity Index
LSFO	: Low Sulphur Fuel Oil

MARPOL	: International Convention for the Prevention of Pollution from Ships
MEPC	: Marine Environment Protection Committee
MH	: Mobile Harbour
MoS	: Motorways of the Sea
MSO	: Mid-Stream Operations
NAPA	: North Atlantic Ports Association
NOx	: Nitrous Oxides
OCPS	: Offshore Container Port System
OECD	: The Organisation for Economic Co-operation and Development
OPEX	: Operational Expenses
PhD	: Doctor of Philosophy
PRD	: The Pearl River Delta
PRR	: Pennsylvania Railroad Company
PSA	: The Port of Singapore Authority
QC	: Quay Crane
RMG	: Rail Mounted Gantry Crane
SECA	: Sulphur Emission Control Area
SIPG	: Shanghai International Port Group
SMP	: Small and Medium-sized Port
SOx	: Sulphur Oxides
StratMoS	: Motorways of the Seas Strategic Demonstration Project
STS	: Ship-to-Shore Crane
TEU	: Twenty-foot Equivalent Unit
TLP	: Tension Leg Platform
TOS	: Terminal Operating System

TTT : Train the Trainer

UK : United Kingdom

UKC : Under-Keel Clearance

ULCV : Ultra Large Container Vessel

UN : United Nations

UNCTAD : United Nations Conference on Trade and Development

US : United States

VOOPS : Venice Offshore Onshore Port System

VTS : Vessel Traffic System

WSC : World Shipping Council

NOMENCLATURE

Symbol	Units	Description
A	m^2	*The required container stacking area for ports*
a	-	*Market behaviour constant*
α	-	*Constant*
bi	-	*The constant slope of the market from port i's market position*
c^*	*Currency*	*The cost of hinterland transportation*
C_b	*TEU/year*	*Average TEU handling per berth*
c_{cr}	*Currency*	*The crew cost*
C_e	*TEU/year*	*The expected container handling*
c_{fc}	*Currency*	*The fuel cost*
CHC	*Currency*	*Cargo handling cost*
C_i	*Currency*	*The total cost of port i*
c_i	*Currency*	*Constant marginal cost of port i*
c_{ins}	*Currency*	*The insurance cost*
CL	*Currency*	*Cargo Claims*
c_{mnt}	*Currency*	*The maintenance cost*
c_{pd}	*Currency*	*The port dues*
c_{st}	*Currency*	*The store cost*

C_t	*TEU/year*	*Container throughput*
DFC	*Tons/day*	*Daily fuel consumption*
DIS	*Currency*	*Cargo discharge costs*
EP	*hp or kW*	*Engine power*
F	m^2*/TEU*	*The footprint per TEU*
FC	*Tons/day*	*Fuel consumption*
FC_o	*Tons/day*	*Fuel consumption at* V_o
h	*Hour*	*Time*
HTC	*Currency*	*Hinterland transportation cost*
ht_{rd}	*Currency*	*Road mode hinterland cost*
ht_{rw}	*Currency*	*Railway mode hinterland cost*
ht_{sss}	*Currency*	*Short sea shipping hinterland cost*
i	-	*The set of tool (crane, vessel, port etc.)*
j	-	*The set of tool (crane, vessel, port etc.)*
k	-	*The set of tool (crane, vessel, port etc.)*
L	*Currency*	*Cargo loading charges*
L_q	*m*	*The length of quay*
$L_{s,av}$	*m*	*The average ship length*
$L_{s,max}$	*m*	*The maximum ship length*
m_i	-	*The acceptable average occupancy rate of the*

		yard
n	-	*The number of berths*
OC	*Currency*	*Operating cost*
P	*Currency*	*The average price*
$P(Q)$	-	*Inverse demand function*
p_{ch}	*Currency*	*The handling price per container*
p_f	*Currency*	*The fuel price*
PHC	*TEU*	*Port Handling Capacity*
Pi	*Currency*	*The price of port i*
PPP	*TEU/hour*	*Port Physical Performance*
Q	*TEU*	*The total port output*
q_i	*TEU*	*The output of port i*
q_{-i}	*TEU*	*The opponent's output*
r	-	*The average stacking height/the nominal stacking height*
RBC	*Currency*	*The total roundtrip bunker cost*
RT	-	*The number of round trips*
SFC	*Tons/hp or tons/kW*	*Specific fuel consumption*
t	*h/day/ month/year*	*Time*

TC	*Currency*	*The total transportation cost*
t_d	*Day*	*Average dwell time of containers in port*
TR	*Currency*	*Total revenue*
V	*Knots*	*Speed*
VC	*Currency*	*Voyage cost*
V_o	*Knots*	*The reference speed*
x	*TEU*	*The amount of containers can be handled (loading/unloading)*
$x_{s,i}$	*TEU*	*Loaded containers to vessel i*
$x_{s,j}$	*TEU*	*Discharged containers from vessel j*
γ	*Currency*	*The cost of tug, pilotage and canal dues*

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1 INTRODUCTION

Ports have an important place in the general transportation activities. While ports are formerly known as asylum for ships, today the importance place of ports in the global economy has been commenced to say with a strong voice. A port can be defined as an intersection in the global transportation system by providing a basically uniform and continuous distribution loop. With the effect of containerisation and the developments in handling equipment technologies, ports eluded complexity of serving all cargoes at one terminal and specialised for a specific cargo type in order to get efficiency. Thus ports can be described according to specific cargo type such as container port, oil terminal, ro-ro terminal etc. (Stopford, 2009).

Before containerisation, manual handling was usually used for goods as break bulk cargo. The manual loading and unloading method was slow and cumbersome due to nonstandard packaging of goods in barrels, sacks and wooden creates. Also this handling method was so labour intensive while there was also high risk of accident, loss and theft. Top it all, ships could easily spend more time in port than at sea and this time consuming operation was causing low transportation efficiency. With the commencement of modern container shipping, purpose-built container ship operations brought a new acceleration to the transportation sector in conjunction with standardised cargo transportation box which is container.

While the modern container shipping was celebrating its 60^{th} anniversary in 2016, the container sector is one of important dominos of the transportation. According to available trade statistics for 2007, containerised cargo value accounted for approximately 52 percent of the value seaborne trade (Valentine et al., 2013). This shows that the higher value of commodities is carried as containerised cargo than other seaborne cargo transportation. An analysis of 1980 to 2014 data reveals that containerised cargo was estimated to have accounted for 23 percent of the dry cargo in 2014 while the share was 6 percent in 1980 (UNCTAD, 2015). This increase in the container shipping continued almost from the first voyage, and in six decades, container vessels would carry about 60 percent in terms of the value of goods shipped via sea.

While the container trade was increasing continuously, container ships have been getting bigger since they began operating in liner services over 60 years ago (Rodrigue et al., 2013). The reason that underlying this containership size increase, the bigger ships produce increased operation efficiency and improved environmental performance and reduced sea transportation costs (Stopford, 2009). Basically, it can be said that the created economies of scale by the increasing parcel size plays a major role in keeping sea transportation costs low. The growth in container-carrying capacity has been observed by approximately 1,200% since 1968 (WorldShippingCouncil, 2014) and the share of container vessels in world fleet has reached 13.0% by year 2015 (UNCTAD, 2015). According to the Review of Maritime Transport of UNCTAD (2015), the container-carrying capacity per service provider tripled between years 2004 and 2015 while the average number of service provider companies, which have services from/to each country, reduced by 29 per cent. The figures show that while container companies have included larger vessels in operation to benefit from the advantages of scale economics, they also resort to the strategy of decreasing port time, number of ports visited and service numbers. In this context, the operational strategic development of the container sector can be defined as the main container liner companies prefer to serve on main routes with bigger containerships for achieving economies of scale while relatively smaller companies remain in local markets for providing short sea connectivity for main routes. Thus, the benefits from economies of scale, the sustainability and energy efficiency of container transportation industry can be improved.

Today, the development of the economy is very important in terms of commercial companies. However, almost all authorities are concerned that this development should be made environmentally sensitive, and warning the public to be conscious and sensitive, and shaping their policies in this direction. On the industry side, it can be observed that international authorities are also in an effort to solve this problem in the transport sector as well as in all industries, with emission reduction policies and regulations for more efficient transport operations (Smith et al., 2014, IMO, 2016). Thanks to IMO's applications, maritime transport also strives to fulfil its role in emission reduction. At this point, the maritime industry has been produced some solutions aim at reduce emissions per unit with the help of developing technology, and at the same time, the solutions produced makes possible to perform more profitable transportation economically with the advantage of economies of scale (Smith et al., 2014). Especially in the container transportation, containerships have reached a huge size in recent years and now it is becoming commonplace to see vessels capable of carrying more than 20,000 TEUs of 400 meters (Hacegaba, 2014, Davidson, 2014b, Merk, 2015b).

Economies of scale approach and energy efficiency requirements of national and international organizations have caused to order bigger new vessels by the leading shipping companies. For the top 20 shipping liners, the average vessel size for new container vessels on order is around 13,000 TEUs, while the average vessel size of existing fleet is approximately 5,000 TEUs (UNCTAD, 2015, Alphaliner, 2017). As it is mentioned in the previous paragraph, this shows that the leader shipping companies tend to operate the container sector with ultra large container vessels (ULCV), at least main routes. The all container sector has been affecting with this trend; for details see Hacegaba (2014), because together, the three largest liner shipping companies, that operate the container ships deployed on regular services, have a share of almost 43 per cent of the world total container-carrying capacity, while this number is reaching up to 88 per cent for the top 20 leading liner companies (Alphaliner, 2017). However, new generation of ULCVs expands the container-carrying capacity very fast and this causes to confront the oversupply problem (Chua et al., 2014). Liner shipping companies concentrated on mergers and collaboration with other liner shipping companies to cope with the oversupply issue (Aymelek et al., 2014). Shipping alliance strategy can be shown as one of tactics to utilize available container-carrying capacity. The alliance mergers offer more frequent and wider cooperation of shipping lines on all routes, thus the alliances aim to provide more and more homogenous services. A resulting situation in the industry is the main container transportation corridors which stretch across East-West and South-North routes with ULCVs deployment by connecting the lines with hub ports as junction point of the containerised cargoes (Notteboom, 2010a).

The significant positive improvements in fuel consumption and cost reductions per unit of cargo have been achieved in course of time (Notteboom and Cariou, 2009). However, the increasing ship sizes and the number of containers shipped and handled all at once have brought operational problems on ports (Lane and Moret, 2014). It can be also said that ports need to focus on the solutions to the problems encountered because the global container companies are persistently striving to operate ULCVs, despite the idle capacity that has arisen in parallel with the rapid increase in ship size and number in the container sector. On the other hand, as an important part of the maritime transport, ports are required to enter the game for efficient and environmental container operations by IMO (2014). At this point, the pressure on harbours is increasing, and it is expected to provide both efficient and environmentally friendly operational solutions for the simultaneous increase in container traffic and ship dimensions (Lane and Moret, 2014).

In parallel of the ever-growing container trade and containerships, the importance of ports has increased day by day because ports are one of the key milestones in the modern container shipping. It cannot be denied that ports formed their strategies toward to handle larger parcels of cargo comes with larger vessels in a lump as the container sector turned the direction and strategy to bigger and more efficient vessels. The modern container shipping requires that a port should be more energy efficient and executer with very sophisticated and excessive cargo loading/unloading operations in a short span of time as addition to benefited from the opportunities of economies of scale and hold economically sustainable structure. In business context, a modern container port description can be made in the context that harmonizes economy, efficiency and eco-friendly terms in practice in a port structure.

In this business context, a strategic modern port structure can be given as seen in Figure 1-1. According to the given strategic modern port structure, it is required that the focus of today's ports should be on energy efficient, renewable energy usage and hence economical port structures to obtain for sustainable port operations. These three parameters influence each other positively by the increasing values of these parameters due to their interrelationships. As a result of this relationship among these parameters, the sustainable port operations are emerging as a common set of these three parameters.

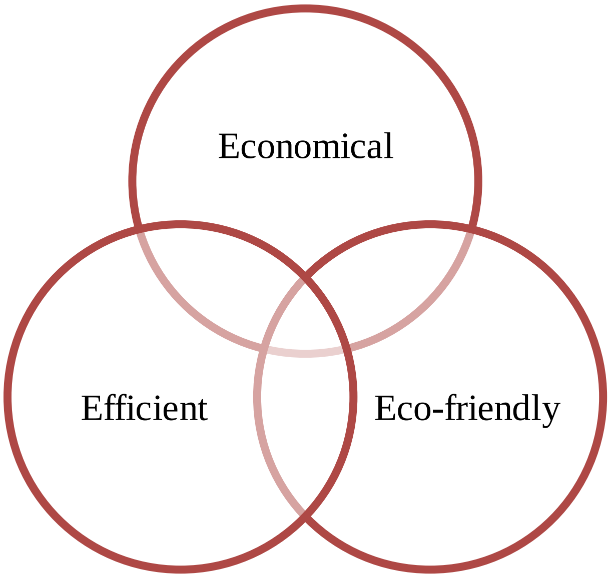

Figure 1-1 A modern container port structure in business context

EU (European Union) and UN (United Nations) policies and regulations also support the defined modern container port structure design. EU targets to cut GHG emissions by increasing energy efficiency and renewable energy production for 2030 in accordance with energy security strategy (EU, 2014a). UN's 2030 sustainable development policy also aims to ensure access to affordable, reliable, sustainable and modern energy for all, and to take urgent action to combat climate change and its impacts (UN, 2017). According to the policies and regulations, energy efficient, eco-friendly and economical port structures and thereby sustainable port operations come into prominence.

It can be noted that the provided standardization by containerization is the most influential step to catch the required port structure. However, the irrepressible growth in the container trade and containership size with the developments in technology and demands of the sector, various challenges and changes appeared are to be coped with by ports. On the one hand, while ports are taking position to cope with the challenges generated by bigger ships, growing container volume; on the other hand the rising cost of infrastructure development, and volatility in the investment climate are other issues (Haralambides, 2002, Wilmsmeier et al., 2013). The environment, especially emissions (CO_2) which might be most sensitive topic of the industry, is another affecting element for the port strategy with together new levels of security along with new threats, the world economy affecting the import/export balance and last but not least volatility in fuel prices (Darbra et al., 2005). However, the developing technology offers some opportunities which may be applied by ports. Offshore container ports can be shown as an example for these opportunities when designed according to industry requirements (Pluijm, 2015b).

The participation of the offshore ports, which can be considered to be a novel solution, has been proposed by some experts and there are presently offshore container port applications in the sector in different technical features (Pluijm, 2015a, Rowland, 2015). It is envisaged that offshore ports will contribute to container transportation in terms of economy, environment and safety. However, due to the limited application of these new port constructions, it cannot be said that the impact on the container sector can be accurately measured at this stage. In the first place, however, it is thought that there will be operational differences in container transportation due to the separation of offshore ports from other ports as a location. With the adaptation of offshore ports, the first possible changes may be considered that containers cannot transported to land without transhipment, minimum container stocks on offshore structures required, and the system can encourage the use of large vessels thanks to no dimensional and navigational constraint.

The offshore port structure can bring a breath for container sector. Because this offshore structures have advantages to accommodate larger vessel while the structure have some challenges to be solve such as stability, regular distribution ways of cargo from offshore to shore or vice versa with suitable logistic approach (Glauser, 2014, Pluijm, 2015b, Pachakis, 2015). Assessment of strengths and weaknesses of the offshore structure is essential to give investment decision on an offshore container port system (hereafter referred to as OCPS) at the first stage. Besides the strengths and weaknesses of OCPS, the system may provide local and international economic opportunities for container sector by encouraging using larger containership (Rowland, 2015). The position of OCPS may be provide another opportunity to ensure homeland security against terror threats from sea, as addition to it may be considered an alternative for sea level rise instead of conventional port structures (Glauser, 2015).

The developments in container trade, containership fleet and the desire to meet demands from both of them leads to make correct strategic investment decisions on port structures. The correct and strategic port investment decision depends on analysing the requirements of container industry which includes shipping liners, shippers, cargo owner, law-makers at national and international level and other third parties. Also the strategic port investment decision at a specific and key area for container shipping gives a fillip to local and international container ports to take a strategic position in fierce port competition. Therefore a strategic investment decision depends on the accurate management of investment decision which is as mind games need correct move on time.

With the full adaptation of the offshore ports sector, the competition among container ports is expected to be exacerbated. Because of the strategic solutions offered, offshore ports aim to be able to handle large container vessels without experiencing dimensional problems with the advantage of being in the open sea. At this point, it can be expected that there will be a regional and continental competition between offshore container ports and existing conventional container ports (Martinho, 2008, Ducruet, 2009, Ishii et al., 2013). In other words, with the entry of offshore ports into the market, the existing container ports can undertake a new strategic struggle to protect their position in the container port competition. It is important to see how the existing ports in this competition will follow the strategy and how the offshore ports will play a role in this competition in terms of the productivity and development of the industry.

The main factors affecting competition among the container ports, which are envisaged to be realized, can be clearly stated.

- With which strategy and how existing ports will involve in the competition,
- To cooperate with offshore port or not,
- What the strategic positions of offshore ports are,

In this thesis, the factors affecting the competition between the ports will be analysed. The analysis of the effects and roles of these factors depending on competitiveness will be also made. Furthermore, with the help of case studies, the competitive structure to be formed by including offshore ports will be examined, and advantageous and disadvantaged situations of the ports will be determined, and a competition game will be presented. Strategy decision making based on game theory will be applied as a method in the generated competition games.

1.1 Research Motivation

The container shipping is a major transportation mode, and the main cause of the container shipping has gained popularity in the sector is that it offer easy, quick and low-cost cargo transportation. Containerization can be called as revolution of shipping industry. However, the passage from break bulk cargo to containerized cargo was not easy although the containerization offers several advantages which are highlighted by Rodrigue et al. (2013) as standardization, flexibility, costs, velocity, warehousing, security and safety. The difficulty of this passage was coming from the concerns on the huge investment cost of developing port, road, and railway infrastructures which are prerequisite for container shipping. The investment on containership and millions of container boxes is priority and comes before the infrastructural investment. However, the containerization reduced shipping time and cost, and goods reached to market in shorter time by 84% with 35% less cost when compared to break bulk cargo transportation (Bohlman, 2001). Therefore, the sector has seen that the reductions in shipping time and cost and the other advantages of containerization would make valuable the huge structural investments in container shipping. Today, with the leadership of Maersk Line shipping company, the billion-dollar investment decisions of tens of new generation ULCVs in a lump can easily be given (MAERSK, 2016). The leader shipping companies commenced to operate ULCVs, which are bigger than the Empire State Building with the length reached up to 400 metre, on the main container routes. Containership continues to grow and container shipping companies around the world are increasingly using bigger and bigger ships.

In the ever-growing and complicated container shipping, the role of ports is crucial and as response the ports are upgraded with sophisticated new equipment in order to increase productivity and efficiency, and they are formed for loading and unloading containers to/from ULCVs. The conventional container ports face challenges with the new generation of ULCVs due to water depth limitations, berth length and crane outreach. It is anticipated that after the introduction of mega vessels, these constraints might cause obstructions to the operational flexibility of some conventional container terminals (Lane and Moret, 2014, Davidson, 2014c). To cope with the impact of ever increasing vessel size, the port authorities turned their focus on this issue in the last decade because, terminal congestions, inadequate port handling capabilities of mega vessels and eventually low productivity, efficiency and accordingly total port performance cases may lead some of the ports to be excluded from the networks serviced by the mega-containerships. It is an anticipated outcome in today's dynamic and very competitive container shipping industry. The emergent issue as a consequence of the challenge against ULCVs affects almost all container terminals directly or indirectly. Already some ports with high throughput are not capable of handling the new generation of ULCVs due to inadequate water depth at port area (includes anchorage area/s, port access canal/s or way/s and berthing), limited handling equipment -especially ship-to-shore cranes with dwarf outreach- and the length of berthing space, and poor performance of IT systems to solve the overflow traffic (Lane and Moret, 2014). Also the ports, which have collaboration with incapable ports to accommodate ULCVs, make concessions on efficiency and economies of scale. Therefore, the port authorities go into the effort of efficiency and performance increase and try to think of ways to berth ULCVs to their container terminal (Davidson, 2014a). For this purpose, seabed dredging, infrastructural improvements and amendments to fix terminal for ULCVs, IT systems' improvements are some of the proposed solutions to enable ULCVs' operations at the container terminal (Cullinane and Khanna, 1999, Rothberg and Sisson, 2013).

Another proposed solution for the accommodation of ULCVs is the offshore structures. The usage of offshore structure is under consideration by some authorities such Venice Port Authority, US Government for container shipping with the deployment of ULCVs on the lines that are connected to the offshore container port (APV, 2013, Glauser, 2014). However, while the offshore structure may offer an alternative way for the conventional container ports to operate container network with more efficient and eco-friendly ULCVs on suitable container routes and markets, there are some operational and technical concerns about the offshore structures to use as a container terminal.

The operational concerns firstly focus on the transfer of container from the offshore structure to the shore. The container transfer concerns are held in perspective of the mode of transport and the most suitable transport mode for the container transfer is considered for more efficient, economic and eco-friendly offshore container terminal. The operational concerns also cover the challenges which are about from optimum crane size, number and operation to the layout of offshore structure to enable maximum efficiency at per square of the structure. While the effect on port competition of offshore container terminals is another concern in the sector, the environmental and safety effects are also considered. Initially the effects on port competition can be assessed as when an offshore port facility is used as link to main routes by smaller ports, the role of those smaller ports in the port competition against bigger ports. Latter, while the environmental effects are considered in terms of air emissions from vessels and port facility on humans within close port area, water quality for underwater habitat and animal, soil and waste pollution and noise and safety concerns can be noted that terror attacks, smuggling, human trafficking, illegal immigration and other threats come from sea. On the other hand the operational concerns form another side to analysis the offshore structures. They are held in the context of stability, mooring of structure and the reaction of port structure to weather and sea condition which are depending on structural layout of the platform as the structure is a fixed or floating platform.

In this general context, when the offshore structures are considered as a sustainable container terminal with its all advantages and challenges, the offshore container port facility may have a competitive identity by taking up the challenges. A strategic decision mechanism is essential to enable the offshore container facility to be a direct competitor. Therefore the motivation of this study comes from the belief that the offshore container port systems could offers a new strategic container shipping structure. According to views and pre-analysis of the sector, the author’s belief is that the system can bring an arrangement for container shipping network and the collaboration among container ports and container shipping lines. In addition to all these structural gains of the offshore container port systems, new port competitive environment, this will be shaped once again thanks to the offshore systems, is a main motivation source. So the research question in accordance with the described research motivation can be asked as “How will the new competition environment between container ports, which will be formed through the adaptation of OCPS and ULCVs, strategically affect port investment decisions?

1.2 Problem Definition

The problems of container sector fall under three headings; (1) the energy efficiency problematic and GHG (Greenhouse Gas) emissions; (2) inadequate or restricted port structures for ever-growing container trade and correspondingly growth in other components of the container sector; and (3) competition among container shipping lines and ports.

The energy efficiency is important problem in the container sector as important as in other energy consumer sectors (Parker et al., 2015). The importance of energy efficiency increases much with the depletion of energy resources and the increase of energy price. It means that the operation will be carrying out at less profit. Also, the usage of energy causes gas emissions which are required to reduce to the determined level. Policy makers such as IMO (International Maritime Organization) and EU are taking the necessary steps to make necessary regulations in order to increase energy efficiency and to reduce the environmental impact of the container industry as a subcategory of maritime transport. To solve energy efficiency and GHG emission problems in the sector, EU supports IMO energy efficiency projects, and in this context the European Commission developed a strategy for reducing GHG emissions and for increasing energy efficiency in accordance with the suggestions of the Commission’s White Paper (EU, 2011). The set out strategy consist of 3 consecutive steps: (1) monitoring, reporting and verification of CO_2 emissions from large ships using EU ports; (2) greenhouse gas reduction targets; and (3) further measures (EU, 2017b).

The industry has developing various solutions to enable the energy efficiency of container shipping. These solutions are too numerous to be counted. However, it can be said that the passage from break bulk cargo to containerisation and ever larger containerships are most common way to increase energy efficiency. Also, the technological measurements on hull and machinery, which will be not discussed in this study, are other solutions to cope with the inefficient energy usage. The gas emissions are strictly regulated by IMO. Thus, alternative fuels and new engine technologies to burn alternative fuels are adopted to comply with international gas emission rule and emissions. Meanwhile, ship-owners have to give strategic investment decision to adopt the fleet in accordance with international rule and regulations by targeting to retain profit margins. The most common decision is either retrofitting the existing fleet or to order new technology-equipped containerships which are generally bigger vessel to gain advantages of economies scale. The position of ports cannot be assessed as discrete approach for energy efficiency and GHG emissions. The adaptation of ports generates based on the developments in container trade, fleet trends and the rule and regulations. In this manner, the container ports aim to allow vessels to sail in possible shortest time by completing loading/unloading operation with the provided optimum and energy efficient port performance. Therefore, it can be said that the first part of problem cannot be described without container port even if other third party providers for a sustainable, energy efficient and gas emission reduced international seaborne transportation.

The second part of mentioned problems is inadequate and restricted port structures for ever-growing container trade and correspondingly growth in other components of the container sector. The root of the problem is not able to find a common ground by shipping lines, ports and shipper. Herein, container ports play a key role by gathering both sides on a common ground. This is provided however that the demands of both sides are met at junction point which is a container port in the container sector. The relation between shipping lines and container ports depends to supply operational capability which will not allow missing the container shipping line schedule of liner companies. The problem here is that most of the container ports do not have adequate structural and technical capability to accommodate new generation of ULCVs. Therefore, the shipping liners have to choose the specific ports which can give service their mega vessels. In the perspective of ever-growing container trade and vessel size, a container port can be an alternative for the accommodation of ULCVs if the port offers operation without any dimensional and technical restrictions. However, limited numbers of ports exist to accommodate ULCVs so ULCVs are operated at specific routes which are connected to export/import location. Thus the shipping liners deploy their vessels and plan their network schedule according to the port capability if their fleets need special requirement from ports such as water draft, berth length, crane outreach, stowage area etc. to be able to operate the line.

The third issue in the perspective of study is that the competition among container shipping lines and also among container ports. Both competitions can be assessed at international and national level or at global and local levels. The competition among container shipping lines based on the first and largest… "beggar thy neighbour" policy. The international and global competition is in the global container market that is run out by leader container shipping companies in top 30 positions of ranking list in terms of TEU capacity and market share (Alphaliner, 2017, WPS, 2016). As it is noted by Basedow et al. (2012) that the container shipping lines shows peculiarities to avoid competition among themselves, inter alia, (1) very high fixed costs; (2) very high entry and exit barriers; and (3) oversupply.

Due to these conditions of sector, the container shipping lines develop cooperative agreement in the liner shipping. Liner conferences, consortia, mergers, global shipping alliances have been developed in accordance with antitrust law. In the past, liner conferences, which began in the 1870s as a device used by ship-owners in the cargo-liner trades to address problems of over-competition, seasonality and cut-throat pricing, have always attracted opposition. Liner conferences are a cartel agreement and were offering a standard schedules for shipping lines serving on same route, in order to rationalise the capacity and the frequency of services offered to their customers, as well as the tariffs that are publicly available. For many years, liner conferences coexisted with consortia, and sometimes with global alliances: when these two sets of agreements were contemporaneously in place, liner conferences concentrated more on tariffs, whereas consortia focused on technical matters: indeed, antitrust concern for consortia is certainly less than that for conferences; this is the reason why conferences have been finally banned, whereas consortia are still practiced in the liner shipping sector. Containerisation has weakened the ability to enforce cartels and the lines have resorted to other strategies such as mergers, alliances, and consortia. The day of the conference, it seems, has passed.

Today's most common cooperative agreement, global shipping alliances allow medium-sized shipping companies to compete bigger liner companies which have capability to operate independent liner services on all markets, in fact, have witnessed a profound merger and acquisition development over the past twenty years and nowadays shows impressive levels of concentration worldwide. The biggest shipping alliances was announced by the first leading shipping lines in the world and they aim to characterize fluctuating freight rates, increasing cost and diminished profitability (Lloyd'sList, 2013a, Lloyd'sList, 2013b, Lloyd'sList, 2014, Premti, 2016). Also the alliances are combined with overcapacity in the container industry and unpredictable demand. The sector actors have some concerns for the proposed alliances (Davidson, 2014b, Premti, 2016). It is concerned that the size of alliances is enormous, according to shipping analyst Alphaliner (2017) after the P3 and the 2M network announcements with G6 and CKYHE, the four biggest shipping alliances would be have roughly 90% of the global container market shares and it will probably affect smaller liner companies negatively, in terms of number and tonnage of ships, sailing frequency and port coverage as well as on their scope which crosses jurisdictions. Some other concerns are considered about possible negative effects of alliances on shippers and fair competition in general. The alliances at this size and with so huge competition power incapacitate smaller carriers to compete with the leading container shipping lines in global perspective. Therefore, the smaller carriers stays local and run their operations as feeder for big shipping companies services on main routes or relatively with smaller vessels on shorter routes which have low throughput.

According to Drewry (2016) and Alphaliner (2017), the four alliances will be deployed ULCVs, the smallest average vessel size between these alliances is around 12,000 TEU. When the larger vessel size is considered with the total container capacity of the alliances together, the competition among ports depends on the capability of ports which is sufficient or not to pull alliances to the port. Port competitiveness from shipping liner perspective, the factors, which are cargo volume, terminal handling charge, berth availability, port location, transhipment volume and feeder service providers, can be expressed to affect port choice decision of the shipping lines.

1.3 Aim and Objectives

What is not yet clear is the impact of OCPS on the container port competition. Also the response of container sector to the OCPS is not fully understood. However, this is clear that to date, studies investigating OCPS have produced equivocal results. Some studies have shown the beneficial effects of ever-growing container sector, but others showed deterioration in container sector. On the one hand, some studies do not see sufficiently feasible ULCVs by reason of overcapacity and not fully loaded operations of ULCVs. Hence OCPS cannot be considered feasible for sustainable container transportation network under the conditions of oversupply. On the other hand, despite this, very few studies have investigated the impact of OCPS on the container transportation network in terms of accommodating ULCVs, economic feasibility, energy efficiency, environment, homeland security so on.

This study investigates the developing container sector and the developments in the container port industry. The purpose of this investigation is to explore the relationship between the developing container sector and the developments in container ports in terms of the port competitiveness. In this regard, the study traces the development of container ports and determines the factors that affect the container port competition strategies and shipping business economics. The expectation from this thesis is to provide guidance to container shipping market players, especially container ports and shipping lines, in order to overcome to the competition challenges of the upcoming container transportation business trends.

There are primary objectives in order to achieve the determined research aims.

- This thesis attempts to historically review the literature on the development of the container industry, the development of container ports, and the operational challenges faced in the container sector.
- Secondly, an objective of this study is to investigate alternative solutions can be produced for the operational problems in the sector in the light of the developing container sector and port structures.
- Analysing the possible response of the container industry to the solutions offered can be another objective of the thesis.

- In addition, the analysis of the competition between the ports, which is expected to occur due to the developing port structures, is one of the important aims in order to make this study important.
- But more importantly, a new and sustainable method for the analysis of competition between ports in the emerging new competitive climate and its application is another objective.

In accordance with the objectives, the main aim of this thesis can is described as "the development of a new and sustainable game theoretical method to analyse strategic decision making behaviours of the competitors in the especially designed new competition environment with adaptation of a novel container network system based on the collaboration of ULCVs and OCPS"

1.4 Contribution to the Field of the Study

The modern containerization celebrates its 60th anniversary by year 2016. During these 60 years and in advance of the first modern container shipped, a considerable amount of literature has been published on the containerization and the container ports. While each study is aiming to develop the adaptation of containerization to maritime shipping sector, they also make valuable contribution the existing literature knowledge with the different research designs, analysis methods and case studies. Despite this, very few studies have investigated the impact of offshore structure on the ever-growing and developing container sector to generate more energy efficient container transportation activities. Therefore, as other studies, besides making a precious contribution to the existing literature to build up more efficient container shipping, this study applies the offshore container port system with different game theoretical approaches. The study also follows a case-study design, with in-depth analysis of port competitiveness, to generate a decision-making concept with a new methodological approach and scientific knowledge.

The major contributions to the field of the study can be given as follow:

- Extensive operational container transportation analysis, on the basis of the identification of alternative port solutions to meet the expectations of the -developing container sector and ever-growing ship dimensions,

- As an alternative port solution, the adaptation of OCPS to the container sector and the examination of the system's impact on the conventional container transportation network due to the integration with ULCVs and the examination of the operational adequacy of the system,
- As a result of evaluating the created competitiveness in the existing container transportation sector by the OCPS, the determination the dynamics that will affect this competition and the examination of the these dynamics' role in the inter-port competition,
- Developing a non-cooperative game theory methodology on the selected container port competition case which is related to the OCPS adaptation on the container port system and an application of Stackelberg game theory to analyse the inter-port competition,
- For an OCPS based case study, the calculation methods of total transportation time and cost for door-to-door container transportation network. The determination of the competitive positions of the ports as a result of the values to be obtained from this calculation. Also, the calculation of capacity and size of the OCPS and its construction costs,
- The final contributions of this study is to take a guiding role in terms of the determination of tactical behaviour for competitive ports, the strategic decision-making on port investment, and the assessment of port competition dynamics as a whole.

2 BACKGROUND & CRITICAL LITERATURE REVIEW

There is an increasing interest in container shipping so the studies on this area have been accelerated during the recent years. The undertaken research on the evolution and research trends of container shipping by Lau et al. (2013) analyses the container shipping in 2 terms, namely, the traditional term spanning between 1967 and 1990 and modern starting from 1990 and extending up today. The latter category has been formed to identify the functionality aspects of container shipping. An indication of the increasing scientific interest in the container shipping is the number of the published papers. While 71 papers were published during traditional term of containerization, they reached up to 211 in the contemporary period until 2012 (Lau et al., 2013).

There are relatively studies in the area of container terminal transport operations. An extensive search conducted by Carlo et al. (2014) focused on published scientific research between 2004 and 2014, and it is found that 61 scientific publication including articles and book chapters. The container terminal transport research has been mostly conducted in Asia and Europe origin countries. It is also available to see early examples of research into container terminal operations which were inspected in other literature review studies (Vis and de Koster, 2003, Steenken et al., 2004).

As OCPS is relatively new topic, there has been no detailed investigation of literature review on the offshore based container port operations. However, in recent years, it can be addressed that there has been an increasing amount of literature on the field of offshore port adapted container shipping. The first serious discussions and analyses of offshore based container shipping systems emerged after the 2000s with the floating container terminals (Ali, 2005, Evangelos, 2006, Kim and Morrison, 2012, Baird and Rother, 2013)

It is broadly agreed that the container ports have experienced significant challenges in the recent years such as ship size enlargement, increasing container trade, bunkering source switch, increasing port competition, and financial management problems (Brooks et al., 2014). The most attention-grabbing of these is the ever-growing containership size and container trade, as some of the ports in shipping liner schedule could be eliminated if they remain insufficient to accommodate those of larger vessels and to serve the increasing container trade. The encountered challenges in the container sector aggravate the discussions and increase interest in the OCPS in the container shipping industry.

Constitutively, two important themes emerge from the studies discussed so far: the first theme is that the ever-growing containership size and latter is that the insufficient operational and technical aspects, and the limited number of container ports/terminals to accommodate ULCVs. Therefore, it can be said that there is a need to enhance the number of operationally and technically capable ports for handling of ULCVs. In accordance with this purpose, it can be taken in consideration the application of offshore based container ports at suitable regions as an alternative for the conventional container ports to provide flexible container shipping.

It may be required to highlight the variation of offshore structures' logistics concepts in terms of prefiguring. To better understand the mechanisms of logistics concepts for offshore transfer systems applied on shipping sectors, Pachakis (2015) classified offshore cargo transfer models into 3 distinct types which are; (1) offshore terminal for container shipping; (2) vessel to vessel transfer for oil and dry bulk shipping; and (3) vessel to barge/platform or to vessel for dry bulk.

There is very little scientific research to understand the mechanism of offshore structures' logistics concepts for the container shipping. In terms of operational aspect, the offshore structures in the shipping industry can be categorised in two main types: floating service concepts and offshore port systems. Although the research to date has tended to focus on floating services concepts rather than OCPS, the growing body of literature recognises the importance of OCPS in the container shipping from the point of new generation of ULCVs.

2.1 History and Developments of Containerization

The first usage of boxes is seen in coal mining in the late 18th century. These boxes were enabling the transportation of bulk cargoes without multiple handling and delays. The boxes were keeping the costs down, saving time and increasing the reliability without multiple handling and handling related delays (Crowley, 2008). The first developments in containerization have been commenced with the first wooden box and the developments have gone on as it is illustrated in Figure 2-1 (Essery et al., 1970, Ripley, 1993).

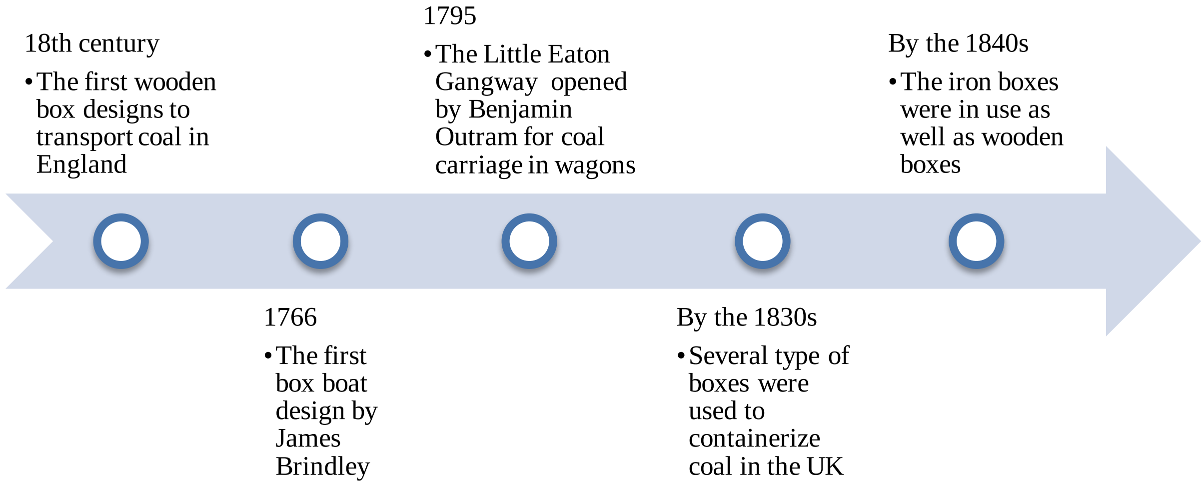

Figure 2-1 Early stages of the containerization

Source: Adapted from studies of Essery et al. (1970) and Ripley (1993)

In 1917, the known first container-crane-truck system and the system was co-ordinated to Cincinnati railway terminals (Lewandowski, 2015). In 1919, a structure has been developed to transporting containers to enable ease movements between road and rail systems (Lewandowski, 2014b). The development of containers has been discussed in World Motor Transport Congress in London (1927) and Rome (1928) in terms of suitable road, rail infrastructures and various ancillary components for the best container system in terms of efficiency, economy, technical aspects and international standards for cross-country use (Lewandowski, 2014a). As a result of these developments in the congresses, the International Chamber of Commerce organized a competition based on agreed dimensional standards by aiming to seek the most effective container system (Lewandowski, 2014a). Figure 2-2 shows the development of containerization in the early 20th century.

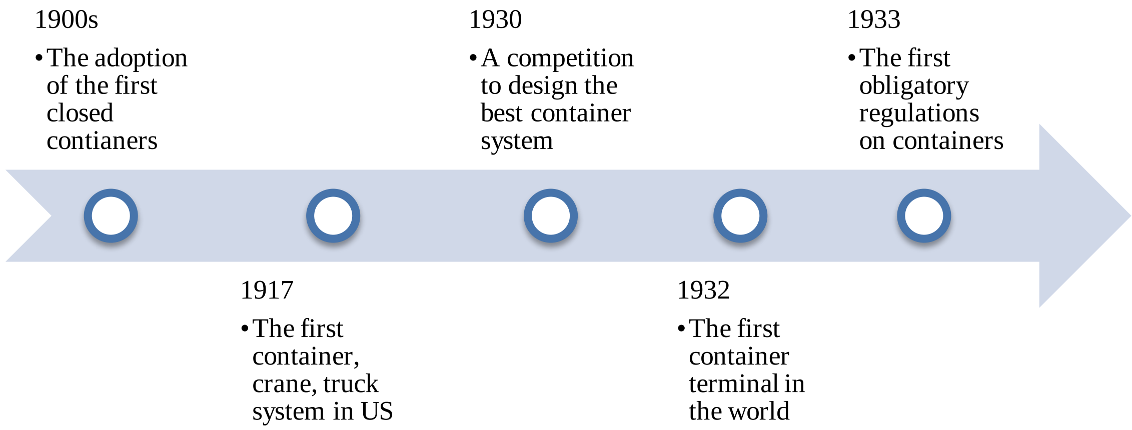

Figure 2-2 Development of containerization in the early 20th century

Source: Adapted from studies of Lewandowski (2014a), Lewandowski (2014b) and Lewandowski (2015)

The developments encouraged to lay the foundation of first container terminal which is designed as a rail terminal (Lewandowski, 2014a). In the light of these developments in containerization, some regulations were in evitable. Thus, in 1933, the International Container Bureau (French: Bureau International des Conteneurs, so BIC) published initial obligatory regulations on standardized container size, allowable loading capacity (Lewandowski, 2014a).

The modern intermodal containers were hoisted off by the orchestrating of McLean in 1956 (WSC, 2015). This modern transportation model had to be waited to do something on his venture since the idea was realized by Malcolm P. McLean in 1937 (Cudahy, 2006, Smith, 2014). Because this containerization model needs huge capital investments at whole transportation chain to provide sustainable intermodal transportation. However, the attempt of McLean was different from other attempts which have been experienced in UK, Netherlands, Denmark and US, because McLean has reached a great success in the modern intermodal container transportation in terms of business economics (Levinson, 2016). The success of this venture has birth the first container shipping company Sea-Land Service in 1960 by hauling down McLean's the Pan Atlantic house flag (Cudahy, 2006). The further developments progressed with the retrofitting T-2 tanker vessels in order to transform to a cellular container vessel (Cudahy, 2006). The fledgling marine transportation method attracted considerable attention and the first international container shipment has been carried out in a span of 10-year time (MAERSK, 2016). The containerization has showed very good acceleration over the years and the annual container trade has reached 171 million TEU movements in 2014 with the aid of developments after the modern intermodal containers. Some of the containerization's milestones are represented in Figure 2-3.

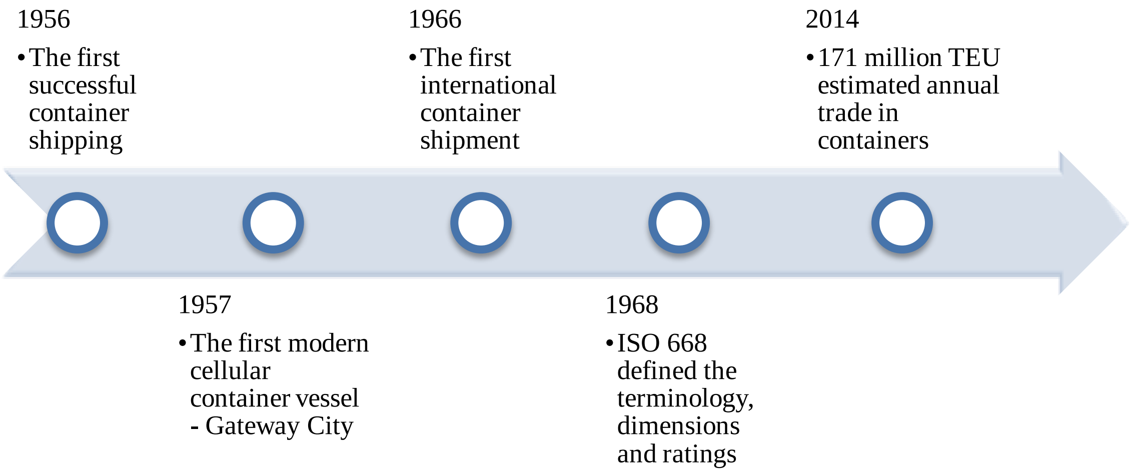

Figure 2-3 Development of containerization after the modern intermodal containers

Source: Adapted from studies of Cudahy (2006), Smith (2014) and Clarkson (2015)

The reason under this success is that the intermodal container transportation is much simpler and quicker because container offers seamlessly handling between transportation modes from ships to truck or trains, or vice versa (WSC, 2015). The containerization idea is based on the theory that allows transporting the small size of packaged cargoes in the same container, thus several parcels of cargo can be handled with minimum manpower and interruption among different transport modes during their journey. It cannot be denied that the containerization is the revolution in cargo transportation and international trade because thanks to this idea the whole logistical process would be simplified. The ground-breaking effect of containerization is defined by Donovan and Bonney (2006) as that 'the box that changed the history'. As a conclusion, the revolution of cargo transportation, -not only marine transportation-, has been commence with the departure of first modern container on board of Ideal X from the Port of Newark for its destination the Port of Houston.

2.2 History and Developments of Container Ports

Ports are a fundamental property of the transport system. While Liu (2010) defines ports as one of main components of the maritime shipping, and it is defined as third component of the maritime transport system after ship and cargo by the phenomenon of maritime economics Stopford (2009). It is necessary here to clarify exactly what is meant by port as Stopford (2009) defines a port is “a geographical area where ships are brought alongside land to load and discharge cargo – usually a sheltered deep-water area such as a bay or river mouth”. However, unfortunately this definition remains a poorly defined term for modern ports because besides the defined function of ports, they have functions from cargo handling to storage and to custom services. The main functions of a conventional port are presented in Figure 2-4.

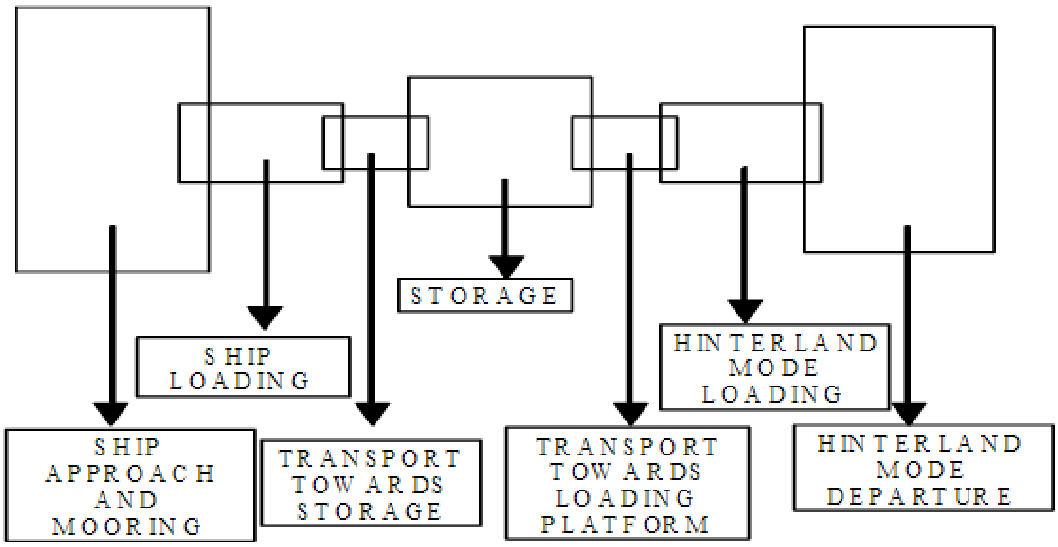

Figure 2-4 Main functions of a conventional port

Source: Van de Voorde and Vanelslander (2009)

The requirements have changed from ports in conjunction with the developments in the maritime sector. While a secure berth was only a beginning function of ports, the expectations from modern ports can be described as deep water access for big vessels, improves cargo handling by storing freights on a versatile port facility and a well-integrated hinterland connection with transport modes of railways, roads and inland waterways, and finally regular and simplified custom services.

To meet the expectations from modern port structures, there was a great need for a standardised method of transport but for this to be realised a whole host of industries needed aligning, such as: ships, trains, and trucks and also port terminals. As it can be imagined, it would require a lot of work and persuasion to make such a feat possible. This would be occurred with the adaptation of all involved industries to containerization. At the same breath, the port terminals had to be adapted and to be developed to comply with the developing container transportation. In conjunction with the developments in containerization, the first example of container terminal was seen in Enola, 1932 and it was opened by Pennsylvania Railroad Company (PRR) as a railway container terminal. The first container port was opened by the Port Authority of New York and New Jersey on August 15, 1962 in the harmony and cooperation among ports, containerized cargo and containerships (PANYNJ, 2016). The chronological progress of container ports is presented in Figure 2-5.

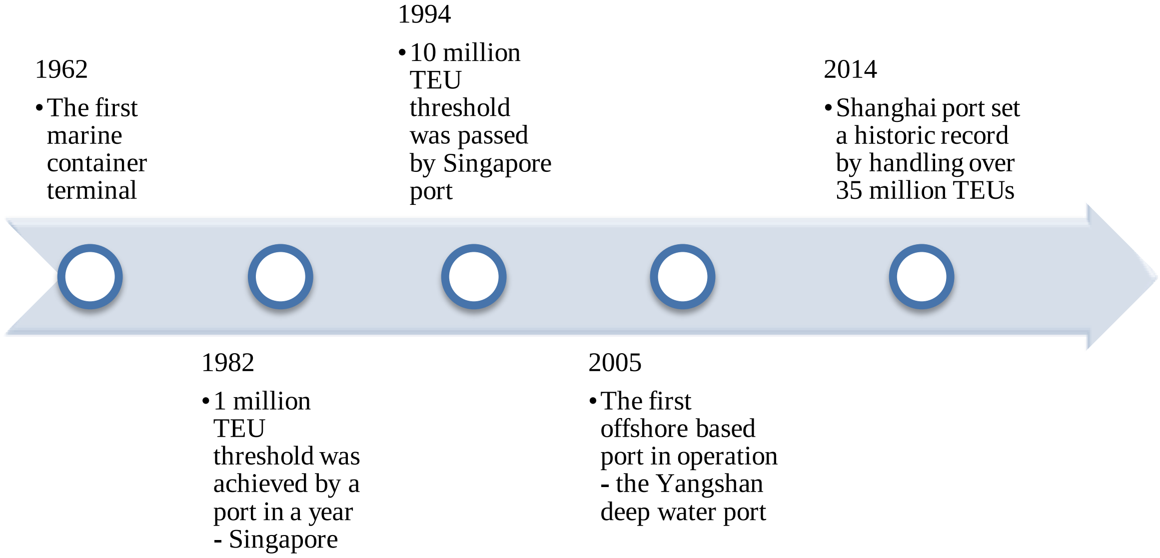

Figure 2-5 Development of container terminals

Source: Adapted from WSC (2015), PSA (2016) and SIPG (2016)

With the adaptation of container transportation, port dynamics has substantially changed to favour the emergence of specialized container ports. The main changes in port facilities are appeared as capital intensive cranes and well as ample storage space to stack containers dockside because the mostly containerships did not have on-board cranes when compared to conventional break-bulk cargo ships. The other seen development in the container terminals is that the berths were redesigned to accommodate for quick ship turnaround and more effective port operations between the crane and the container storage areas. Therefore, the maritime container terminals are designed technologically advanced and to be able to handle high volume with high-productivity performance. It is also required that the maritime container terminals are essentially to be larger and tend to be located near major cities, which have high volume of import/export cargoes to transport in containers, with good and well-designed rail and road connections for hinterlands.

Port location also plays a key role to determine the strategy of a port, beside technologic and structural advantages of the container terminals. The importance of a port's location is strategically linked to maritime access by Rodrigue et al. (2013). The maritime access of a port can be understood as the availability of port to accommodate modern cargo ships in terms of depth and available space which are fundamentals for port selection. The position of port in container port competition also bases on the advancement of infrastructure, equipment and land access beside the geographical importance of the port. In this regard, the Port of Singapore provides a locational advantage because it is operated as a junction point at the Strait of Malacca. Thus, the locational advantage makes the Port of Singapore one of important hub ports in the world. The importance of location for a port progress can be understood with the analysis of the tiny country of Malta which acts as a transhipment hub and takes part in the major world ports. The major container ports in the world are clearly demonstrating the whole development progress from the date when the first marine container terminal had been opened and they are also demonstrating the truly global nature of the liner shipping business and the importance of the network of ports that facilitate timely and efficient ship and cargo movement.

Another point of view for the development of container terminals is that the ports have to progress the port developments to cope with the ever-growing containership size. For example, the required draft allowance for a Post-Panamax type ULCV is more than 12 meters water depth for safe berthing and manoeuvring in the port facility. However, according to Rodrigue et al. (2013), there is a limited number of ports can give service ships of more than 10 meters draft and more than 200 meters in length. In this regard, many ports are considered as unable to provide maritime access and modern cargo operations for larger container vessels due to restricted fundamental aspects of these ports as depth and available space. Therefore, these ports mostly remain to serve local markets which are relatively deployed smaller container vessels and they cannot get involve in the challenge to obtain share from the main container routes directly. However, in this situation the intra-port competition arises for the local container hinterland market among similar port facilities, which are incapable to handle mega vessels, serving to same hinterland.

Consequently, in the light of the developments in container terminals, the largest container terminal is able to handle more than 35 million TEU as annual throughput by 2014 (WSC, 2015). As the largest container terminals, Asian ports have the biggest share among other countries' container ports as parallel to export figures of containerized cargo, and the top ten of ranking list is dominated by Asian ports. The Port of Shanghai located in China ranks at top of in the top fifty global container ports in 2014 (JOC, 2014, WSC, 2015). The Port of Shanghai has obtained this position in 2010 by surpassing another Asian port which the Port of Singapore, and the Port of Shanghai is statistically known as the world's busiest container port with it's the highest container throughput in the world (WSC, 2015, SIPG, 2016). The strategic investment decision on an island port in Shanghai port area -Yangshan Deepwater Port- cannot be denied to understand the development of container ports. With aid of developing technology, at the reached point, today it is also aimed that the container terminals could handle the containers with the strategy of zero-emission and in sustainable business and renewable energy models as it is announced by APM Terminals for Rotterdam port (MarEx, 2015).

2.3 Floating Service Concepts

A rapid evolution of floating terminals has been seen in the last decade. However, as reported by Stanford (2008) that the first examples of offshore operations have been observed during World War II. It is developed by British Army to enable unloading of cargo to transfer shores during the Normandy Landings as seen in Figure 2-6.

Figure 2-6 View of the Mulberry Harbour in 1944
Source: IWM (1977)

Later on, another concept, sea basing, was developed by the US Navy to provide strategically logistics support to its naval forces without reliance on land bases within the operational area (Tangredi, 2011).

In the oil industry, the usage of offshore system is very common approach. Particularly, after oil has been commenced to produce from offshore locations, oil drilling systems are located on the seabed and so very large oil tankers are modified or special design of platforms are built for a purpose of offshore oil production, storage and offloading which are named as offshore oil port and FPSO. As considered port based offshore oil structures, it can be encountered an offshore oil port or terminal anywhere around the world. They connect crude oil by pipeline to shoreline. As a consequences of the developments in oil industry, it is possible to see very large offshore based oil drilling structures: the Louisiana Offshore Oil Port (LOOP) can be shown as example for one of the biggest deep-water port as seen in Figure 2-7 (LOOP, 2016).

Figure 2-7 Louisiana offshore oil port
Source: LOOP (2016)

Floating Liquefied Natural Gas (FLNG) is another version of FPSO applications in gas industry to enable the development of offshore natural gas resources as the FLNG facility will theoretically produce, liquefy, store and transfer LNG. Berner and Gerwick (2001) discuss several key aspects of such platforms from material selection and performance by comparing concrete and steel as material to platform construction consideration even if the areas with shallow water.

The reason under this offshore approach is to minimize operational risk arising from oil operations at ashore ports and to protect environment in responsible manner. However, the effects of offshore oil port or platforms on marine environment are argued in the industry and academia. The offshore system can be considered as a solution to eliminate or at least mitigate oil spill risks from ports or ships which are occurred during operations or other reasons thanks to operations at lower traffic-density open sea (Xing et al., 2015, Liu et al., 2015, Li et al., 2016).

Similarly, it is worthy to say that the floating transfer terminals are also commonly used for dry bulk cargoes. This system based on the transhipment activity from large ocean-going bulk carriers to barges due to draft limitations or lack of adequate handling equipment which are reason to prevent port entrance of those of large bulk carriers. MacGregor (2016) suggests the floating dry bulk cargo transhipment systems due to its several advantages for the efficient, reliable and clean transhipment of dry bulk cargoes. The advantages of floating terminals coincide with necessary aspects of a container port to mitigate the impacts of ULCVs. In addition to those of aspects, the advantages are also including (MacGregor, 2016):

- Avoiding new investments in ports that lack discharge facilities,
- Larger vessels can be used for long distance transportation,
- High discharge capacities,
- A floating terminal can be relocated,
- Reduced pollution in ports and their immediate environment,
- Environmentally-friendly operation.

By way of illustration, it is shown how the floating terminal for the dry bulk cargoes can be layout as seen in Figure 2-8.

Figure 2-8 Floating dry bulk terminal
Source: MacGregor (2016)

To see the examples of offshore systems in specific maritime sectors including oil and dry bulk sectors are not new. Mainly the encountered offshore systems in the applied sectors are listed in Table 2-1.

Table 2-1 Encountered offshore system examples in other sectors excluding container sector

Structure	Design	Sector	Design Objective	Source
Mulberry Harbour	Floating Artificial Harbour	Military	To enable easy access to shore during invasion of Normandy	Stanford (2008)
Sea basing	Mobile Offshore Base at different design concepts i.e. vessel, pontoon, mobile harbour	Military	Logistics support for military forces at large distances from shore.	Tangredi (2011)
Offshore oil port	Static Offshore Deepwater Port	Oil	Drilling offshore oil, tanker offloading, temporary storage, and pumping crude oil to shore	LOOP (2016)
FPSO	Floating tanker or purpose-built	Oil	Oil process, storage and transfer	
FLNG	No exist design	Natural Gas	LNG produce, liquefy, store and transfer	Berner and Gerwick (2001)
Offshore bulk terminal	Floating transhipment terminal	Dry Bulk	Transhipment dry bulk cargoes from large bulk carriers to smaller bulkers	Mobidock (2016)

In the light of the listed advantages of floating terminals, the usage of floating terminals is also proposed for container shipping in some studies such as (Ali, 2005, Evangelos, 2006, Kim and Morrison, 2012, Baird and Rother, 2013, Kurt et al., 2014).

The first systematic literature review of floating structures in the container shipping was reported by Kim and Morrison (2012). Detailed examination of the offshore port service concepts shows that there are various floating structures to give service container shipping industry. Kim and Morrison (2012) discuss the challenges and strategies of floating service concepts for facilitating and promoting the container handling chain.

Ali (2005) defines that the floating terminal can reduce the pressure on existing ashore container ports. In his analysis of the floating container terminal, the feasibility of structure is examined in terms of the design based operability and the financial situation. The study mainly focuses on the design of the terminal, system hydrodynamics, terminal station keeping and finally its financial aspects, respectively. The analysis has been carried out for a certain terminal design approach which is equipped with the pre-determined yard equipment and stability technologies. The results are consistent with data analysed to obtain CAPEX, OPEX and minimum fee. However, this study has been unable to demonstrate that the differences between a conventional container port and the analysed offshore floating terminal. These differences can be explained in part by the proximity of obtained results and the data from a based conventional container port.

In the study of Ali (2005), different type of floating structure concepts including stable and dynamic structures and layout alternatives are also examined to find the optimum concept according to pre-defined conditions and clauses. In this manner, pontoon shaped structure and rectangular shaped marginal berth system have been proposed for his specific case. The proposed design of floating container terminal is represented in Figure 2-9. However, the structure and layout can change according to the user demands from a floating container terminal. The examination of structural aspects of floating terminal is not a topic of our study but it is worthy to know that there are different structural alternatives.

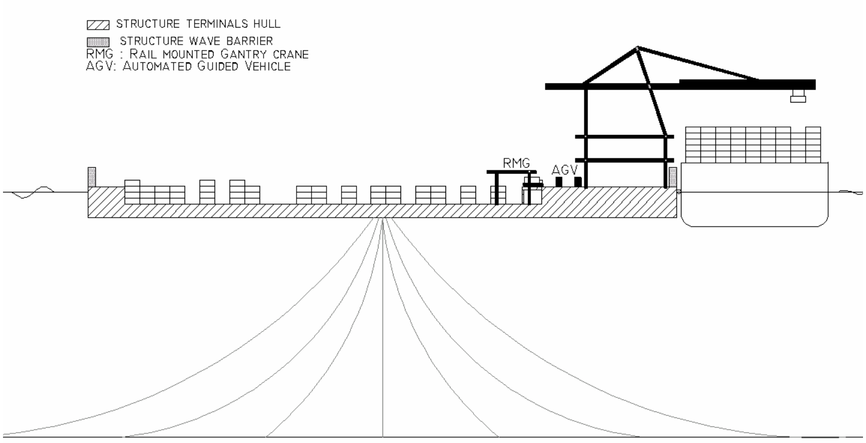

Figure 2-9 Floating container terminal

Source: Ali (2005)

While Ali (2005) was not addressing the proposed floating terminal as a solution for the ever-growing containership size, Evangelos (2006) identifies the floating container terminals as one of major solutions for the continuously increasing container transportation, in conjunction with the container handling operations, the port infrastructure, the changes in ship design and building industry. In his analysis of innovative approach for the ULCVs, Evangelos (2006) dedicates floating container terminal to ULCVs. The draft request of ULCVs is showed as a main problem which would be coped with by the dedication of floating terminals. The indented berth system by Ali (2005) is proposed by Evangelos (2006) to expedite the cargo handling operation with both side allocated cranes as illustrated in Figure 2-10.

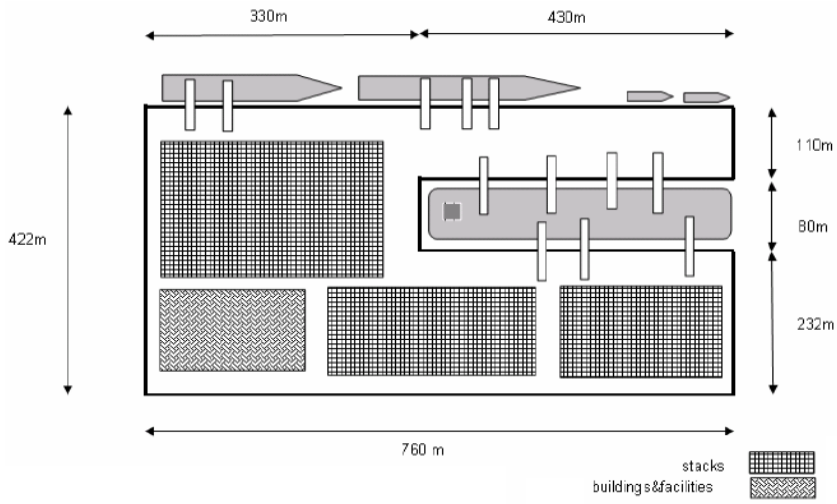

Figure 2-10 Indented berth system

Source: Ali (2005)

Rooij (2006) and co-workers made the technical feasibility analysis for very large floating container terminals. DELFRAC computer software has been used to get the results for the determination of response motions, wave forces, wave elevations and connection forces in the hydrodynamics behaviour of the terminal when it has been modelled as a rigid single-body platform. It is modelled with the pontoon shaped rectangular elements which are connected each other and forms the terminal has a bridge connection to shore. While the hydrodynamics and technical feasibility are examined in his study, he also discusses the capacity increase possibility of floating terminals for the major container ports and the potential contribution to land security is also discussed.

The above container shipping related floating terminal studies may remain at the level of analysis, and the applications of them could not attract the expected attention in the industry. However, in 2013, Baird and Rother published a study which focuses on the technical and economic evaluation of the floating container storage and transhipment terminal (FCSTT) and the study is supported by the EU Interreg IVB North Sea Region Programme via the StratMoS Project (Baird and Rother, 2013). Indeed, the study does not contain a known floating terminal structure which is based on conversion of a large container vessel and has been designed to handle containers at offshore locations where a terminal need is exist. It can be thought that it is inspired from the FPSO example in oil shipping industry. According to conducted economic evaluation of Baird and Rother (2013), the FCSTT has better CAPEX and OPEX values than the conventional shore container terminals. The proposed design concept of FCSTT on converted Panamax containership is demonstrated in Figure 2-11.

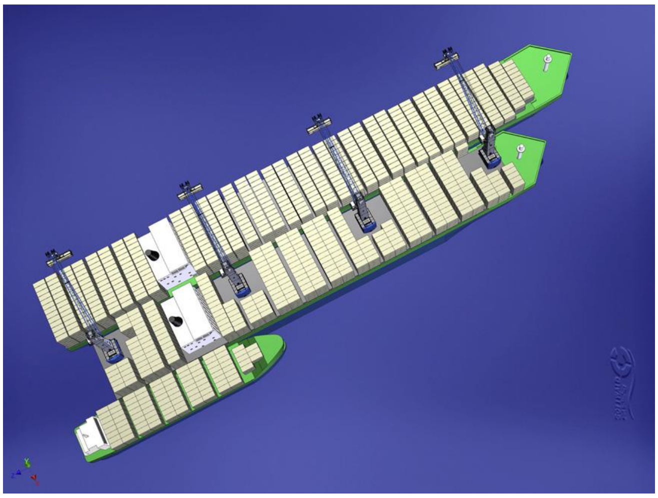

Figure 2-11 FCSTT design concept based on converted Panamax ship
Source: Baird and Rother (2013)

In addition to the floating port or terminal structures, several studies investigating the subsidiary floating structures have been carried out on floating breakwaters and floating crane platforms (McCartney, 1985, Murali and Mani, 1997, Pielage et al., 2008, He et al., 2012). Particularly, research into floating breakwater has a long history and today a wide range of studies can be accessed. In recent years, the studies have been undertaken to improve the hydrodynamic and technical aspects of existing structures more than the development of a concept design (Ji et al., 2015, Wang et al., 2015, Ji et al., 2016).

On the other hand, Pielage et al. (2008) suggests that floating cranes could create additional berth capacity for the ULCVs and they also target to reduce the ship's port time by providing container handling from both alongside of containerships. In his seminal article, Pielage et al. (2008) describes how the handling operation will be carried out as well as the conceptual design of floating crane system and its adaptation to current logistics chain. A concept floating crane concept is given in Figure 2-12.

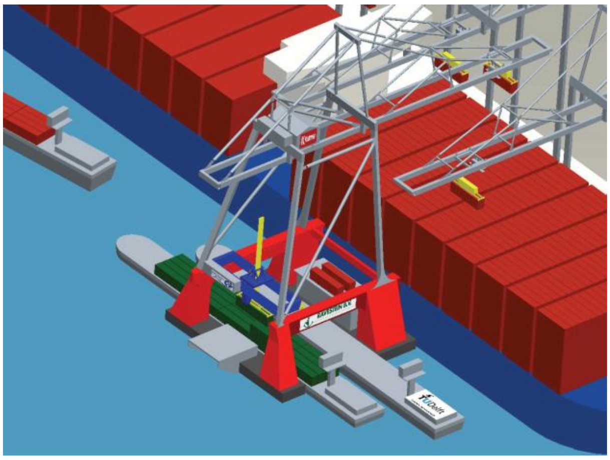

Figure 2-12 Floating crane system for container handling

Source: (Pielage et al., 2008)

The floating crane-barge operations can be seen in container shipping as they are actively used. The evidence of floating crane-barge operations can be clearly seen in the case of Hong Kong mid-stream operation (MSO) which offers cost saving, faster and widening scope for container services when compared to Hong Kong port (HKMOA, 2016). The operation strategy for MSO can be defined as unlike using berths for cargo handling, the system allows handling cargoes on both alongside of a ship at the same time. According to the available data is provided by HKMOA members, despite approximately 7% share of container operations within Hong Kong port area has been handled by mid-stream operations in 2012, in 90s the share of crane-barge system reached up to 30%. Figure 2-13 shows mid-stream operations in Hong Kong.

Figure 2-13 Hong Kong mid-stream operations

Source: Wong (2010)

Kim and Morrison (2012) classify offshore port service concepts and propose a comprehensive concepts called as mobile harbour (MH). The proposed concepts is equipped with a quay crane(s) and may have RORO service capability, makes circle trips between the conventional port and the main container vessel.

As seen from the above, the development of crane-barge system can be a solution for acute container congestions in major ports such as Hong Kong, Hamburg, Rotterdam, and Shanghai etc. As benefits of this concept have been indicated the system's ability to ease container port operation by the following ways:

- Replace container trucking within the port,
- Reduce feeder vessel shifting,
- Provide a better intermodal access for inland waterway vessels,
- Reduce environmental impact of container transfer considerably.

Table 2-2 gives floating service concepts which have been seen in the studies of floating structures in container sector.

Table 2-2 Floating service concepts in container sector

Structure	Design	Sector	Design Objective	Source
Hong Kong mid-stream operations	Floating Crane-barge	Container	Container transhipment	HKMOA (2016)
Mobile Harbour	Several Design Concepts	Container	Container transhipment	Kim and Morrison (2012)
Mobile Crane	Floating Crane Concept	Container	Container handling - Additional berth capacity	Pielage et al. (2008)
Floating Terminal	Floating Container Port with all basics of a conventional container port	Container	Container handling, storage and transhipment	Ali (2005)
FCSTT	Large Container Vessel Conversion	Container	Container handling, storage and transhipment	Baird and Rother (2013)

In view of all that has been mentioned so far, one may suppose that all above studies outline a critical role for the floating container service concepts in promoting container handling flexibility. However, it can be understood that the need for such kind of innovative solution is exist due to the floating structures have a number of practical implications in the container shipping. As ever-growing containership size and inadequate physical infrastructural aspects of most conventional container port considered, the role of floating structures to involve in the container shipping can be assess in better manner. Basically, the demand of container liner from ports can be met with the adaptation of floating service concepts in container handling chain without any other physical construction at main port area such as dredging, berth lengthening etc.

2.4 Offshore Container Port System (OCPS)

The offshore container port system appeared as an output under infrastructural investment for the complex adaptive behaviour of ULCV deployment in the container shipping. There is a relation among container shipping system dynamics and the applied complex adaptive behaviours. This relationship causes some outputs as a result of the industry's complex adaptive behavioural action such as ULCV deployment in the container shipping. As a result of the adaptive evolution of ULCV deployment, the offshore container port system has been developed as a part of infrastructural developments to provide enhanced operational services and solutions for handling ULCVs. The inputs and outputs of ULCVs deployment in the emergent, self-organization complex adaptive behaviour are illustrated in Figure 2-14.

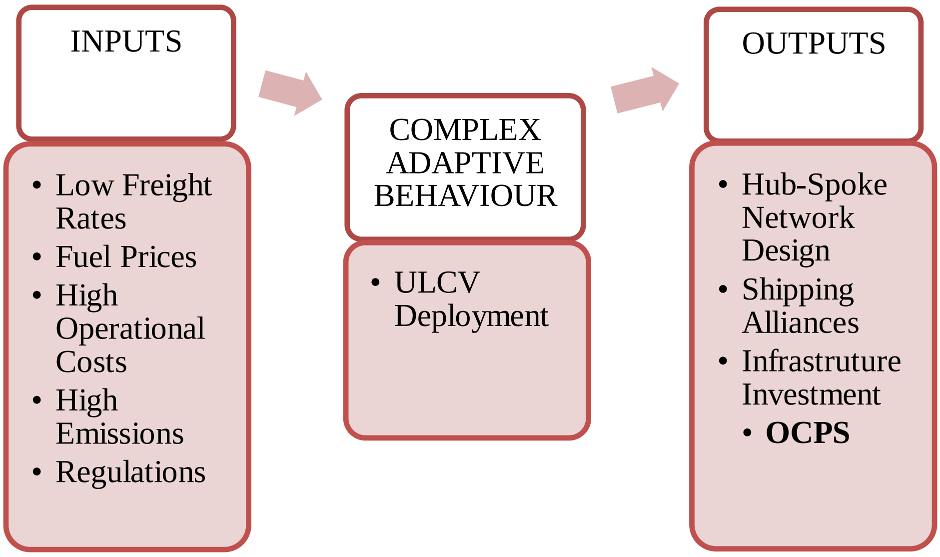

Figure 2-14 Inputs and outputs of adaptation of ULCV deployment

The OCPSs are not entirely new applied system in the container shipping. In recent years, there is an increasing interest in offshore container ports due to ports cannot cope with ever-increasing vessel size. The reasons to consider OCPS can be described as following (Pluijm, 2015a, SIPG, 2016, Kizad, 2016, ADPC, 2016).

- High-cost dredging operations can be required to handle ULCVs,
- Environmental effects of city ports and ever larger vessels on biosecurity and historical areas,
- Land scarcity,
- Restricted hinterland connections (congestion, capacity) put limits on growth and/or quality of life (air quality, emissions),
- Homeland security.

Some offshore container ports are available in the industry and also there are some suggestions which are announced. The all offshore container ports in operation, under construction and proposed are mainly considered as a solution to the given reasons above. Table 2-3 gives the offshore port applications in the container shipping.

Table 2-3 Offshore container ports in operation, under construction and proposed

Structure	Design	Sector	Design Objective	Shore Connection	Capacity	Operation Commencement
China,Yangshan Deep-Water Port	Artificial Island	Container	Mega Container Port to expand Shanghai Port capacity and easy navigational access	Causeway	36.5 million TEUs in 2015	2004
Abu Dhabi, Khalifa Port	Artificial Island	Container	Mega Container Port as state-of-the art gateway to Abu Dhabi	Causeway	15 million TEUs by 2030	2012
Italy, Venice Onshore Offshore Port (VOOPS)	Offshore Structure	Container and Oil	Mega Container Port and Oil Terminal for isolating Venice city from the vessel effects and create capacity in NAPA area	Barge	1.5 million TEUs by 2030	2020
US, Portunus Project	Offshore Structure	Container	Mega Container Port for mainly homeland security and deep water requirement	-	-	-

Structure	**Design**	**Sector**	**Design Objective**	**Shore Connection**	**Capacity**	**Operation Commencement**
US, Louisiana International Gulf Transfer Terminal (LIGTT)	Offshore Structure	Bulk, Container and Oil	An advanced transhipment and logistics “hub-and-spoke” system	-	-	-
Vietnam Hon Khoai Port	Island Port + Offshore Structure	All cargoes	Mega multi-purpose port	Causeway	-	-
Canada, Roberts Bank Terminal 2 Project	Offshore Structure	Container	Mega Container Port to expand Shanghai Port capacity and easy navigational access	Causeway	2.4 million TEUs	mid 2020s
Costa Rica, Moin Deep-Water Port	Offshore Structure	Container	Mega Container Port to expand Shanghai Port capacity and easy navigational access	Causeway	2.5 million TEUs	2018

In his case study of the offshore ports, Pluijm (2014b) identifies cost savings when the containers are delivered via the Suez Canal aimed at reduce container moves from west part of the US to east by rail and road transportation modes. Therefore, the offshore container port system is suggested for the East Coast of US to handle ULCVs. For the better understanding of the suggested OCPS by Pluijm (2014b), Figure 2-15 compares the existing situation with the proposed offshore port system.

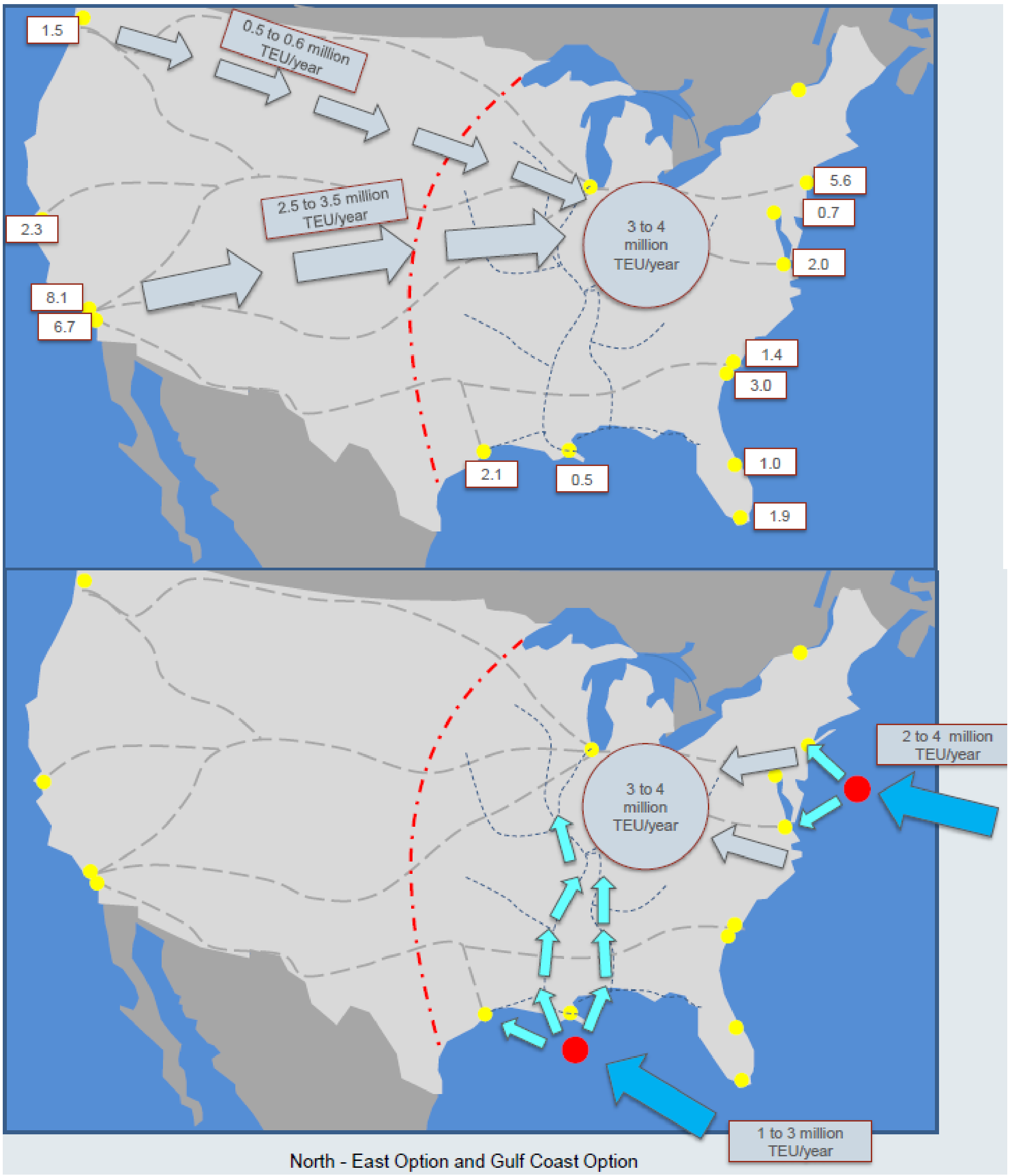

Figure 2-15 Comparison existing and proposed container distribution network in the US

Source: Pluijm (2015a)

The existing container distribution network in the US uses overland transport for the container moves from west part to east part. As alternatively, the suggested system offers to distribute containers directly from East Coast of America thanks to offshore port system.

By deploying OCPS to the US's eastern coasts and by operating ULCVs on the main maritime route between Asia and America, cost savings are targeted. In this system, it is enabled to reduce the number of containers which are handled at the western ports and are passed through the entire continent to deliver to the eastern regions. Thus, significant are also expected in gas emissions with the transfer of containers by the offshore port system on the east coast to inland sea transport (Pluijm, 2015a).

In his studies, Pluijm (2014b) sees the OCPSs as an alternative to handle the new generation of ULVCs for the ports of Africa and US. Likewise, this view is supported by Kurt et al. (2015a) who performed a container network analysis for West Coast of North America where OCPSs are proposed to accommodate ULCVs at offshore location as an alternative for port extension solutions.

Some factors, which should be assessed before making an investment decision in an OCPS, are indicated by (Boulougouris and Kurt, 2015). The factors are argued under the following broad categories: desirability, viability and feasibility; energy efficiency and operational flexibility; location; the approach of container sector; and the connectivity role of OCPS between the global container trade and the hinterland. In the following sections, the principal findings, which have essential role in the investment decision, of the current investigation on the aspects of OCPS under the titles of strategic and economic, structural, operational aspects will be presented.

2.4.1 Strategic and Economic Aspects of OCPS

In a strategic perspective of OCPS, the offshore terminals are addressed as gateway for main country rather than just transhipment because they are designed to be main actor at the region of target market (Rowland, 2015). For example; VOOPS has been planned to serve the growing North Adriatic market and as a distribution hub for European cargoes. The analyses show that the location is strategically favoured in competing with Northern and Tyrrhenian ports (Costa, 2015). Costa (2015) address the strategic advantage of VOOPS in terms of port manufacturing accessibility index which puts Venice at the top of list when compared to other European ports.

As it is discussed by Rowland (2015), Kurt et al. (2015b), the offshore ports have commenced to gain strategic importance with the effect of gigantism trend in the container shipping since 2008. The strategic advantage of offshore structures can be considered in the context of the concentration of container shipping on fewer ports due to operational pressure on logistics chain to handle larger vessels at fewer ports (Fleming and Hayuth, 1994, Notteboom, 2004). However, this strategic approach requires efficient terminal handling and well-designed connections to hinterland.

The main operational strategy of OCPS is to offer deep water access to markets. In this strategy, market access is provided with large ships so economies of scale benefits are obtained by shipping liners. Besides the benefits from larger vessel deployment, the highlighted point is the provided navigational convenience by OCPS which allows rapid access for mother vessels without lock gates, canal and river navigation. The navigational access is an ever-growing issue in the gigantism trend of container shipping, because restricted access inhibits size economies and affects network efficiency for large vessels (Gilman, 1999). Pauli (2016) also discuss the effects of navigational issues on the emissions from vessels and end-to-end logistic chain. The restricted waters need to study on under-keel clearance (UKC) algorithm but the OCPS can bring solution on the navigational access in strategic meaning by providing rapid access for large vessels (Kurt et al., 2014, Liu and Liu, 2016).

In the view of port competition, the OCPS can offer new strategic game for the keen container port competition by providing alternative for the container shipping lines when the competition environment in a port region is exist for the deep water scarcity. Rowland (2015) addresses that the existing of OCPS in a region can eliminate monopolistic pressure on pricing of terminal handling and can provide choice for port customers in unexpected cases such as bad weather, strikes etc. Another foresight of some experts is that each shipping alliance can need its own port so they can prefer the OCPS to provide flexible container shipping activities.

The OCPS also creates additional port capacity with deep water access. The created port capacity and large volumes of traffic required to justify strategic investments can stimulate additional economies of scale. Thus, it can be expected the developments in port-centric distribution and network of intermodal services to serve more extensive hinterland. The existence of a port with deep water access makes the region as attraction centre strategically; it gives the ports in region an opportunity to find a better place in the Liner Shipping Connectivity Index (LSCI) which is identified by UNCTAD if the ports utilize the provided strategic opportunity (Hoffmann, 2012).

As another strategic advantage, offshore container port structures are compatible with the Ten-T projects and Marco polo program, and perhaps indirectly with Horizon 2020 supported by the European Union (EU, 2007a, EU, 2007b, EU, 2014b). Because operationally offshore port facilities are a structure that can encourage more efficient use of inland maritime transport and combined transport systems, as well as the development of the network between regional ports.

2.4.2 Structural Aspects of OCPS

The main physical characteristics of offshore structures can be defined that are man-made, artificial structures which are located or operated far away from shore. The OCPS structures divide from the aforementioned floating service concepts in terms of some structural and operational aspects. While the floating service concepts are structurally designed as mobilize in general, although moored examples are exist with the specialized mooring system; the offshore container port systems may be considered as completely fixed platforms as they are finely stranded on seabed or built on an artificial island. The structural aspects of offshore ports may show variety by the available offshore technologies. Glauser (2015) addresses the involved technologies which are applied in the offshore platform/port construction, are: (1) sea embankment is common for large installations; (2) fixed structures are commonly applied in oil sector; and (3) floating structures are categorised according to stability aspects such as semi-submersible, pneumatically stabilized platforms.

The available offshore technologies, which are mostly applied in gas and oil industry, are demonstrated in Figure 2-16.

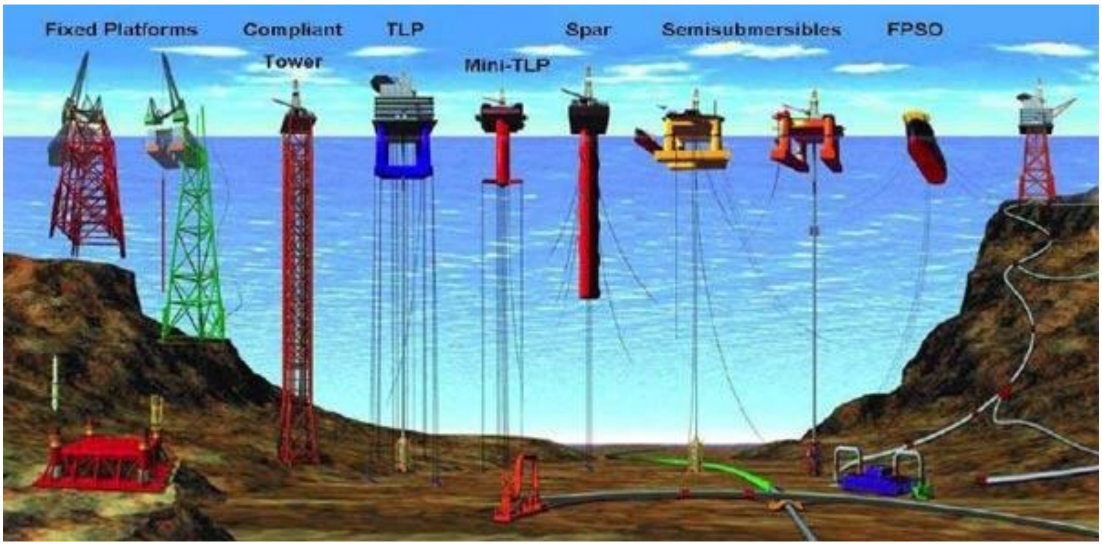

Figure 2-16 Available offshore technologies

Source: see offshoretechnology.com (offshoretechnology, 2016)

On the other hand, in the literature, it can be noted that there are some proposals on the application of available offshore technologies for the container terminal/ports. Ali (2005) suggests pontoon shaped structures for the case of annual container capacity less than 1 million TEU, in his analysis pontoon shaped mega float is also suggested when the annual capacity is over 1 million TEU. The design of offshore container port systems can differ according to geographical aspects of area, available technologies, economic and infrastructural development of local area, the planned position of structure, container volume desired to handle and so on. However, in contrast to (Ali, 2005), the fixed platforms can structurally be more preferable for the offshore container ports.. The available offshore technologies which can be applied for OCPS are given in Table 2-4.

Table 2-4 Available offshore technologies

Fixed Platforms	**Floating Platforms**
Jacket structure	Semi-Sub merged structure
Gravity based	Pontoon-shaped structure
Compliant structure	Tension leg platform (TLP)
Guyed towers	Mega floats
	FPSO

Source: Boulougouris and Kurt (2015)

The OCPS offers some advantages due to its structural aspects. The main obtained advantages from the structural aspects of OCPS can be summarized as follows (Pluijm, 2015a):

- Purpose built, state of the art, multi-purpose offshore terminal facility,
- Minimal surface area, tailor made for each type and quantity of cargo,
- Situated at adequate water-depth, no dredging required.

In terms of the functionality of structures, some differences can be seen in functions of ports. The functionality of offshore structures in the container sector is investigated by Kurt et al. (2015b), Boulougouris and Kurt (2015). The functions of offshore container ports are generally given in Table 2-5.

Table 2-5 Offshore container structure functionality

Functions	Sub-functions	Components
Processing containers	Loading/unloading	Cranes
	Intern transport	Chassis, fork lifts, AGV's etc.
	Storage	Storage yard, apron area and traffic lanes
	Maintenance	Maintenance workshop
Processing vessels	Tugging	Tug boats
	Mooring	Mooring lines/fenders
	Supplying	Supply boats/systems
Supplying personnel	Transport to/from shore	Boat, helicopter etc.
	Hosting personnel	Offices, restaurants, etc.
Supplying terminal	Electricity and light	Light posts, generator station, electricity station
	Fuel supply	Fuel tanks
	Food and water	Storage, supply boat

Source: Boulougouris and Kurt (2015)

A structural port design is made according to the expectations, but the functions to be implemented may not be feasible for every offshore port designed. The defined function applications can vary according to structure technologies for the fixed structure and the floating structures as they are illustrated in the following Table 2-6.

Table 2-6 Offshore port functions' differences for fixed and floating structures

	Function	Fixed	Floating
Processing Container	Loading/unloading	Fast and high automated cranes according to terminal capacity	Cranes with low productivity and direct transfer to feeder or barge
	Intern Transport	Intern transport highly required due to larger terminal land	Not need due to direct transhipment
	Storage	More essential	Not desired
	Maintenance	For cranes and intern transport vehicles	Providing from shore
Processing Vessels	Tugging	These functions are fundamental for fixed platforms and should be considered as conventional ports	Depends on location and technical capabilities of floating platform
	Mooring		
	Supplying		
Supplying Personnel	Transport	One of the most important functions for fixed terminals	Maybe not need a transport function due to terminal's floating feature
	Hosting personnel	Offices, dining hall and other social facilities are important parts	Facilities should be designed at basic level - most of facilities can be located on shore
Supplying Terminal	Electricity and light	Electric power from shore or renewable energy form wave or wind - Transformer and high level and regular electric supply	Electric can be produced by diesel generators
	Fuel	Fuel tanks or pipes from shore or supply boat	Fuel tanks or supply boat
	Food and water	Storage - supply boat	Supply boat

Source: Boulougouris and Kurt (2015)

Boulougouris and Kurt (2015) investigate fixed and floating offshore structures to compare the structural capabilities in terms of the serving vessel size, the handling capacity, the port stability and vessel protection, the port construction time, and the port operational approach. In terms of strategic decision-making, the structural capability of offshore systems is important to determine the strategic position of port managements in order to meet the demand of container sector with more suitable offshore structure (Boulougouris and Kurt, 2015). So, the strategic comparison has been carried out for the fixed and floating structure technologies in the main framework as in Table 2-7.

Table 2-7 Strategic comparison for fixed and floating structures

Fixed	**Floating**
Largest vessels - no dimensional constraints	Larger vessel but limited due to crane outreach and berthing space despite no draft limitation
High container handling capacity	Lower annual container capacity
High stability and vessel protection	Needs stability technologies and protection for vessels
Longer structure time	Shorter structure time
Alternative to conventional ports with high capacity	Supports the existing ports due to limited capacity
Hub-and-spoke system application	Transhipment of large vessels which are not handled at shore port due to draft limitation or berthing space limitation

Source: Boulougouris and Kurt (2015)

2.4.3 Operational Aspects of OCPS

The operational approach for the OCPS is to deploy larger container vessels on main routes, and as a second step of the operation strategy of OCPS, the transhipment of containers is generated by acting as a regional hub for distributing or collecting to/from several junction points on the hinterland by short sea shipping, road or railway.

In terms of the changing operational aspects of container sector, some studies discuss the impact of large ships on existing container ports (Rodrigue et al., 2013, Lane and Moret, 2014). The effects of growing ship length are addressed from different points.

Rodrigue et al. (2013) deal with the problem in terms of increase in hinterland traffic while Lane and Moret (2014) deal with the effect of large vessels from an operational perspective. The comparison of the effect on the hinterland traffic of a port depending on the ship's dimensions is given in Figure 2-17.

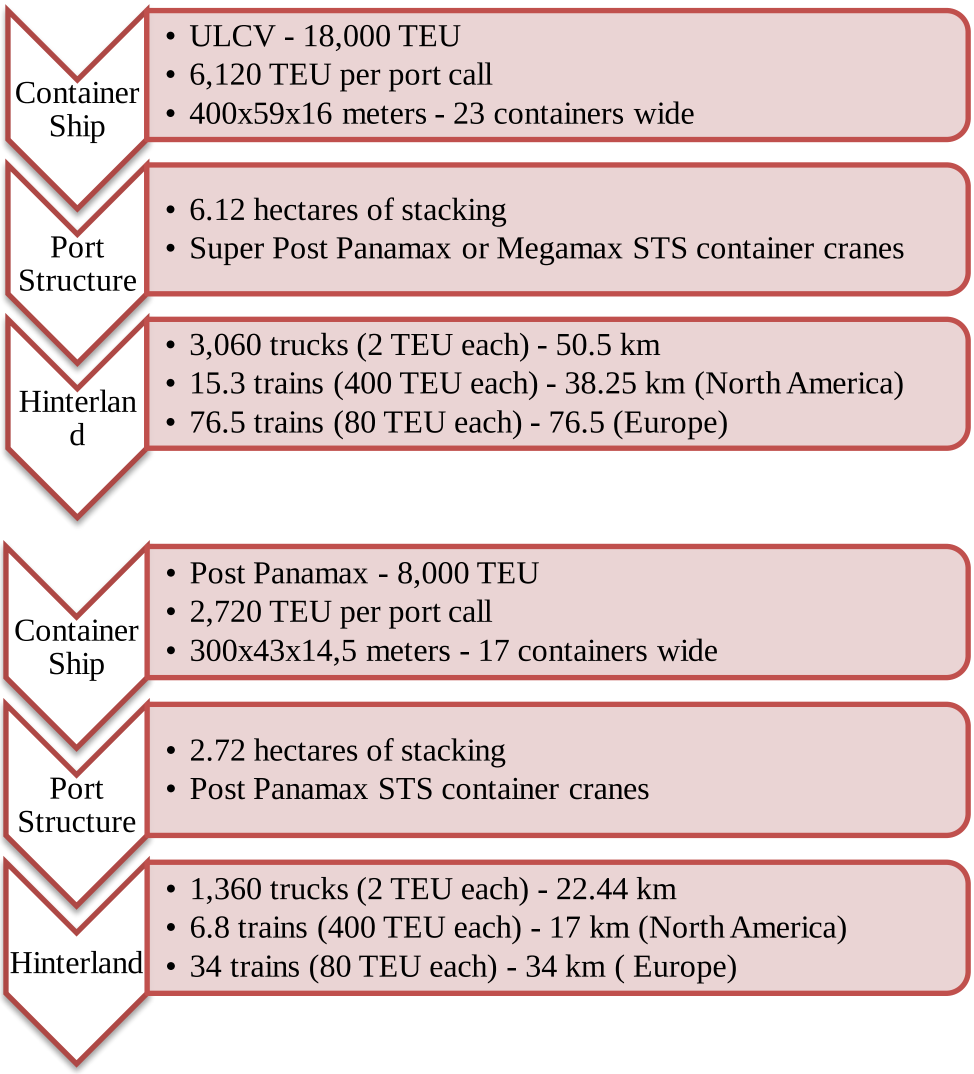

Figure 2-17 Impact of Post Panamax vessels on port hinterland traffic[1]

Source: Adapted from Rodrigue et al. (2013), MAERSK (2015) and LIEBHERR (2016)

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[1] Container stacking area is assumed to be 1,000 TEU per hectare with the usage RTG. Trucks are assumed to be 16.5 meters long, which can carry 2 containers. Trains are calculated as 2500 meters and 1000 meters, respectively, based on 400 TEU and 80 TEU carrying capacities for North America and Europe, respectively.

It is possible to overcome the short-term yet very compact effect of the high volume of containers created by large vessels on the port traffic with the technical development of the handling equipment or the efficient management of the handling equipment. Ports will be able to cope with this through the applications and investments in the development of operational and handling equipment, as long as the presence of large vessels in container trade lines continues.

In order to avoid disruptions in the supply chain, Rodrigue et al. (2013) shows that the increase in hinterland traffic makes the optimization of container transportation network more important. When the impact of larger vessels on the hinterland traffic is discussed from the perspective of offshore ports, offshore ports can be considered to inevitably break the effect of large vessels in hinterland traffic. What makes offshore ports so successful is that, unlike conventional container ports, the connection between the port and the hinterland can be made from multiple destinations thanks to feeder services.

The offshore ports can provide operational advantages by distributing containers to the hinterland from different points to reduce the effect of container transportation on regional traffic. An efficient hinterland connection of OCPS can reduce the energy use and improve the efficiency of the transportation by increasing the ratio of the sea transportation between the transportation modes used to reach the final destination of the containers. Because of the ability to transfer small vessels from large ships provided by offshore ports, it can provide closer land connectivity to the final consumer than conventional container networks.

It is required that OCPS can spread the benefits form scale economies by serving transhipment hub in the container network. Pluijm (2015a) addresses some operational aspects of the OCPS which provides the combination of smart high density throughput handling facilities, direct serving the main carriers, the coastal shippers and barges, direct forward moving cargo, and minimum storage yard on the offshore hub concept.

When the operational zones are investigated in terms of OCPS, it cannot be possible to mention about the landside container buffer and the stacking area appears as minimized due to the operations on OCPS are carried out as transhipment hub for larger vessels. That is to say that the OCPS's operations are carried out at the three operation zones by defined for the conventional container ports. In some situations, the landside container buffer zone can be included; particularly if the road and railway links are provided.

Foroudi (2015) defines two principal options for an offshore container terminal. The initial operation principle is independent offshore terminals on which all containers are received, sorted/inspected, placed on final transport mode for onward transport chain inland and process works vice versa for export, while the latter is offshore/onshore principal which, differently from the first option, based on transporting all containers to onshore terminals where it is sorted/ inspected and then placed on final transport mode for onward transport.

The location of OCPS is a key parameter in the decision of operational principle, because the operational achievement of a port can be associated with the location of the port. As explained in the background chapter, it is clear that a global container port could be located at places where are near to major trade cities, on main routes to serve as a junction point to distribute containers towards hinterlands. In addition to all these, the seeking of deep water is another factor in recent mega containerships era and also the distance from shore has an impact in the OCPS applications.

Pluijm (2014a) addresses that the sufficient depth may be reached 10 to 15 km distance from land so it needs to argue that the consideration of OCPS as an applicable solution to provide deep water access for ULCVs. Therefore, it is argued that the offshore ports can be a response to remove the increasing pressure on the existing ports at the regions (Keefe, 2015, Kurt et al., 2015a).

However, the operational capability of an OCPS is also related the distance from shore. The increasing distance between shore and offshore structure decrease the flexibility of system in terms of the transport modes for the hinterland distribution. The increasing distance means that to make investment at higher level; and it also causes the examination of cost-benefit, operational flexibility and sustainability for the hinterland connection modes. Foroudi (2015) suggests two link options for connectivity to shore: fixed and flexible links. The fixed links can be broken down into tunnel, bridge, causeway and combination of them for the transport modes of road and railway accesses; while the seaway is considering as flexible link via coasters or barges. Thanks to feeder services, the land junction point can be diverted, in contrast to the fixed links which connect the maritime stage of transportation to a pre-determined point. In his comparative study, Foroudi (2015) founds that the barge system to be the most likely in terms of financial feasibility and operational flexibility, although all connection systems have pros and cons.

The main operational functions of OCPS can be identified as following (Pachakis, 2015):

- Berthing and loading/unloading operations for ocean-going main route vessels with minimal dwell time,
- Berthing and loading/unloading operations for feeder vessels. If the causeway access available, loading/unloading operations for rail sets and/or trucks are necessary,
- Container handling, storage and sorting depends on operational capability and expectations,
- Container scanning and customs inspection,
- Maintenance operations and other administration and utility operations as described by Kurt et al. (2015b).

Several recent studies investigating the pros and cons of available offshore technologies have carried out on the operational feasibility of OCPS (Boulougouris and Kurt, 2015, Costa, 2015, Foroudi, 2015, Glauser, 2015, Pachakis, 2015, Pluijm, 2015a, Rowland, 2015). Pachakis (2015) examines three different maritime operating concepts and also a bridge concept for the offshore structure and land connection by using various type of marine vehicles in the operating concepts. Each operating concepts have their own advantages and disadvantages which can be appeared according to the geographical characteristics of area where the OCPS is applied. Without considering the operating concept variations, the main pros and cons for the operation between OCPS and land connection can be summarized as the following on the basis of Pachakis (2015) approach.

(+) Advantages:

- The existing feeder vessels/ barges can be used and they can be matched the average size of the ocean-going main route vessel,
- Direct moving of containers without any sorting and value-added operation at the offshore port in favour of operational efficiency increase and port congestion decrease,
- Location of the onshore port/terminal can be anywhere as far as the feeder vessels/barges can sail without water and air draft restrictions,
- Opportunity to use existing land terminal/port and their infrastructures regardless of the handling capability to accommodate very large container vessels,
- There is no need for investment in dredging, quay extension and large STS cranes so the operations required this kind of investments will be carried out at OCPS.

(-) Disadvantages:

- Requires extra handling operation while the containers are transferred from the main vessel to the feeder/barge,
- If the river transport is applicable, there will be need for small barges which makes the operation less economic for long distance river transport,
- Feeder vessel has to remain at the each port in the schedule until all containers unloaded and loaded so the efficiency will reduce,
- If floating docks are used instead of feeders, the storage and grouping operations for the inland destinations must be done at the offshore terminal requiring sufficient area and dwell time.

2.5 Container Port Competition

Research into port competition has a long history. Traditionally, it has been argued that port hinterlands and the components of hinterlands have importance to determine the competitive position of a port (Sargent, 1938, Morgan, 1951). The construct of seaport competition was first articulated in comprehensive manner and popularised in the study of Verhoeff (1981).

Meersman et al. (2010) note that an important issue in the transportation industry is port competition. In addition to the large amount of throughputs of ports, ports have also economic impact in wider perspective in the consideration of employment area and business investment (Meersman et al., 2010). One can consider that ports are homogeneous facilities due to they handle cargoes from maritime mode to other land based transportation mode or vice versa. However, in practice, each port has its own novel characteristic as ports are defined by Bichou and Gray (2005) in terms of their dissimilarities in their capabilities, specializations, roles, assets, functions and institutional organizations.

According to special circumstances of each port, various port competition situations arise. Port competitions are carried out in a very complex nature so the definition of port competition is also very complex too. In macro competition perspective, the port competition can be related with two main constraints which are: (1) inter-model competition among transportation modes; and (2) inter-port competition among other ports (OECD, 2011).

In terms of the inter-port competition, ports compete with each other at different levels which can be mainly examined within: firstly, the specialized ports try to attract the specialized cargo type with investments aimed to increase port performance; and secondly, the ports compete for a hinterland in terms of the cargo throughput, handling capability and efficiency (Meersman et al., 2010). This view is supported by Notteboom and Yap (2012) who note that the port competition depends the operational characteristics of port according to the port is a gateway, local and/or transhipment port and the type of commodity. Indeed the port competition strategy focuses on the terminals rather than ports (Heaver, 1995). For this approach, the terminals appear as the physical units in the port competition for transportation while the entire port facility is representing all components in the sector including industrial enterprises, port authorities, policy makers so on.

In the inter-port competition, the price and quality of services are the main constraints. By using the advantages in price and quality, ports tend to be preferred either the initial origin or the final destination of freight among the ports serving same hinterland. At this point, the ports within a region have a well-supported competitive advantage to dominate the competition for same hinterland traffic due to lower transport cost.

According to UNCTAD's report on port pricing in 1975, port pricing is one of major aspects in the implementation of port management concept to obtain competitive advantages in terms of operational, financial and marketing objectives (UNCTAD, 1995). UNCTAD bases the port pricing strategy on the port's value chain and the sources of competitive advantage components. Accordingly, the strategic pricing can be defined as an important mechanism for achieving competitive advantage. Pricing strategies of each port are different because of the physical and economic differences of each port (Nash, 2015). However, in today's logistics concept, it is observed that the pricing strategy of the entire logistics chain is more effective for attracting the attention of customers in the framework of the mentioned components. From a general point of view, as a part of the logistics chain, ports may prefer to gain competitive advantage rather than maximizing profit, thanks to their pricing strategies (Meersman et al., 2014). At this point, the pricing strategy of offshore ports, the field of study of this thesis, should tend to set a competitive pricing strategy on the ULCV market. At this stage, the pricing strategy could be to provide competitive advantage by evaluating offshore and onshore services as a whole and strategically combining pricing instead of making a profit from every service offered.

Apart from the competition for same hinterland, another inter-port competition is to receive a satisfactory share from transhipment traffic appropriately port's market targets. Veldman and Bückmann (2003) say that the choice of transhipment port depends on the container shipping companies and shipper/consignee does not have any impact on this transhipment port choice in the container shipping. However, the users can decide for the shipping lines by assessing the hub-ports choice of shipping lines in the consideration of cost, transit time and service quality optimization. North European port competition can be showed as a good example model of transhipment container flow competition for the inter-port competition.

It is noted by OECD (2011)'s in the policy roundtable study to understand the distinction between hinterland competition and transhipment competition that the ports in competition can be operated in the same geographic area but their captive hinterlands can be different. In other words, it can be said that the ports have a national position in the hinterland competition while they have an international approach in the transhipment competition (OECD, 2011).

Ever-increasing requirements of trade and international logistics chains make the port competition more complex with the globalization impacts on the relationship of port-hinterland-logistics (Notteboom and de Langen, 2015). Notteboom and de Langen (2015) indicate that the changing competition trends and dynamics push the ports to be a node in container transportation chain rather than a selection decision of shippers, consignees and shipping lines. Because in today's container shipping, the users make choice between logistics chain which covers shipping line, port/s, and hinterland connections and tries to offer cheapest, faster, and high quality service.

Consequently, it is tried to say that the container port competition is very complex and multifaceted system. Port authorities are generally competing to bring the main container shipping lines or the global terminal operator with their existing and potential throughput capacity for the hinterland and transhipment; while the global terminal operators are competing as a representative of transport, logistics by using the physical competing units, terminals.

2.5.1 Container Port Competition Levels

In the literature on container port competition, different trends have been found to be related to competition levels in container ports. As it is noted by Verhoeff (1981), port competition trends manifest itself in the various geographical and functional levels due to the complex nature of container port competition. Verhoeff (1981) interprets the main competition trends of container shipping in broad concept, the levels include competitions among: (1) container port terminals; (2) port ranges; (3) port areas in a certain port range; (4) ports in a certain port area; and (5) global port operators in a certain port. Similarly, Notteboom and de Langen (2015) identify four characteristics of port competition levels as intra-port competition, multi-port gateway region competition, port range competition, and lastly the competition between rivalry port ranges. In the light of categorization by Verhoeff (1981) and Notteboom and de Langen (2015), the container port competitions will be analysed in the main three competition levels:

- Intra-port competition,
- Multi-port gateway competition,
- Competition in a certain port range.

2.5.1.1 Intra-port Competition

Intra-port competition addresses a situation where more than one terminal operator competes within same port facility for the same hinterland or market. De Langen and Pallis (2006) examine the benefits of intra-port competition, and in the study, the intra-port competition is defined as beneficial for the competitiveness of ports, for local and national economies and for consumers and exporting industries. The World Bank (2007b) carries the situation of intra-port competition one step further and adds another competition level within a port structure which is the intra-terminal competition. It can be defined that terminal operators competing within the same terminal to provide more attractive services. However, these two types of competition are considered as an inclusive intra-port competition which provides services in the respect of the same port infrastructure.

The intra-port competition has been implicitly or explicitly debated regarding to its level and conditions (Notteboom, 2002, Defilippi, 2004). There are two main arguments for the benefits of intra-port competition: the first one is the prevention of economic rents against the monopolistic pricing; the second argument is that the contribution of intra-port competition on specialization, flexible adaptation and innovation (De Langen and Pallis, 2006).

Goss (1999) argues that the existing economic rents for the container ports in the situation of intra-port competition lacking as a first and most widely acknowledged argument. The lack of intra-port competition causes that port users suffer from abnormal service tariffs and inflexible operation atmosphere. It can be considered that intra-port competition is a method against the monopolistic approach, otherwise some regulatory frameworks are needed to regulate the monopolistic pricing policies of ports (Trujillo and Nombela, 1999, Juhel, 2001).

The second argument is about that the intra-port competition provides benefits in terms of specialization, flexibility and innovation (Baptista, 2000, Defilippi, 2004, De Langen and Pallis, 2006). In fact that, the intra-port competition offers oligopolistic competition environment, so the rivals have to offer different service by aiming the satisfaction of their customer to secure advantageous position in oligopolistic competition (Ponter et al., 1998).

2.5.1.2 Multi-port Gateway Region Competition

Multi-port gateway definition is thrown out by Notteboom (2009) but the competition is defined as the competition among port ranges by Verhoeff (1981). In this competition model, the approach is based on the theory of grouping ports within the same gateway region where the ports serve more or less same hinterland.

Notteboom (2009) carries out an analysis on the economics of the European seaport system, and the European seaport system is divided into 12 multi-port gateway regions which are in a port range competition with respect to their European hinterland. Notteboom (2010b) concentrated on multi-port gateway regions and carried out a study series on this topic, it can be seen in his studies that the impacts of multi-port gateway region competition on the throughputs of ports in European seaport system.

In the multi-port gateway competition approach, there is a locational relationship between ports at a region where ports have locational position patterns in terms of apply to identical traffic hinterlands and also have similar service patterns in terms of the connectivity of container shipping networks and hinterland (Notteboom, 2009). These relationships can help to group port to be a part of multi-port gateway. While the ports are vying in the multi-port gateway competition, the neighbouring ports can compete for the purpose of gain share from the same hinterland cargo flows due to different competition strategies of separate port managements. In this regional competition co-operation, every single port even terminal focus on their own position in the competition environment by using its idiosyncratic advantages, while at the same time port authorities are encouraging local development all together with the multi-port gateway ports.

Feng and Notteboom (2013) examine the role of small and medium-sized ports (SMP) in the northeast China in terms of enhancing the competitiveness and logistics performance of multi-port gateway regions and associated inland logistics systems. The study identifies some variables to increase importance of role of SMPs in the competition against gateway ports. These variables: (1) cargo volume and market share; (2) international connectivity; (3) relative cluster position; (4) port city and hinterland connection; and (5) logistics and distribution function.

Liu et al. (2013) present in his study the Pearl River Delta (PRD) port system development by covering the underlying forces driving the port system evolution. Thanks to the collaboration between ports of Shenzhen and Guangzhou, the leading role of Hong Kong port in the regional competition has weaken while the multi-port gateway port has acquired the market share from one gateway port, Hong Kong.

The above studies investigate the positions of relatively small or medium sized ports in the competition against a huge gateway port. The geographical characteristic of some continents such as Europe allow ports to create regional multi-port gateway and to compete against other regional multi-port gateway. As Verhoeff (1981) discusses the competitive relationship between the northwest European and Mediterranean seaports with respect to their mid-European hinterland. More specific regional competition can be seen among North Adriatic Ports Association (NAPA) ports region and Rhine Scheldt Delta ports region.

2.5.1.3 Competition in a Certain Port Range

In this thesis, this competition level will be handled by covering competition among ports and also among port areas in a certain range. In other words, the third and fourth levels of competition as listed by Verhoeff (1981) and Notteboom and de Langen (2015) are discussed under one single title.

The competition at this level can be defined as between ports in a certain port range to strengthen their strategic position in the competition (Verhoeff, 1981, Notteboom and de Langen, 2015). This competition can be also seen as the competition between port areas in a certain port range.

In this port competition, one can observe a harsh competition environment due to ports which are situated at the same shore and serving more or less same hinterland. Verhoeff (1981) identifies the competition in a certain port range as very complicated because it has various connections at national and international levels. This level of competition sees the transport activities as the arterial road of society at hinterland while the ports are seeing as being like junction points of arteries and outward-opening door of national trade by public authorities. Public authorities require that the ports should have power to be dominant to keep hold of the advantageous position in the competition.

Verhoeff (1981) and Notteboom and de Langen (2015) address the range between Hamburg and Le Havre as the most important range in Europe for a certain port range competition. There is a fierce intra-range competition on the scattered range across four countries of Germany, Netherlands, Belgium and France which have developed their ports in their own best interests: as part of a national port policy or otherwise. Each situated main ports in the range follows their own policy.

In this competition level, ports are striving to keep edge over in the competition against other ports in the range. Verhoeff (1981) notes some cases are applied by ports to strength the position in the competition. The cases includes investments in handling equipment to proceed the efficient harbour work, highly developed and integrated hinterland connection to reach industrial regions easily like Ruhr region in Germany.

2.5.2 Container Port Competition Dynamics

The all players in the maritime transportation system are influenced, including container ports, in the intense global competition environment. As addition to the impacts of innovative systems and new technology, the container ports strive to edge over in the competition by adapting the operational changes. The endeavour of port users and port service providers is to survive by creating a consolidated position in the fierce competition environment. On the other hand, in company with technological and operational dynamics, the concerns on environmental, safety and security force ports to develop port structures in accordance with regulations and law without any commercial expectation on investment (WorldBank, 2007a).

In the study of WorldBank (2007a), port dynamics in the 21st century have been explained to be able to understand the roles and functions of ports and be able to place the ports in the context of current and historic port developments and competition. The trends shaping port dynamics can be given under five main titles including: globalization, changing technology, shifting bargaining power, changing distribution patterns, and environmental and safety concerns. Those of trends, which can affect the container port competition dynamics and can provide some advantageous for ports in the rivalry container port competition, are presented in Figure 2-18.

Globalization of production

- Vertical specialization
- Focused Manufacturing
- Expanded Logistics reach
- Increased Sourcing Alternatives

Changing Technology

- Containerization of World Trade
- Future Containership Designs
- Impact on Port Operations
- Need for Container Port Productivity Improvements
- Growing Role of Information Technology
- Port Requirements for Large Ships
- Other Technology Affecting Port Services

Shifting Bargaining Power

- Consolidation among Ocean Carriers
- Emergence of Global Logistics Service Providers

Changing Distribution Patterns

- Becoming a Hub
- Benefits of Hub Status
- Hub Problems
- Inland Container Terminals Shifting Activities from the Port

Environmental and Safety Concerns

- Growing Environmental Concerns
- Recent Environmental Article
- Issue of Substandard Ships

Figure 2-18 Port competition dynamics

Source: Adapted from WorldBank (2007a)

2.5.2.1 Globalisation Effect in Port Competition

The first dynamic which affects the position of port in fierce port competition is globalization. In several studies, ports are defined as an important node of the logistics systems (Coulter, 2002, Gunaydin, 2006, Ducruet, 2009, Inoue, 2010). The globalization has also increased the need for ports and has created a value-adding task to ports as a unique opportunity in the supply chain (WorldBank, 2007a, Corbett and Winebrake, 2008). Ports became an interface between intercontinental transport and hinterland and value-adding entity for production, assembly and final distribution (WorldBank, 2007a). The impact of globalization on container port competition can be addressed that the role of port in the competition in terms of port capability and efficiency can greatly influence the location decision of a producer compete at international stage. Therefore, the main challenge for ports in globalized trade is to take advantageous position in the container port competition by meeting the needs of customers and assist them with low-cost and efficient port services.

Ducruet (2009) notes that globalization has generated an interaction for regional port development. It can be said that the mass production needs to sell products globally and transport them to worldwide, so maritime transportation and ports have gained great importance. However, it is resulted in Ducruet (2009)'s study that the globalisation has a negative impact on port performance due to vertical specialization, focused manufacturing and extended logistics needs while gross domestic product (GDP) and service concentration are making a positive impact on container ports.

Gunaydin (2006) argues that the growing maritime market attracted the private entrepreneurs to invest in ports as a result of globalization. The high qualified and efficiency focused private sector operates ports with principles of cost/benefit optimization along with the rapid increase in transport of goods, developments in integrated logistics systems. Moreover privatization played a significant role to reduce the effect of slack public ports on economic globalization, efficiency, heavy infrastructure investments, management skills and governance (Gunaydin, 2006, Cullinane and Song, 2002). Thus, it can be said that the port privatization has importance to change the monopolistic public ownership of the ports to consolidate the advantageous position in container port competition.

2.5.2.2 Changing Technology

The major technologic changes play a vital role for the sustainability of container shipping and they also affect requirements for port structures and services. In fact that, the containerization is independently a trend which dramatically changed requirements for cargo handling and port facilities, raised the financial stakes of investing in these facilities, and radically affected manpower and labour skills required to handle cargo, creating serious labour redundancy issues and retraining needs in many ports (Al-Kazily, 1982, Gilman, 1999, Notteboom, 2004, Günther and Kim, 2005, Cudahy, 2006, WorldBank, 2007a, Imai et al., 2013). At the same time, it is expected from container ports that the harmonization of sophisticated information technologies (IT) with the requirements for port infrastructure and service to be able to remain in the competition.

While Cullinane and Khanna (1999) and Gilman (2015) argue the impacts of large container ships on scale economies and network efficiency, the impact of ever larger vessels on ports are discussed by Lane and Moret (2014). It can be noted that the emergence of ultra large vessels has two significant effects on international shipping including: the handled ship size can determine competitive power of ports; and the handling ULCVs becomes a major criterion in determining the size of a port.

The changing technology in container sector has reduced labour intensive port operations and thus the ship's time in port and at berth has greatly reduced. However, in today's container port operation, the ship time in port is gradually increasing due to ever-growing container vessel and the operations turned from labour-intensive system to capital-intensive system (WorldBank, 2007a, Lane and Moret, 2014).

In the light of the changing technology to improve the holistic competitiveness of container ports, it is important to ask how a port is to be in physically fit for the trend of growing container vessel size. The larger vessels have the economic impacts besides the operational impacts of them. As it is reported by Cullinane and Khanna (1999), an ULCVs deployment instead of a 4,000 TEU increased the operational costs at the rate of 17%. It is resulted from the equipment upgrading and extension, and other changes in the yard. Returning to the subject of the physical infrastructural expectation from a container port to eliminate the impacts of ULCVs, Rothberg and Sisson (2013) identifies the necessary aspects as follows:

- Easy navigational arrive in terms of water width and depth, and also air draft on access route,
- Operational efficiency thanks to depth alongside, quay length and expanded height and outreach of ship-to-shore cranes (STS),
- Sufficient landside capacity to store high volume of containers and sufficient yard equipment to manage storage area with advanced terminal operation system (TOS),
- Good links to the hinterland by railways, roads and inland waterways converge on the port.

The growing vessel size impacts are indicated by Rothberg (2014) as the larger vessel deployment cause lower frequency but it cause congestion due to coming high volume of container in one time. Thus, the improvement of physical infrastructure aspects is being more crucial in conjunction with the agreements of shipping alliances which generally deploys larger vessels.

According to the 5-year analysis on the deployment 18,000 TEUs containership instead of 13,000 TEUs containership, the service impacts of larger containerships on Asia-North Europe container network have changed operational mechanism at the ports because the number of vessels reduced while the average vessel size and annual throughput were increasing as demonstrated in Figure 2-19.

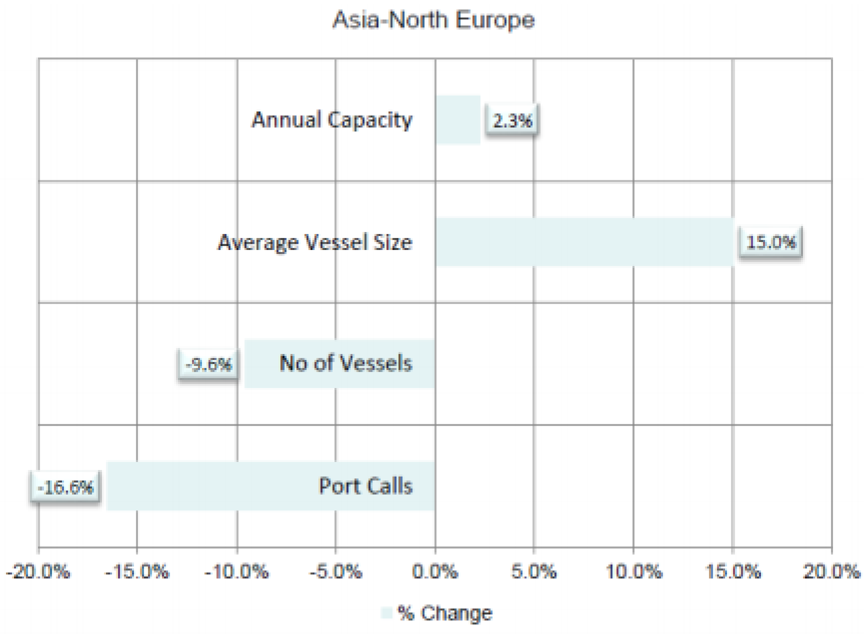


Figure 2-19 Service impacts of larger vessels on Asia-North Europe Route

Source: Rothberg (2014)

Cullinane and Khanna (1999) argues that economies of scale in large containerships can be obtained by the use of increasingly larger containerships. It can be noted that the latest generation of ULCVs consume less fuel than some first generation of ULCVs (14,000 – 16,000 TEU). Merk (2015a) represents that the relationship between speed, and propulsion consumption patterns of the vessels in Figure 2-20.

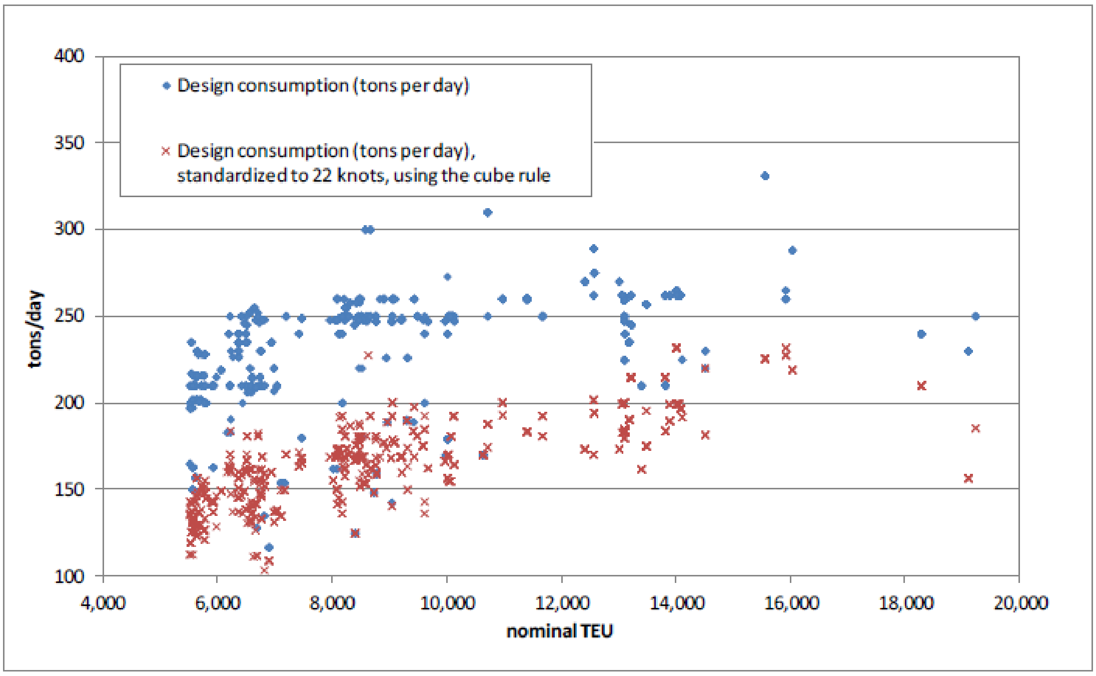


Figure 2-20 Propulsion consumption as a function of ship capacity

Source: Merk (2015a)

A conducted study shows that to be player of the container port competition depends on making essential investments in the infrastructural improvements to increase port operational capability and efficiency (Lane and Moret, 2014). The operational requirements from container ports have changed due to steady dimensional growth in the container vessel size. Lane and Moret (2014) represent some numerical information about the relationship between the growth in vessel size and the impact of growth on port operations in Table 2-8. WorldBank (2007a) also notes that "There are no technical reasons preventing containerships from getting larger, so economic and strategic considerations will be the source of any barrier". For the next generation, several experts report that it is likely to see ship length increase dramatically, they could carry about 24-25,000 TEU (Rodrigue et al., 2013, Rothberg and Sisson, 2013, Hacegaba, 2014, Lane and Moret, 2014, Tiedemann, 2015).

Table 2-8 Relationship between vessel size and operational efficiency on container ports

Year	Loading Capacity (TEU)	LOA (M)	Beam (M)	Draft (M)	Moves/ Rotation	Ports	Moves/ Port	Moves/ Meter	Increase	QCs	Moves/ QC	Meter/ QC	QC MPH	Port Days
1974	2400	239	30	11.5	6813	9	757	3.2	-	3	252	79.7	28	3.4
1981	3600	267	32.3	11.5	10219	9	1135	4.3	34%	3.5	324	76.3	28	4.3
1988	4800	294	32.3	13~14	13626	11	1239	4.2	-1%	3.8	326	77.4	28	5.3
1995	6600	318	42.9	13.5~14	18735	11	1703	5.4	27%	4.2	406	75.7	28	6.6
2001	8724	352	42.9	15	23991	11	2181	6.2	16%	4.5	485	78.2	28	7.9
2006	15500	397	56.5	16	42625	11	3875	9.8	58%	6	646	66.2	28	10.6
2013	18000	400	59	16	49500	11	4500	11.3	15%	6.5	692	61.5	28	11.3
2020	24000	456	63.9	-	66000	11	6000	13.2	17%	7	857	65.1	28	14.0

Source: Adapted from Lane and Moret (2014)

The benefits from economies of scale can be increased with increased cargo handling productivity that reduces port time Therefore, it can be said that ports can strengthen their position in the competition with the impact of increasing port productivity on voyage cost per TEU. While the ports are yielding from the increasing container vessel size, additional gaining would also be obtained with the port productivity increase as seen in Figure 2-21. Thus it is not improper to say that ports functionality in terms of handling larger vessel with the improved productivity can gain advantageous in the container port competition according to competition environment and strategy.

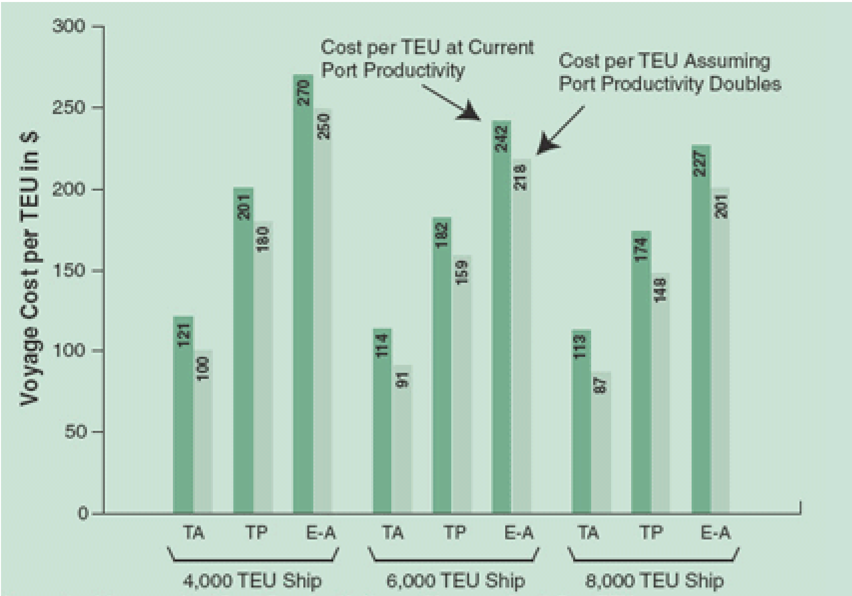


Figure 2-21 Impact of increasing port productivity on voyage cost per TEU

Source: Cullinane and Khanna (1999)

The changing technology requires expanding the use of IT by port users in order to provide easy accessibility to the system with the aid of provided electronical link between port administration, terminal operators, truckers, customs and other members of the port community (WorldBank, 2007a). This electronic link between port users can be drawn as in Figure 2-22. IT systems provide to manage the cargo process from ship arrival or before to final paperwork completed and container leave the port by reducing time consuming, manpower and increasing port productivity and efficiency thanks to improved planning and coordination among port users in the port network. It is expected by users that ports to be keep pace with IT to support information to them, so ports will have advantageous position in the competitive container transport market.

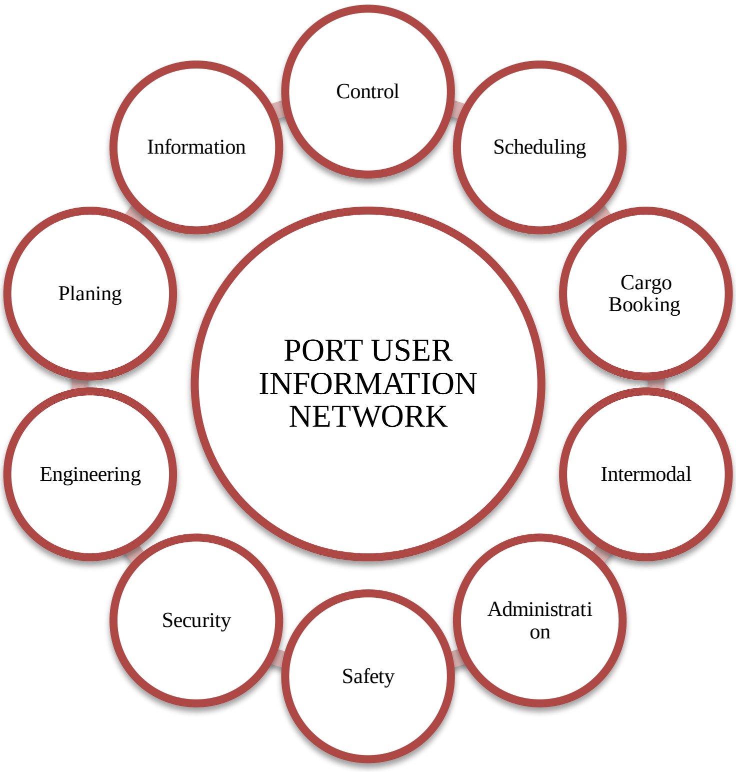
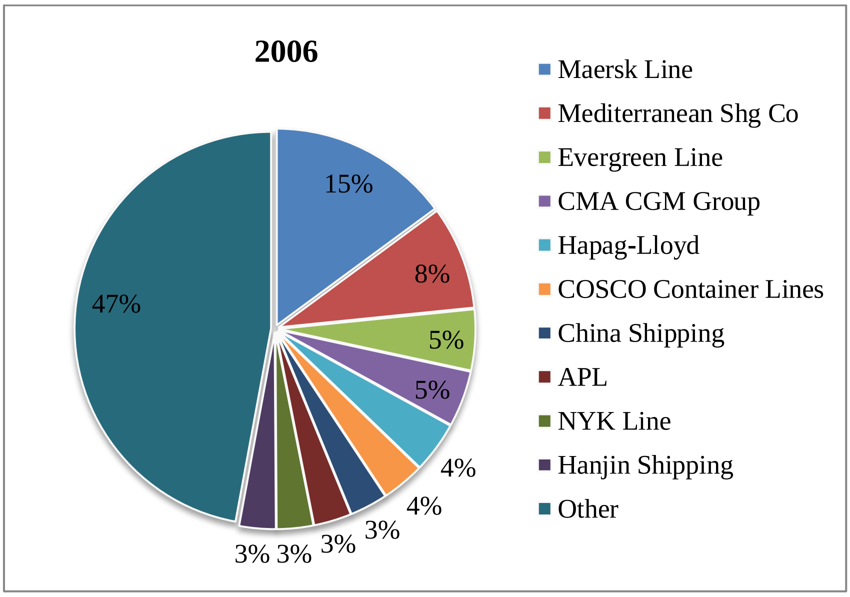


Figure 2-22 Port user information network

Other new technologies can potentially strength the position of port in a container port competition. Introducing offshore port technologies can be an example for the improvement of port competitiveness position by providing additional port capacity with deep water opportunity, by allowing shore port to remain in deep sea container port market, and can spread the benefits by acting as a regional hub, serving several smaller terminals on land (Rowland, 2015, Lyridis, 2015).

2.5.2.3 Shifting Bargaining Power

In the container port sector, negotiations are generally made among major parties such as ocean carriers, port authorities and terminal operators. Here, the position of port in the container transport market depends on how the port meets the users' requirements. The trumps of negotiation parties are addressed in two type: first is the ocean carriers alliances which produce important bargaining power due to high volume container carrying capacity, latter is that global terminal operators have negotiating strength against demands of individual terminal users (WorldBank, 2007a). Figure 2-23 demonstrates the changing market share of leading container carriers (WorldBank, 2007a, Alphaliner, 2017). It can be deducted that the bargaining power of leader ocean carriers has been increasing due to their huge amount of carrying capacity; i.e. it can be said that Maersk's bargaining power increased in parallel with doubled carrying capacity in 10 years.



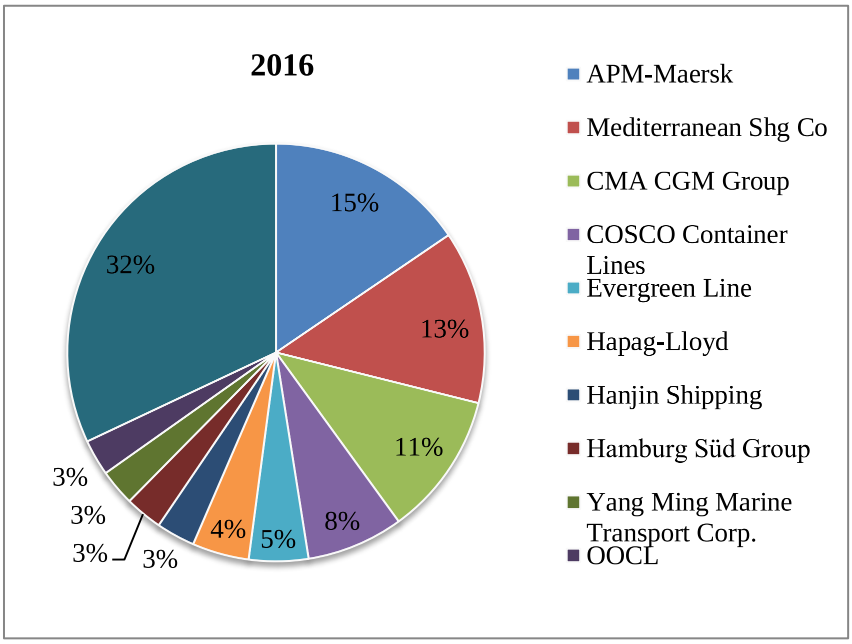


Figure 2-23 Top 10 container carriers as of June 2006 vs June 2016
Source: Adapted from studies of WorldBank (2007a) and Alphaliner (2017)

While the container shipping witnesses the fierce competition among ports to attract the ocean carriers, the global terminal operators competes to take the largest share of global container port throughput which is expected to exceed 840 million TEU by

2018 (PortTech, 2014). Good acceleration in traffic drives the competition, and encouraging new players to enter the sector or existing player to make investments with the impact of strong profitability performance of port operations.

Table 2-9 gives the changes in TEU throughput by main global container terminal operators and their market share (WorldBank, 2007a, UNCTAD, 2014, Drewry, 2016). During the given six years, the container throughput increased more than 50% and this may represent some investment opportunity to keep pace with the increasing demand and to strength competitiveness position.

Table 2-9 Top 10 terminal operators 2006 vs 2012 (TEUs and market share)

	2006			**2012**		
Ranking	**Operator**	**Million TEU**	**Share (%)**	**Operator**	**Million TEU**	**Share (%)**
1	Hutchinson Port Holdings	33.2	8.3	PSA- Singapore Port Authority	50.9	8.2
2	PSA- Singapore Port Authority	32.4	8.1	Hutchinson Port Holdings	44.8	7.2
3	APM Terminals	24.1	6	APM Terminals	33.7	5.4
4	P&O Ports	21.9	3.3	DP World	33.4	5.4
5	DP World	13.3	2.5	COSCO	17	2.7
6	Evergreen	11.5	1.7	Terminal Investment Ltd.	13.5	2.2
7	Eurogate	11.4	1.6	China Shipping Terminal Development	8.6	1.4
8	COSCO	8.1	1.5	Hanjin	7.8	1.3
9	SSA Marine	6.7	1.4	Evergreen	7.5	1.2
10	HHLA	5.7	1.3	Eurogate	6.5	1

Source: Adapted from studies of (WorldBank, 2007a, UNCTAD, 2014) and (Drewry, 2016)

Notteboom and Rodrigue (2012) note that the global terminal operators are controlling large multinational terminal assets, and the study also examines the global terminal operators' operational involvements in the container sector and their investment strategies in terms of geographical alignment in the changing transportation trends.

There are strong links between the ocean carriers and the global terminal operators such as APM terminals and APM-Maersk, Evergreen terminal operator and Evergreen Line, and China Ocean Shipping Company (COSCO) operates its terminals through COSCO Pacific and COSCO Container Lines Company. Thus, the strategy of companies aims to operate terminals with supports of their liner companies to enlarge their presence in container ports.

At this point, the location choice becomes strategically more important rather than specific port choice to improve the competitiveness power at a certain area. Thanks to the co-operation among ocean carriers and global terminal operators, strategic and financial investment decisions are applicable as acquisition and/or transfer of operating rights of an existing port or new port building if the geographical orientation is obtained in accordance with operators` investment strategy.

2.5.2.4 Changing Distribution Patterns

Transferring container with onward service to outlying locations with the aid of a regional and local hubs network is greatly seen distribution pattern in container sector. The container carriers offer transhipment service when a direct call cannot be justified with main route ships. The interchange of containers is also applied between liner companies at strategic hub ports without abandon the schedule. The hub and spoke container distribution system is applied for more efficient container transport thanks to fine-meshed container transport network all around the world.

Veldman and Bückmann (2003) note that the increasing intermodal points and high connectivity index of ports lead to the increase in route options with aid of transhipment operations. Veldman and Bückmann (2003) present a model to explain market shares of ports in the transhipment system. This model is used to determine the routing choice of users for the forecasting port traffic so the economic and financial framework can be drawn for the container port project investments.

It can be also argued that there is a relationship between the routing alternatives and the connectivity index of ports in the selected container transport network for forwarding containers. Therefore, it is expected that the connectivity index of a hub port should be high if it act with a strategy of performing hub port patterns.

Hoffmann (2012) developed a Liner Shipping Connectivity Index (LSCI) model to capture and follow the connectivity levels of countries and thereby ports. It can be said that the desire to keep pace with the fierce container port competition can be achieved by turning into advantage its strong points such as location, capacity, port performance etc. with higher connectivity links to its own and other regions. The changing distribution pattern make hub and spoke container distribution system more attractive so ports can establish a market presence, of course thanks to take a place at well-connected point.

Imai et al. (2009) carry out a comprehensive study for multi-port versus the hub and spoke calls by containership. It obtained results shows that the hub and spoke is more advantageous for the European container distribution system in terms of cost while multi-port distributions have been expecting to be superior.

Asgari et al. (2013) investigate the competition and cooperation among three parties two main hub ports, Singapore and Hong Kong, and the ocean carriers to develop a game theoretic network design model. As a conclusion, horizontal, vertical and full cooperation are observed and the cooperation is suggested as a potential substitution for competition. It means that the changing distribution patterns require cooperation rather than competition for the consolidation of container transport network. However, it cannot be denied that the competition will be always existed between ports to take more advantageous place in the sector.

2.5.2.5 Environmental and Safety Concerns

Some approaches and actions can guide the ports to take more advantageous position in the fierce container port competition towards lower emission of greenhouse gases and air pollutants, and in general terms to be more sustainable port (Abood, 2007). Ports face environmental problems shaped around certain criteria, although environmental and managerial assessments of each port depend on their own characteristics. Many recent studies (Bailey and Solomon, 2004, Darbra et al., 2005, Autry et al., 2013, Chiu et al., 2014, Hiranandani, 2014) have addressed the following issues:

- Energy conservation,
- Air quality,
- Water conservation,
- Dredging and disposal of dredge materials,
- Management of hazardous substances,
- Ballast water control,
- Habitat.

As other organisations, ports could upgrade their competitiveness through enhancing their green performance in order to be compatible with eco-friendly regulations (Bacallan, 2000). Yang and Chang (2013) also note that the competitiveness can be upgraded as depending on eco-friendly port design in coordination with their locations, promote high productivity, enhance mass trading, improve general framework, and provide a connection to the community. In this context, some measures can be taken in accordance with the procedure aimed at increasing efficiency and reducing redundant source usage by applying measures on material selection, water consumption, energy usage, general waste handling, hazardous waste handling, habitat quality and greenery, community promotion, and education, as well as port staff training (Autry et al., 2013, Chiu et al., 2014).

However, in terms of competitiveness, the reduction of energy usage from shipping by port activities can be considered more important issue due to regulative activities adopted by the agents of shipping sector. Some regions have been defined under MARPOL Annex VI as Emission Control Area (ECA) which are required change over to use of low sulphur fuel oil (LSFO) for general steaming, and also two existing SECA's are defined which are namely the Baltic Sea Area and North Sea including the English Channel for SOx limit. The existing and future ECAs under consideration are represented in Figure 2-24.

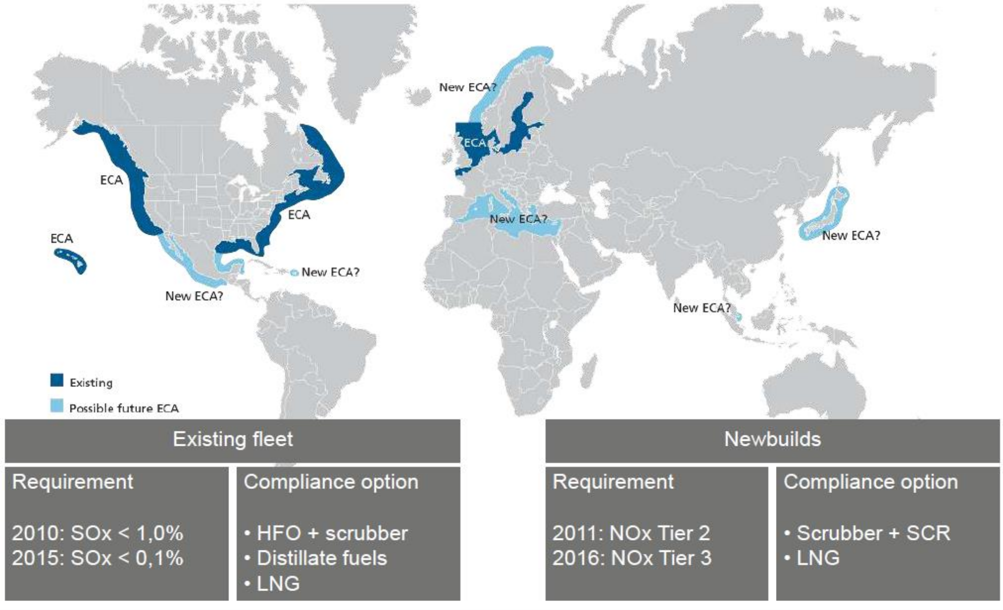


Figure 2-24 Emission control areas

Source: IMO (2011b)

The port competition in ECAs has different competition conditions due to the regulations on gas emissions from ships. In ECAs, if the ports can supply cleaner fuels for the suitable vessel, then the ports may have stronger role in the competition in terms of environmental perspective. Skramstad (2013) suggests that LNG is the most attractive fuel type among other proposed alternatives to meet the requirements of ECAs.

With regard to the impact of fuel supply advantageous on the port competitiveness, Acosta et al. (2011) note that fuel supply and location are the two main advantageous of ports to be chosen by shipping companies. For example, the other port performance factors are considered later than bunker and geographical advantages of the ports at Gibraltar Strait due to strategic location of them.

In operation stage, the impact of ports to reduce gas emissions can be considered by introducing some programmes and policies to address gas emissions. Winnes et al. (2015) conduct a study to analyse potential gas emission reduction from ships under favour of measures applied by ports. Various types of measures are identified and the performed case study shows that a potential for reduction of GHG emissions from ships in ports. When ports are considered at the operational part of taken measures for the emission reduction, the ports can have a significant role with the impacts on emission reductions due to the feature of operational measures as low investment cost and applicable to all ship types (Eide et al., 2011). The fulfilment of emission reduction can be achieved with the strong coordination between ships and ports. Faber et al. (2012) address the relationship between ships and ports in terms of slow steaming which gains importance within the port area by reducing speed 10% can succeed the reduction in fuel consumption up to 27%.

As it is reported by World Bank (2007a), the Port of Los Angeles/Long Beach launched a program to reduce harmful emissions of diesel particulate matter (DPM), nitrogen oxides (NOx) and sulphur oxides (SOx) by cutting speed of ships to 12 knots or less within 20-mile radius of the port in 2005. Since 2005, thanks to the applied program to reduce harmful emissions from port-related vehicles including ocean-going vessels, heavy-duty trucks, harbour craft, cargo-handling equipment and railroad locomotives; the port has achieved to cut diesel particulates, nitrogen oxides and sulphur oxides by 81, 54, and 88 percent through 2012 (POLB, 2016). Also another pilot project has been launched under the partnership between the ports of Los Angeles and Long Beach and APL to reduce harmful emissions from auxiliary engines of containerships (Mongelluzzo, 2011). Thus it can be seen the importance of port to create a response for the environmental concerns and also the ports can improve their competitiveness by courtesy of strategic partnerships with leader container carriers.

Another approach to create more energy efficient port operations, ports publish their own port energy management plans to get action for short-term, medium term and long-term (POLA, 2014). Ballini (2017) notes that energy management strategies of ports aim to maximise profit and minimise costs by improving energy efficiency, reducing energy use and cost with monitoring system and management strategy. The Port of Los Angeles builds the energy management action plan on five port energy pillars to improve energy management in support of continuity and competitiveness of port operations (POLA, 2014).

The relation of ports with energy efficiency can be divided into two main categories. While the initial is to be enabled by reducing air emissions in port facility, the latter is about the reduction of ship-related emissions. The air emissions in ports are depending on activities which are originated by equipment used for cargo handling and from building facilities. They can be achieved with adaptation green-technology, eco-friendly equipment usage, and the environmentalist design approach for buildings. In terms of "green" and "eco-friendly" container terminals, automatic guided vehicles and transtainers with electric engine may offer less GHG emissions depending on less energy usage (Yang and Lin, 2013). It can be said that there is need an investment based improvement of energy efficiency.

However, increasing the energy efficiency of overall maritime transport system depending on how efficient the ship-port interface is provided, and at this junction port authorities or terminal operators face the complexity of port management. Modern ports are more multifaceted so different operations are carried out by different actors. The main actors and other service providers, which have different roles in a conventional container port structuring, are presented in Figure 2-25.

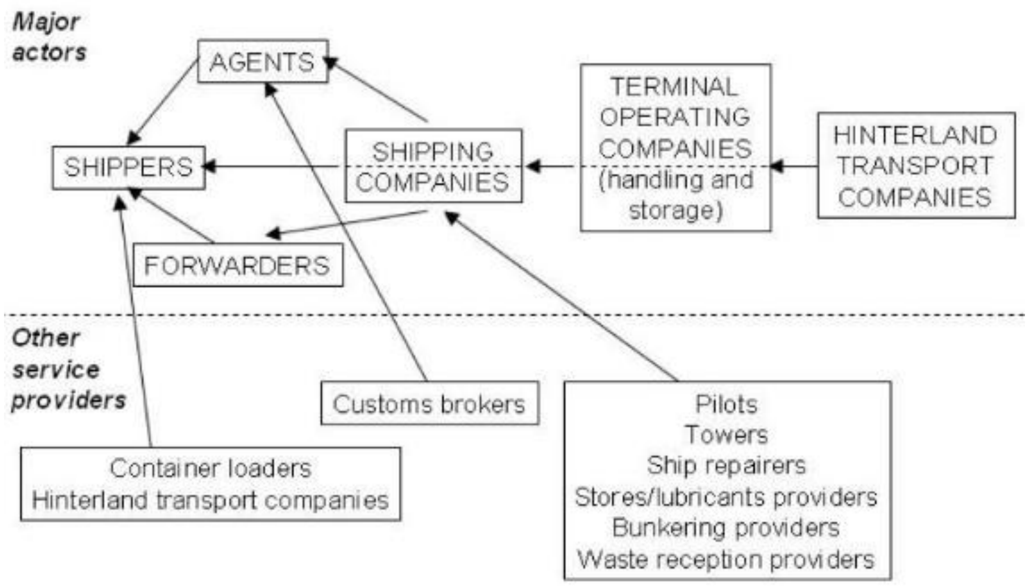


Figure 2-25 Major actors of conventional ports

Source: Van de Voorde and Vanelslander (2009)

The ship-port interface is a topic that discussed by IMO commissions to develop technical measures in a systematic approach. They are categorized as equipment measures, energy measures and operational measures (Bazari, 2016). Although numerous technical measures are developed to enable energy efficiency in the range of from crane systems to alternative fuels, it is obvious that there is not only one measure for all cases.

Nervale (2010) identifies 2 goals in the working field of energy efficiency and ship-port interface. According to the goal 1, the documentation of cargo would be carried out through streamlining and standardization; and the use of electronic system can create an intelligence to improve energy efficiency. On the other hand, the goal 2 is to keep all components in the maritime transport system in a holistic operational energy efficiency concept.

In the perspective of operational approach, the container shipping companies requires to depart their vessel at the expected time according to their schedule. For this target, the expectation from ports is just-in-time operations and to reduce the ship`s idle time as far as possible. It is obvious that the containerization has brought a successful transport method by reducing port time. In 1985, a comparative study by Stopford (2009) found that a containership can reduce port time at level of 17% of its time while a general cargo liner vessel is spending 40% of it. However, the growing vessel size has undesirable impact on the ship`s port time. One study by Banks et al. (2013) examine the trend in container shipping for understanding ship operating profiles and it is obtained that the duration in port has over 30% of total voyage time as given in Figure 2-26. Therefore, the proficient port operations are critical to improve the energy efficiency of whole system which can defined as ‘door-to-door’ transport.

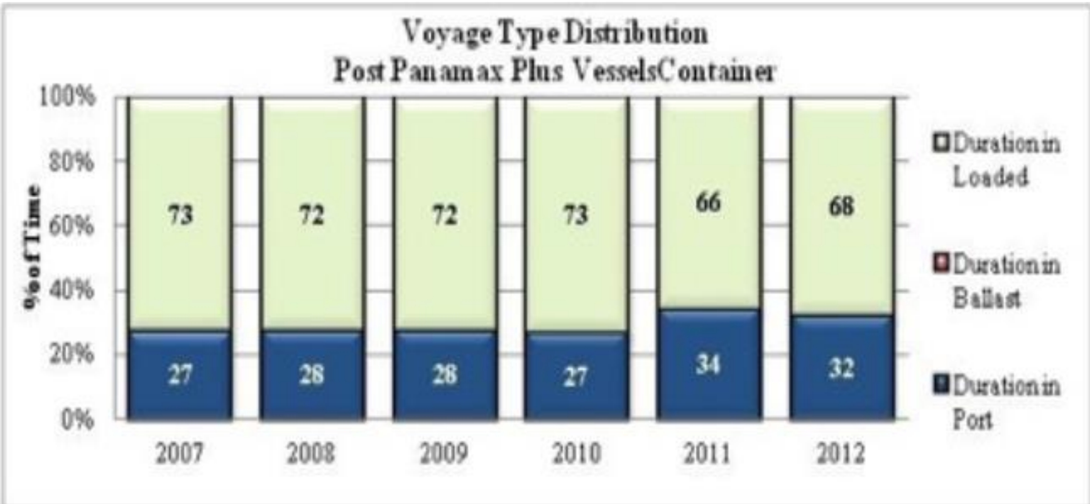


Figure 2-26 Vessel time distribution for the case of container vessels

Source: Banks et al. (2013)

The duration in port does not represent the spent time in a single port, it represents the cumulative port time of whole journey. With regards to the port stage within whole transport system, the purpose is to reduce the overall port time with the maximized productive time while all other unproductive times are reducing as the identified times in a port represented in Figure 2-27.

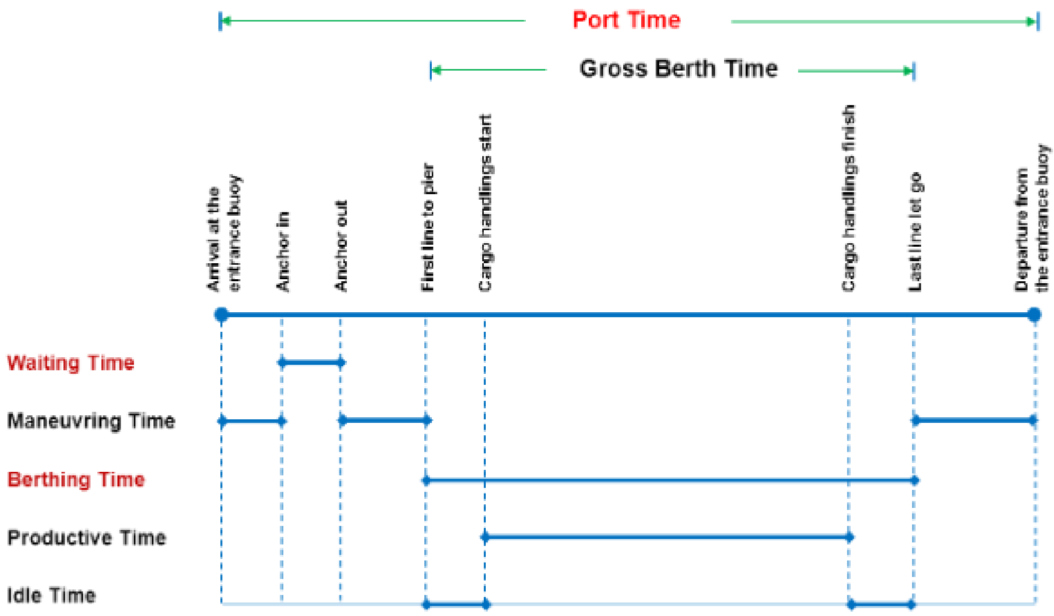


Figure 2-27 A ship`s port times

Source: Bazari (2016)

There are some port related services out of ship loading/unloading activities and they have also impacts on ship's port time. They cover pilotage, towage, mooring, vessel traffic service (VTS), documentation and other supporting services. As associated with all services together, the management of port operations is being more complex and, there is a need a good port management system to be able cope with this complex process (Bazari, 2016). According to IMO's Train the Trainer (TTT) course document, the ship's waiting time in port at any operation stage can be avoided with the measures of improved port management, virtual arrival, and improved cargo handling (IMO, 2011a).

On the other hand, it is worthwhile to mention about safety concerns and also security concerns at the container ports. It is required that ships have to be issued with valid certificates to comply with international standards for safety pollution prevention, and shipboard living and working conditions. However, the strictness and accuracy of inspections, which are carried out by port states, may cause to change the routes of substandard ships, and so the ships may choose ports with lax of inspection procedures in the same region. The enforcement practice can affect the competitiveness of ports because ports enforcing inspections without comply with international standards creates unfair competitive advantage (WorldBank, 2007a).

The other aspect of safety concern is the content of carried goods. It can be argued in the context of elimination of this concern by inspection and screening containers. Glauser (2015) defines the main concerns as terrorism and smuggling. He argues that these concerns affect the country economy negatively due to the dangers can threaten home security via ports on shore. Therefore, the offshore ports are proposed due to advantages:

- Ability to scan up to 100% of inbound freight away from critical infrastructure, screening integrated into freight movement process,
- Ability to match up electronic manifest with scan data to,
    - Aid in customs,
    - Tariff collection,
    - Provide an operator aid to reduce false positives/negatives.
- Aids Law Enforcement.

The critical objective of container scanning and inspection is to do with minimal investment during high-risk phases without significant adverse economic impact on the port competitiveness (Glauser, 2015). Ramirez-Marquez (2008) sees the container inspection on US ports as essential and in his study, port-of-entry safety via the reliability optimization of container inspection strategy is analysed in terms of minimizing the total cost of inspection while maintaining a user-specified detection rate for “suspicious” containers.

From the another perspective, Fabiano et al. (2010) carried out a study on the port operational safety which is affected by human factor and occupational accidents. The changing port infrastructure with the impact of containerization has involved a modification within the work organization which reduced the human-intensive operations hence the number of employee. However, Fabiano et al. (2010) notes that low experienced workers cause a significant increase of the occupational injuries risk. Herein, it can be clearly seen that the evolution of operational safety will be provide competitiveness for port with smooth functioning of ports depending scot-free operations and the increase of port performance thanks to experienced workers with safety awareness. In the situations that a large number of companies use same port or terminal creates more complex human, operation and risk management, and hence more complex port competitiveness which is called inter-port competitiveness.

2.6 Game Theory

The applied method falls within the game theory domain that is a strategic decision-making application for the studies of human conflict and cooperation within a competitive situation. Game theory is also a very complicated theoretical study of strategic decision making between independent and competing actors; two or more players; in a strategic setting (Aumann, 1989). In 1944, the publication of American mathematician John von Neumann and Oskar Morgenstern, “Theory of Games and Economic Behaviour”, had a major impact on strategic decision making mechanisms (Von Neumann and Morgenstern, 2007). John Forbes Nash is known as the pioneer of equilibrium point in n-person games and Nash’s non-cooperative game analysis was a milestone in game theory (Nash, 1950). The issue of strategic decision making has received considerable critical attention. Therefore, game theory has been used as an object of research since the 1970s. However, in real terms, the theory found significant impact and attention from academia after the Nobel Prize awards gone to John Harsanyi, John F. Nash and Reinhard Selten for their pioneering analysis of equilibria in the theory of non-cooperative games in 1994 (Harsanyi et al., 1994).

The game theory is applied to envisage outputs in a transaction by taking consideration of various elements including gains, losses, optimality and personal behaviours with mathematical formulas and equations. The basics of game theory should be known for the formal application (INVESTOPEDIA, 2016). The basics are:

- The identity of independent actors,
- The preference of actors,
- What the actors know,
- Which strategic acts the actors are allowed to make,

- To know the influences of each decision on the outcome of the game.

According to the application area of the game theory, various other requirements may be required. In general, the usage area of game theory includes very wide range of sectors including psychology, evolutionary biology, war, politics, economics and business, especially thanks to implementations in experimental economics; the theory can be tailored to test economic theories in real-world economy applications (Gibbons, 1992). The theory can also be applicable for the container port competition strategic decision making.

The game theory can be analysed in terms of these situations, techniques and game forms. The themes identified in these responses are presented in Figure 2-28.

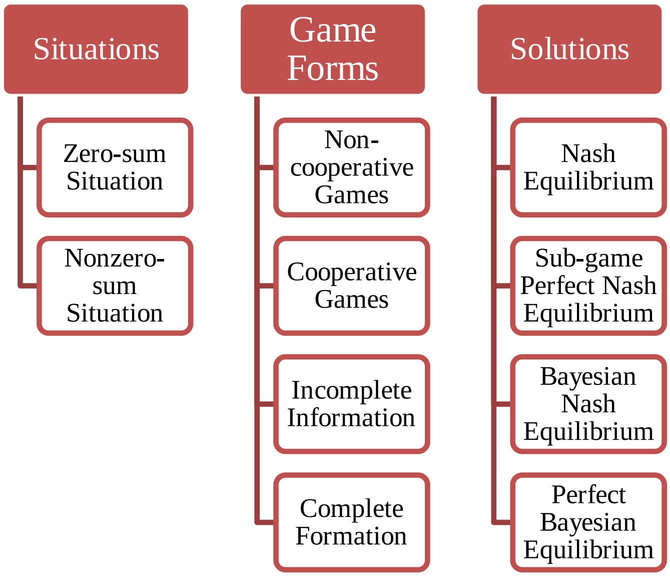


Figure 2-28 Types of game situations, forms and solutions

It is necessary here to clarify exactly what is meant by situations, techniques and forms in the theory. So it can be mentioned two situations in the theory. They are sum-zero and non-sum-zero situations. In financial view, contract negotiations can be considered as zero-sum situation, while a party gains on a contract, there is a losing counter-party. Gelbaum (1959) analyses symmetric zero-sum n-person games mathematically to provide contribution to the basis of game theory. On the other hand, Cournot Competition (Cournot and Fisher, 1897), Prisoner's Dilemma (Rapoport and Chammah, 1965) and Centipede Game (Rosenthal, 1981) are known as the most popular game theory strategies of nonzero-sum situations.

When looked into game forms, the player can be described as the basic entity in all game theoretic models. A player can act as an individual or as a group of individuals making a decision. Thus the individual players are referred to as non-cooperative, while in the later model the players interpreted as a group and that type of games is referred as cooperative (Osborne and Rubinstein, 1994).

Xu et al. (2015) discuss the non-cooperative game and the cooperative game on the income in terms of container port alliance. In the study, the non-cooperative game is described as the strategy selection problem while the cooperative game is about income distribution problem.

Tirole (1988), Gibbons (1992) and Phlips (1995) discuss the games in four classes as derivatives of static and dynamic forms in complete and incomplete information sets. According to form types, the static form based on single move of each player simultaneously while the dynamic games represent sequential moves of players. The games are also faced in non-cooperative and cooperative game forms with symmetric or asymmetric player alternatives. In game theory, four solution concepts have been developed as their characteristics are represented in Table 2-10.

Table 2-10 Characteristics of game theory solution concepts

	Nash Equilibrium	Subgame-perfect Nash equilibrium	Bayesian Nash equilibrium	Perfect Bayesian equilibrium
Introduced by	John F. Nash	Reinhard Selten	John 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	Baye's rule	Sequential rationality based on updated beliefs
Information set	Complete	Complete	Incomplete	Incomplete

Source: Shi (2011)

The Nash equilibrium can be defined as a concept of game theory which offers one optimal outcome for the game. It means that the players take the best decision, and there is no incentive to deviate from the strategic decision, and to gain incremental benefit from changing strategic position is not possible with each player considering others' strategic decision. A subgame perfect Nash equilibrium can be defined as an improved version of Nash equilibrium to apply mostly in dynamic games (Osborne, 2004). This solution concept is designed as subgames of the original game and containing a sub-set of all available choice in the main game, and they are handled as Nash equilibrium within themselves so they will have a subgame perfect Nash Equilibrium strategy (possibly as a mixed strategy giving non-deterministic sub-game decisions) for the games with complete formation (Harsanyi and Selten, 1988). Bayesian game is described by Harsanyi (2004) as a game with incomplete information on the other players. Thus, the players focus on the known probability distribution. The reason of called as Bayesian is that probabilistic approach to analysis other players' positions due to imperfect information scenarios. The other given equilibrium is a perfect Bayesian equilibrium in which the player's action depends on the history of given information-set. The perfect Bayesian equilibrium can be described as a refinement of Bayesian Nash equilibrium and subgame perfect equilibrium combination within strategy and belief components (Fudenberg and Tirole, 1991). The strategy and belief should also satisfy sequential rationality and consistency.

As is widely appreciated, for example, oligopolies present multi-player problems - each firm must consider what the others will do. As a footnote, in this thesis, container ports are assigned as players of game theory. At the micro level, intra-port competition (models contain terminals as players) involve game theory. At an intermediate level of multi-port gateway region competition include game-theoretic models of the behaviour of multi-ports for their capacity throughput in their region in holistic perspective. Finally, at a high level of aggregation, ports in a certain range includes models in which ports compete in choosing tariffs and other trade policies, and macroeconomics includes models in which the port authority and cost or price setters interact strategically to determine the effects of economy policy.

This thesis is designed to analysis container port competition on basis of game theoretical methodology to those who will later construct game-theoretic models in applied cases within container transportation industry. The exposition emphasizes the container port competition applications of the theory with the involvement of offshore systems at least as much as the pure theory itself, for three reasons. First, the applications help understand the theory. Second, the applications illustrate the process of model building game-theoretic problem to be analysed. Third, the variety of applications shows that similar issues arise in different areas of container port competition, and that the same game-theoretic tools can be applied in each setting. In order to emphasize the broad potential scope of the theory, conventional applications from industrial organization largely have been replaced by applications from price, cost, operational capability and flexibility, and other applied fields in offshore system adopted container port network competition.

2.6.1 Game Theory Applications in Container Ports Competition

It can be considered that game theory is a struggle of players in a generated game to gain maximum benefit at the end of game against other players or by moving in cooperation with other players. The competition environments can be noted as important application fields of game theory. Therefore, the container port competition can be identified as a field in where game theory can be applied.

In many field, game theory is applied to help decision makers understand the strategic phenomena that can be observe when other decision makers in a game interact according to changing strategic positions.

Many researches have utilised game theory to measure competitiveness of container ports in different level and criteria. A number of game theory solution techniques have been developed to examine the container port competition. In the game theoretical competition analysis, the use of qualitative case studies is a well-established approach.

Anderson et al. (2008) develop a game theoretic analysis model to understand investment and competition positions of the major South Korea (Busan) and China (Shanghai) ports. The model is developed on the strategy of serving as a hub port by building deep-water berths with supported large terminals to accommodate large container vessels and facilitate necessary transfer operations. It is aimed how the ports will be able to capture or keep the share in market with the changing competition dynamics.

Similarly, Ishii et al. (2013) examine the case of inter-port competition between the major container ports of Busan and Kobe cities. The game theory model is constructed on a non-cooperative game with a Nash equilibrium solution concept for port charges to examine the effect of capacity expansion on the port charges and hence the competition between the chosen major ports in the case study.

Saeed and Larsen (2010) argue the positions of container terminals in Karachi Port in Pakistan if they keep their singleton position or decide cooperation in a coalition to port operations. In the study, a two-stage game modelled for the analysis of intra-port competition as first stage and the analysis of competition between terminal coalition in Karachi port and outside competitor by applying Bertrand game as second stage of model. The obtained results say that the grand coalition among terminals in Karachi port enables the best payoff for all players in the game theoretical model.

Another conducted study by Kaselimi et al. (2011) investigate the competition between multi-user container terminals. The focus of study is on terminal management systems in two different frameworks which are the port authority and the private terminal operators based port management. In the generated framework, Cournot competition is applied and the results give chance to compare the impacts of fully dedicated terminals on container port competition between multi-user terminal management systems.

Game theory is also applied for the analysis of appeared competition due to specialization of ports on cargo types. Zhuang et al. (2014) carry out a study on China port industry competition which escalated with the effect of growth in Chinese economy and international seaborne trade. With the decentralization regime in port managements, some changes have been seen in the strategic positions and operational decision-making capability of Chinese ports and thus ports became freedom for making investment. This study investigates the role of ports in the developing competition environment according to decentralization regime by applying duopoly games for the ports which are specialized in containerized and dry-bulk cargo. As a result of game theoretical competition analysis in China port industry, specialization may cause overcapacity in overall due to ports' local strategies so the author suggests the government coordination and intervention to strength the competition position of ports.

Zhang et al. (2009) analyse the behavioural impacts of participants in decision mechanism on container port competition with the aid of bi-level game theoretical model. The analysis is carried out with an equilibrium problem with equilibrium constraints (EPEC) model for non-cooperative container port competition. The model is validated by comparing Shanghai Port and Ningbo Port price strategies for container transportation to California destinations via Port of Long Beach and Port of Oakland. Thanks to a game theoretical model, scientific base of the transport benefits of the network is provided.

The study of Seo and Ha (2010) can be considered as one of the most interesting and maybe the most relevant studies in terms of the ever-increasing containership size and the approach of this thesis. In the study, the role of port size and incentives are investigated from the perspective of port users' strategic port selection decision. The investigation is carried out by applying a game theoretical model to address port competition in order to attract port users to select their ports with their port size and incentive advantages.

In 1994, a game theory based study in economics field was awarded the Nobel Prize. This increased the popularity of game theoretical model and their applications in other study areas as well. As it is also seen in this section, in recent years, game theory models are commonly commenced to use as a method in port competition problems and port users' port and terminal selection problems which are handled in different approaches. However, none of published academic research to date examined the influence of offshore ports on container port competition with the aid of any scientific methods including game theory. This situation is obtained as a result of toilsome and detailed literature review.

At this point, in methodological perspective, it is aimed to discuss likely to be new competition dynamics thanks to the integration of offshore port structures with the existing container port competition.

2.6.2 Game Theory Competition Models' Comparison

In this section, the three competition models which are the Bertrand model, the Cournot model and the Stackelberg model, will be compared. Basically these three models differ in two concepts: (1) The timing of the competition movement; and (2) what the competition is for. The concept differences can be defined for each model as follows:

- The Bertrand Model: What situation can be faced when firms (can be referred to herein as port or player) compete simultaneously on the price of homogenous service,
- The Cournot Model: What situation can be faced when ports compete simultaneously on the quantity of output, they produce of a homogeneous service,
- The Stackelberg Model: What situation can be faced when ports compete sequentially on the quantity of output, they produce of a homogeneous service.

2.6.2.1 Bertrand Competition

The Bertrand competition model defines competition among players and this competition influences the price of the products or services of the players, and the users decide on the price of the specified product or service (Bertrand, 1883). If the ports offer a homogenous service and have to choose the optimal level of prices (P_i = price level of port i) for these services simultaneously, then the Bertrand competition model can be used to analyse the situation. The homogeneous service means that the port can offer operational services for the same cargo and ship types through similar technical features. The model has the following features.

- There are at least two firms that produce a homogenous product and do not cooperate at all,
- Firms compete by setting prices at the same time, and consumers want to buy everything from a company and a lower price (because the product is homogeneous and does not have a consumer search cost),
- If the firms demand the same price, the demands of the consumers are equally divided,

- It is easiest to concentrate on the duopoly case where only two firms are present, although the results are valid for any number of companies more than one company.

2.6.2.2 Cournot Competition

The Cournot competition model is developed by Antoine Augustin Cournot as an economic model. Unlike the Bertrand competition model, this model is used to define the competition on the output of ports in an industry structure (Cournot and Fisher, 1897). In this model each firm independently determines its strategic decision for competition at the same time (Varian, 2014). In other words, it can be defined that the Cournot model is assumed as a one-period game, in which ports produce an undifferentiated services with a known demand curve. The ports compete by choosing their respective level of output simultaneously. Each port chooses quantity assuming their opponents' output is fixed. General features of this model can be given as follows:

- There are more than one firm and all firms have a homogeneous output, so there is no output differentiation,
- Firms do not cooperate, in other words there is no agreement,
- Firms have market power, that is, the output decisions of each firm affect the price of goods,
- A fixed number of companies is available,
- Firms compete in output amounts and select quantities at the same time,
- Firms act economically, rationally and strategically, often seeking to maximize profits when their competitors' decisions are taken into account.

2.6.2.3 Stackelberg Competition

The Stackelberg competition model offers a kind of leadership model. It is based on the principle that in the case of strategic competition in the economy, the decision of the lead player is to be decided upon then the strategic competition decision is taken by other players in the market after the strategic decision of leader player (Von Stackelberg, 1934). As in the Cournot model, the Stackelberg model assumes a one period game, and in which ports offer an undifferentiated service with known demand. Ports have to compete by choosing the amount of output q_i to produce, but unlike the Cournot model, one of the ports goes first. As with the other two competition models, some features of this model are described as follows:

- In terms of game theory, the players of this game are defined as the leader and follower, and the competition is done by the quantity of the product. In other words, this point is similar to Cournot,
- The leader must know in advance that the followers observes its action;
- The follower cannot act as to be non-Stackelberg in the future, and the leader should know it,
- Indeed, if the follower can be found in a Stackelberg leader's action and the leader knows this, the leader's best response is to act as a Stackelberg follower,
- Once moving gives an advantage, firms can take part as a player in the Stackelberg competition,
- In general, the leader must have the power of commitment. Acting as the visible first is the most obvious commitment: the leader cannot take it back after it has moved - it is determined for the action,
- Managing/holding excess capacity is another commitment tool.

2.7 Gap in the Field of the Study

In this chapter, a detailed literature search was done regarding the study. The literature review focuses on the history and development of the container industry, the examination of the economic, structural and operational characteristics of offshore port structures, the competition of container ports and finally the methodology to be used in this thesis.

In the first part of this chapter, it is understood that the containerization has brought considerable operational simplicity for the transportation facilities. With the help of the developing technology, an economic, efficient and easily operated container transportation operations can be carry out with ULCVs today. In parallel with the development of the container sector, significant developments are also seen in the port industry. They were in operational and structural change to serve container vessels in time. However, due to the growing ship lengths, the port authorities have plunged into a search for different solutions. Alternatively, one of the proposed solutions is OCPS. It is considered that ULCVs can be handled in open sea without dimensional constraints thanks to this system.

As a second step in this chapter, OCPS has been studied in detail in terms of the strategic and economic importance, the structural features and the operational characteristics. The first offshore structure in the literature is seen in the defense industry. It is usually possible to see offshore structures in the oil and bulk sector. But there are few offshore structure examples in the container sector, especially in port concept. There are some offshore port project planned to be made in the container sector, but there is not much academic work related to them. The existing literature is largely based on project-based studies or scientific quality is low. It can be said that the academic literature on the offshore container port system is inadequate.

Thirdly, the competition between container ports has been discussed in detail. The competition between the ports has been examined in detail at different levels by scholars, academicians, who can be described as the guru of the port sector. The academic studies on competition between container ports in the literature do not consider the offshore container structures as one of the players in these competitions. It would not be wrong to say that the structurally different offshore container ports can bring a novel understanding to the competition between container ports.

Finally, applications of game theory on the container port competition are examined. As known, the game theory is a method that has been developed over the strategic decision-making for competitive situations. It is examined in the previous section that the method has been used mainly for two-player container port competition analysis. Also the Stackelberg competition strategy, the leader game strategy, does not appear as a method of using for container port competitions.

Briefly, this research proposes an alternative offshore port structure to meet the requirements of the more sustainable handling of ULCVs, which are growing in parallel with the development of the container sector. However, the absence of much study in the literature related to this proposed offshore container structure can make this research an important resource for future studies. There is also an unknown in the literature regarding how the competitive environment develops as a result of the adaptation of offshore container ports to the inter-port competition. Through this study, a three-stage complex approach has been presented aimed at the determination of the components of competition and the positions of competitors through the developed analytics and game theoretic methodology of the 4-player container port competitions to which the OCPS is adapted.

3 METHODOLOGY

In this section, the methods regarding the game theory methods, the port construction elements for an offshore container port model design, and the mathematical methods to analyse container transportation network are given. Firstly, the game theory competition models' comparison will be represented. Secondly a model design will be examined to clarify the OCPS adapted inter-port competition. As a next step, Stackelberg competition model for four player game will be explained. Then, the mathematical formulas will be explained to analyse the container transportation network. Finally, Nash solution will be applied for the determined states.

3.1 Methodological Framework

The methodological framework generated is combining both operational and tactical decision making processes of the container port competition. Therefore, the mathematical steps generated in the methodology includes cost calculations of the players for each container port competition platforms, Stackelberg competition optimal capacity deployment and port handling fee mechanism, additional capacity increase or capacity reduction decision scenario building, and Nash solutions for the designed game. 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 Figure 3-1.

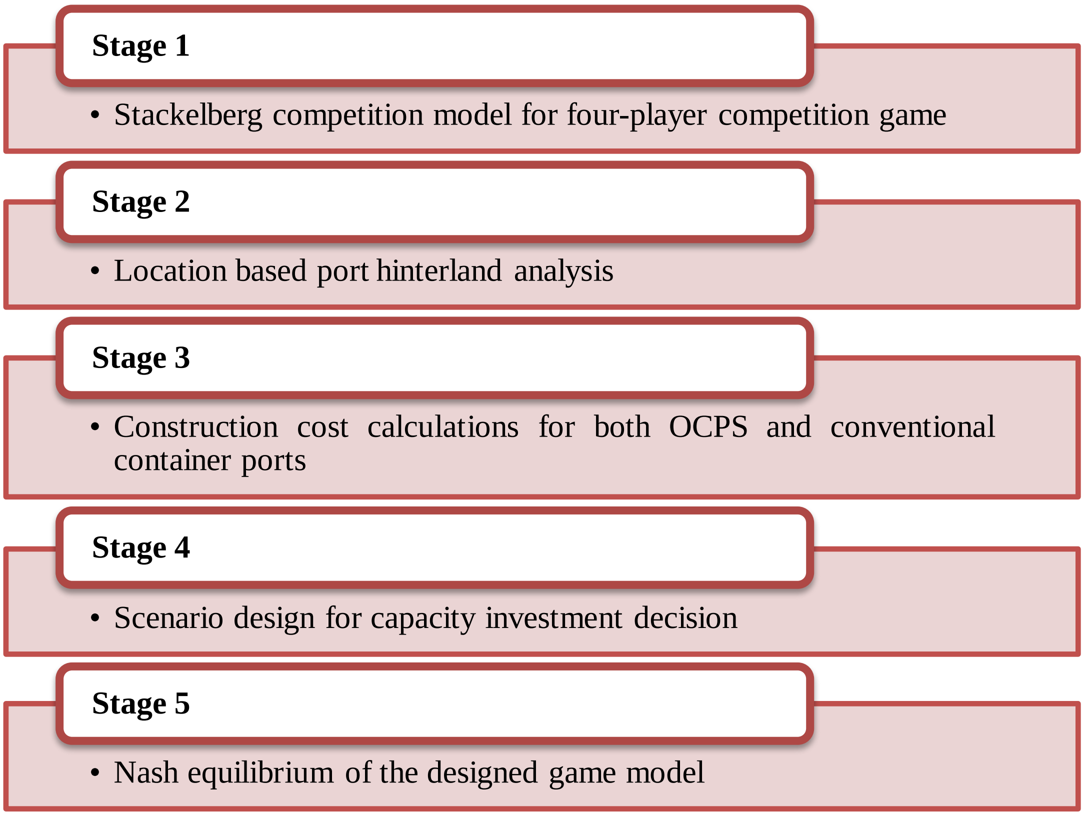


Figure 3-1 Methodological stages

3.2 Model Design for the Container Port Competition with OCPS

3.2.1 Model Description

The model designed in this study will examine the offshore ports in terms of performance indicators and network optimization and will try to compare the competitiveness with other rival ports with the aid of the designed game theory model. This model, which we can define as a port competition analysis model, is designed as three stages: (1) Hinterland network analysis in terms of total transportation time and cost, (2) Size and capacity analysis in terms of integration of offshore ports with ultra-large container ships depending on location of port and finally (3) the design of the game theoretical competition model which will be able to use the results from the first two stages for competition analysis.

Port performance indicators are considered from different angles in different studies. Wu and Goh (2010)'s study gives a general idea of how performance indicators in container ports can be examined from different points. As first stage, in this study, port performance indicators will be evaluated in terms of importance of port size and capacity before going to game theoretical competition analysis. Port performance indication for OCPS can be basically considered as handled container numbers from ULCVs per crane, per metre of quay, per staff, per stowage slot and used energy etc. This is because the model is designed to analyse whether offshore ports are advantageous in handling ultra large container ships compared to competing ports.

In addition, the location analysis and network optimization are important because offshore ports are located in the open sea. It is clear that offshore ports will bring a new understanding of container networking (Foroudi, 2015, Rowland, 2015). For this reason, the examination of how the offshore ports in the port competition will have the position to deliver the containers to the final destination will constitute the second stage of this model.

The latest model includes an adaptation of an original game theory approach that provides an assessment of which ports will have a more advantageous container transportation network in a competitive environment that will result from the integration of offshore ports into the container sector.

When we consider it in the model as a whole, we have a structure that can assess the positions of competing ports in terms of port size, capacity and network optimization for handling ultra-large container vessels and guide port management to make critical strategic investment or operational decisions so that ports can be competitively advantageous.

3.2.2 Model Design

If a port is planned to be constructed, primarily the regional cargo demand depending total export and import figures are required to provide understanding for its right size of port should be constructed at the area. This requires a long-term prediction about cargo capacity changes as ports are constructed with a social long-term overhead capital for their life cycle. It can be said that participating in a competitive container port system commences at the construction level to enable the advantageous competitive pricing during port operation stage. At this point, it should be noted that the structural functionality a port is one of the main elements to determine its construction cost. Therefore, when OCPS is considered as a design option, the following elements play a key role to determine its construction cost (Kurt et al., 2015b).

- The storage and berthing structure: static structure or floating platform,
- Container handling equipment: container transfer and stowing cranes and transfer equipment and vehicles,
- Vessel related facilities: berthing space, towing of vessels (if necessary), mooring,
- Personnel transportation and facilities such as offices, restaurants and accommodation,
- Supplies: energy and provisions.

At the construction point, in terms of sunk cost of structure, it can be considered that the construction at shore could be more advantageous but other approach can defend the opinion that the developing technologies can put forward OCPS due to high land prices (Lyridis, 2015, Guglielminetti, 2015). Concerning this discussion, it can be said that OCPS does not require high-priced land, but fixing and sinking costs cannot be excluded (Seo and Ha, 2010).

When the decision for the construction of a container port is taken, it is obviously desirable to operate in a monopoly market. However, in the developed container network several container ports can serve the same hinterland. Therefore, for a newly entered port, it is difficult to attract port users such as cargo owners, shippers and cargo liners, forwarders, 3rd party logistic providers, consultant companies etc. due to competitive behaviour of ports in operation for the same market (Haralambides, 2002).

Seo and Ha (2010) discuss the various entry barriers of ports when entering the sector, and the barriers to entry should be re-evaluated as a new competitive characteristic that emerges when entering a new port sector. The mentioned entry barriers can be identified as: ports physical characteristics such as size and capacity; behavioural patterns of port users in the market that can be change with more advantageous position of the newly entered port (Cahoon and Notteboom, 2008); and the provided incentives to port users by ports to keep their customer in order to secure their share in the competitive port industry.

OCPS is assumed to have no dimensional constraints to accommodate ULCVs, especially if is assumed that no draft and crane outreach constraints exist thanks to advantageous positioning of OCPS and the application the latest crane technologies. Overall the physical and operational capacity of newly designed offshore container port system should meet the hinterland requirements, which it intends to serve, by taking into consideration the future predictions about the region.

Effective use of port capacity is an important factor in assessing the level of port performance. At this point it is necessary to talk about the factors that influence the use of port capacity. Böse (2011) identifies these factors which must be taken into account when estimating the throughput capacity of a container port. The featured factors in the port throughput estimation include terminal area, length of quay, cranes and other handling equipment. As addition to those of technical factors which have the calculable functions, some external factors such as wind, tidal and human factor.

The impacts of factors on port capacity and throughput are represented in Figure 3-2. They are gathered under four main titles by Böse (2011): (1) Infrastructure capabilities; (2) terminal capabilities; (3) handling demand; and (4) environmental influences.

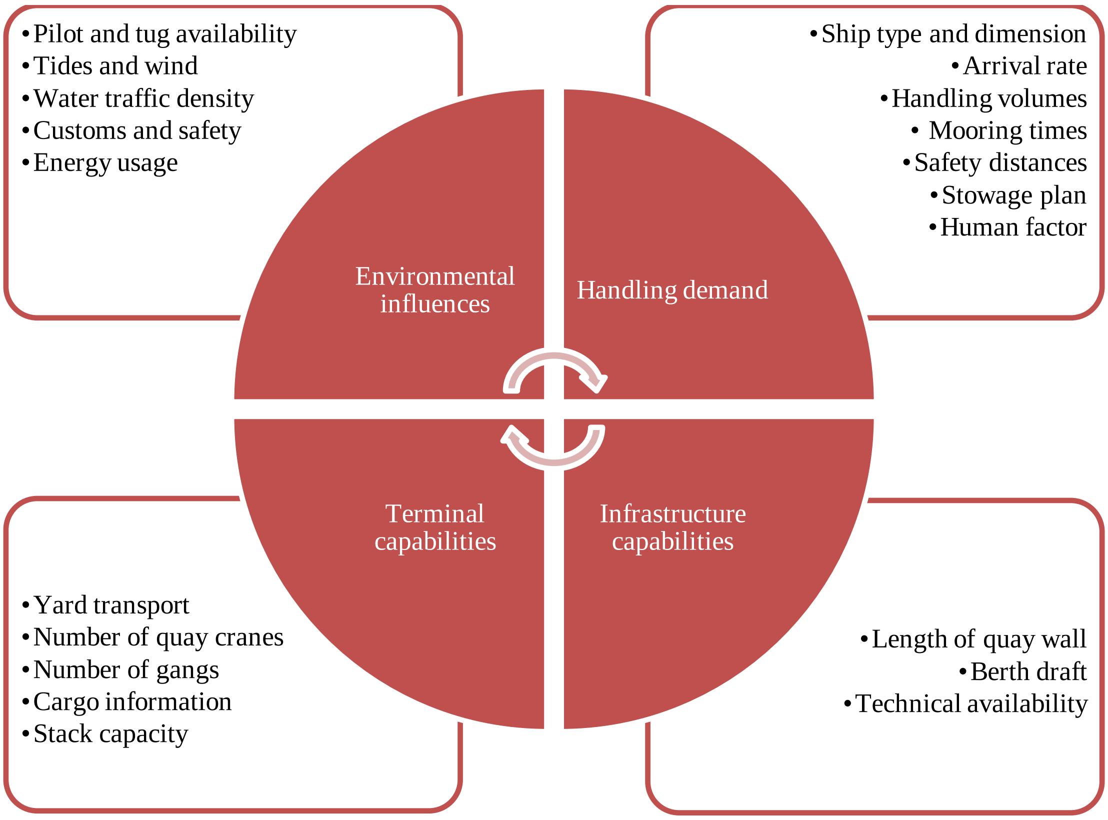


Figure 3-2 Factors for port throughput capacity

Source: Adopted from Böse (2011)

The effect of the factors shown in Figure 3-2 is inevitable. However, some of these factors can be improved during the port operation, such as the number of cranes or IT services, but for example, the length of quays and the storage area should be decided on the way to construction. In order to reduce the effects of wind and wave fluctuations, the long-term past wave and wind data should be taken into consideration and the location of the planned harbour structure should be determined.

When we consider the factors to be determined during the construction, port capacity analysis requires the following calculations to meet the requirements of port users on a port in order to compete in the container port industry. These calculations are also key elements to design the model that will be used in this study for the preliminary analysis for the ports in the competition.

The port handling capacity is calculated according to the technical specifications of the port handling equipment. Therefore:

$$PHC = \int_{0}^{t} x_{ci} \cdot td(x)$$

3.1

Where:

- PHC : Port Handling Capacity,
- x_{ci} : The amount of containers can be handled (loading/unloading) in TEU by crane c_i per time unit, t,
- i : The set of STS cranes; $i=(1,...,n)$,
- t : Time unit,

In practice, the port handling capacity is not always operated in full capacity. However, it is aimed to capture by port authorities. The used capacity during a specific time period which is utilisation rate of port's handling capacity. It can also be called as port throughput. The port throughput is always calculated to be sum of handled containers in a year.

$$C_t = \sum_{i}^{n} x_{s,i} + \sum_{j}^{m} x_{s,j}$$

3.2

Where:

- C_t : Container throughput TEU/year,
- $x_{s,i}$: Loaded containers in TEU to vessel i in a year,
- $x_{s,j}$: Unloaded containers in TEU from vessel j in a year,
- i : The set of containerships called the port for container loading in a year; $i=(1,...,n)$,
- j : The set of containership called the port for container unloading in a year; $j=(1,...,m)$,

The functions given above can make guidance on the port performance which can be considered as an important factor to determine the competitive capacity of a port among other competitor ports. The port performance can be assessed from the perspective of carriers with the value of port physical system which gives the handling efficiency in number of containers in an hour. The port physical system which is important to know the handling performance of a port for containership operations and it can be calculated as following.

$$PPP = \frac{C_t}{h}$$

3.3

Where:

- PPP : Port Physical Performance,
- C_t : Container throughput TEU/year,
- h : hour,

The port performance is also be assessed by the efficient usage of physical capacity of operation zone from the perspective of port administrator. Rodrigue et al. (2013) consider the capacity of infrastructure in static and dynamic capacity. The improvement of static capacity depends on facility expansion which needs investment in infrastructural development, while the dynamic capacity can be improved according to achievement of port administration authorities in technical and managerial manners. The improvements in physical and administrative status of a port structures provides to keep the optimum nominal capacity. The illustration of optimum nominal capacity depending on the static and dynamic capacity changes represents in Figure 3-3.

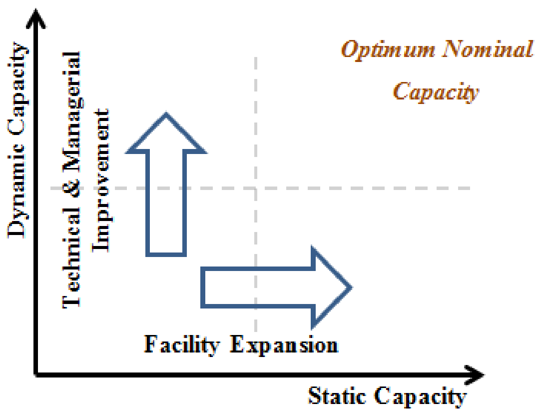


Figure 3-3 Relationship between static and dynamic capacity of transport infrastructures

Source: Rodrigue et al. (2013)

The optimum nominal capacity can be considered as a factor including technical, operational and administrative aspects to be able to measure and evaluate ports' competitiveness level. The determinative factors of nominal capacity are static and dynamic capacity levels which have various components. The components of dynamic capacity are covered while the container port competition dynamics were discussed in section 2.5.2, so it has been considered that there is no need to discuss under different title by covering capacity improvement components. Thus, the components affecting the static capacity will be argued henceforth. The static capacity depends on infrastructure area for operating, quay length, quay depth, number of berths. It is required an optimum combination of these factors. The static capacity deterministic factors can be given by using some mathematical equations. Actually, it cannot be right to mention a relationship among these deterministic factors for a conventional port, but in offshore structures there is a relationship between infrastructure area and quay length by depending aerial correlation among them.

The surface area for a container port can be obtained as sum of container stacking area, apron area, area for buildings and facilities, and intern transport roads. The calculation of container stacking area can be given as follow (Ligteringen, 1999):

$$A = \frac{C_e \cdot t_d \cdot F}{r \cdot 365 \cdot m_i}$$

3.4

Where:

- A : Required area for container stocking in m^2,
- C_e : Expected TEU handling per year,
- t_d : Average dwell time of containers in days,
- F : Footprint area per TEU,
- r : Average stacking height/nominal stacking height (0.6 – 0.9),
- m_i : Acceptable average occupancy rate of the yard (0.6 – 0.7),

The required total port area can show changes depending on the assigned areas for apron, buildings and facilities and intern transport roads. The conventional shore container ports are flexible in this respect due to their facility expansion opportunities. However, the offshore structures have almost no opportunity to expand the static capacity; the capacity can just be increased in dynamic way by the improvement of port's operational and administrative manners. For the static capacity, the required total area should have been calculated during planning stage of port in that it is a physically restricted structure. DLH (2007) suggests that the apron area should be designed between the range of 15 m and 50 m to provide handling operation flexibility and safety depending on type of quay cranes for container terminals, but it is expected to keep at minimum level, especially for offshore structures, in order to prevent additional cost. Ligteringen (1999) identifies the required area within the lay-out of apron area such as service lane between the coping and crane; the crane track spacing which is used for container drop off and pick up as addition it is determined to use for crane stability; and the third area is place for special container lifting or generally designed for traffic lane of vehicle which shuttle between the stack yard and the quay.

The other dimensional factor, which is also important for offshore structure to determine the size of surface area, is quay length. For a single berth, the quay length is typically determined by the length of the largest vessel frequently calling at the terminal, plus an additional 15 to 30 m fore and aft to account for mooring lines. The minimum required quay length is calculated by taking consideration the largest ship's dimensions which is expected to serve (Ligteringen, 1999, MarCom, 2014).

$$L_q = L_{s,max} + (15 \cdot 2)$$

3.5

Where:

- L_q : The length of quay in metre,
- $L_{s,max}$: The maximum ship length using the berth in metre,

For multiple berths in a straight continuous quay, the quay length can be estimated as follows. This allows for a berthing gap of 15 metre between two vessels berthing adjacent to each other and an additional 15 metre at the two outer berths. Pachakis (2015) highlights that 1.1 is a factor allowing variability in vessel length.

$$L_q = 1.1 \cdot n \cdot \left(L_{s,av} + 15\right) + 15$$

3.6

Where:

- L_q : The length of quay in metre,
- $L_{s,av}$: The average ship length using the berth in metre,
- n : The number of berths,

According to the known vessel size, the quay length can be estimated with above equations 3.5 and 3.6. However, an approach is that the quay length is estimated depending upon the number of berths which is calculated with the following equation generated by Ligteringen (1999).

$$n = \frac{C_t}{C_b}$$

3.7

Where:

- n : The number of berths,
- C_t : Container throughput TEU/year,
- C_b : Average TEU handling per berth TEU/year,

It is tried to define the factors which affects the role of port in a competition among rivalries in terms of port size and capacity. Especially if a port such as offshore hub, aims to serve ULCVs, then the size and capacity is also getting more important. However, these factors do not mean anything by itself. A port can find a meaning in terms of performance when it is built by efficient use of size and capacity utilization (Esmer, 2008).

Apart from the factors affecting the port size defined above, the performance of the handling equipment is even more important in order to improve the efficiency of the port operation. Tongzon (2001) relates to output performance with input performance. It means that the number of docks and the number of cranes affect the amount of the handled container in a direct proportion. However, the real performance of the port is linked to how effectively the berths and cranes are used. The efficiency of the berths and cranes is affected negatively due to the delays in the operation and the worker factor, which can directly affect the port performance negatively (Tongzon, 1995).

The most important criterion in calculating the number of cranes and workers is the total number of containers to be handled annually. Although the port capacity required to be reached is sufficient to calculate the number of cranes required to be in the port, there are some other unknowns that affect the number of workers required, for crane calculation. So it is not possible to talk about a function in order to get a clear result about the number of workers.

Efficient port performance has a significant positive impact on the container transportation economy and therefore good port services provided by the port to customer satisfaction. A significant reduction in unit costs of transport can be seen thanks to efficient port performance. This brings the ports in a more competitive position in the economic sense; it also helps the port to reinforce its advantageous position in the competition with the customer satisfaction provided by the port performance. Buxton (2012) compares container ports that offer good port services and weak port services on the basis of container quantity and unit cost. Figure 3-4 is adapted from the study of Buxton in order to explain this comparison.

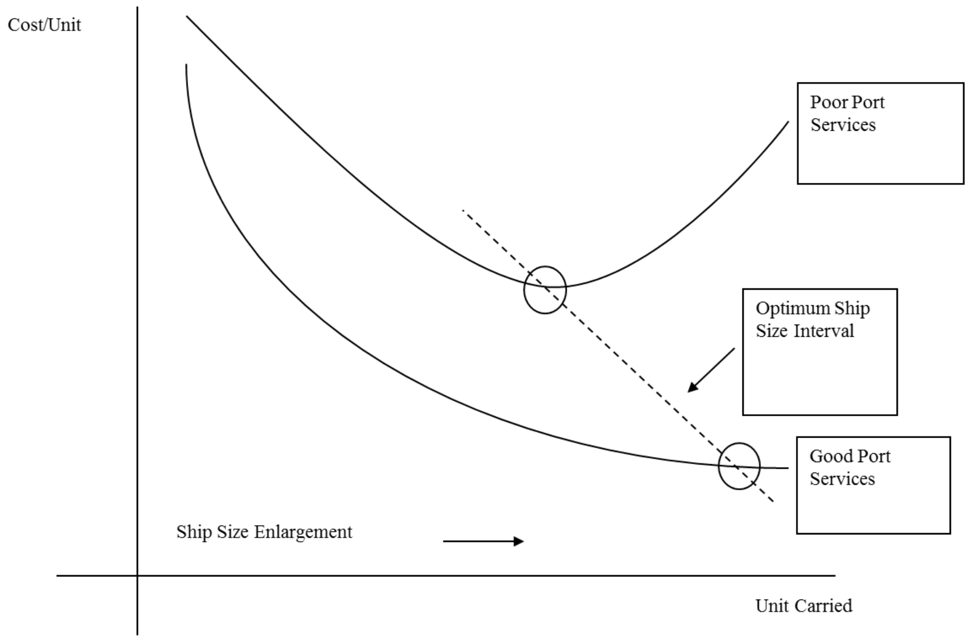


Figure 3-4 Comparison of port service

Source: Adapted from Buxton (2012)

When port, container ship and hinterland components are discussed in the same frame, the port should provide a service understanding that will meet the demands of the other two components. The connection between the ship and the hinterland is provided by the port. Although there is a demand for freight from the hinterland, if there is not a port with optimum suitability, the hinterland will first be directed to other competitor ports and then to other competing modes of transportation to find a suitable transportation alternative.

Figure 3-5 represents a model to show the requirements of the components in the container transportation from the perspective of this study.

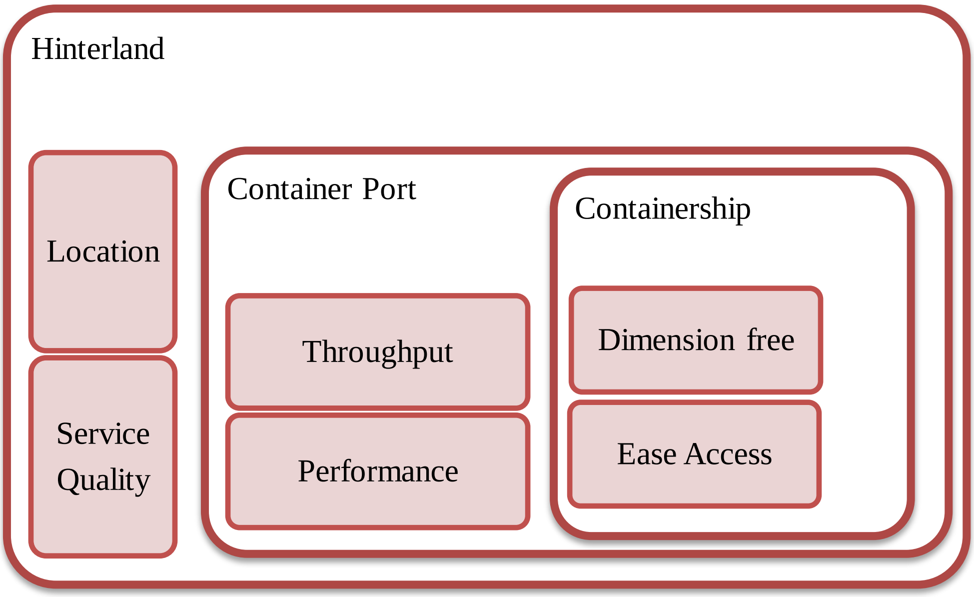


Figure 3-5 Containership – Port – Hinterland relationship model

The model can be designed as container network optimization for application of offshore container ports, ULCVs and offshore ports for the focal point of the study.

When viewed from the point of view of the ship, the basic things that would be required from a model design are the convenient port access without the distress caused by the size of the big ships. And therefore also easy hinterland access by the influence of the port location. From the point of view of the hinterland, if the port is considered as offshore, the port will bring an advantageous position in terms of port location, port service quality and the flexibility and sustainability of the transfer links to the hinterland in order to provide easy access to the hinterland. In addition, the port will respond to ship and hinterland requests as well as an effort to maximize profit at the same time. Of course, when we evaluate the business economy together with this, it is to minimize the cost of the general container transportation work that is targeted in this work. In addition to the effort to minimize the total container transportation cost, the position of the offshore port in competition with other ports will be seen through the game theory method.

3.3 Stackelberg Model for Port Competition Game

As previously mentioned, the Stackelberg model offers a leader / follower model. When the container liner system is considered, it is also possible to meet with a form of leader / follower game among the container companies. The most obvious example of this in the near future is the investment made in ULCVs. A leading company was the first to invest in ULCVs. Then this company was followed up with other companies doing ULCV investments. The purpose here is to reduce the unit cost through the economy of scale. The low unit cost made it possible to be more competitive in the market as well as to make more profitable container transportation.

A similar situation can be seen in the competition between container ports. In the competition among container ports, as a perspective of Stackelberg model, it is assumed that the leader port moves first by investing in order to attract ULCVs to the port.

To begin port competition game from the perspective of Stackelberg model, let us first recall some definitions and formulations and related structures associated with a non-cooperative port competition game.

First we consider a single market for a homogeneous service supplied by n ports whose outputs are denoted by $q_i = (q_1, q_2, \dots, q_n)$. The total outputs of the port can be given as follows.

$$Q = \sum_{i}^{n} q_i$$

3.8

Where:

- Q : Total output,

- q_i : The output of player i,

The inverse demand function $P = f^{-1}(Q)$ of the economy theory. It is a linear function which is used to simplify the demand-price relationship (William and Stephen, 2003). Economists usually place price (P) and quantity (Q) on the x-y axes. The inverse demand function is written as $P = a - bq$ and the slope = b since the vertical axis is P. The constant a gives the market position. The average price of container port on a specific case can be mathematically shown as follows.

$$P = a - b_i q_i$$

3.9

Where:

- P : The price of player i,
- a : The market behaviour constant,
- b_i : The constant slope of the market from player i 's market position,

The total revenue functions are derived from Equation 3.8 and 3.9. The total revenue calculation relies on multiplying the inverse demand function by Q.

$$TR = P \times Q$$

3.10

Where:

- TR : Total revenue,
- P : The average price,
- Q : Total output (demand),

The cost function required to calculate the profit is as follows.

$$C_i = c_i q_i$$

3.11

Where:

- C_i : The total cost of player i,
- c_i : Constant marginal cost of player i,
- q_i : The output of player i,

Profit is obtained by deducting the total cost from the income. According to Equation 3.8, 3.9, 3.10 and 3.11, the profit of player i is represented by the following function.

$$\Pi_i(q_{-i}, q_i) = P(Q) \times q_i - c_i \times q_i = (P(q_{-i} + q_i) - c_i)q_i$$
$$= (a - b(q_{-i} + q_i) - c_i)q_i$$

3.12

Where:

- q_{-i} : The opponents' output; $q_{-i} = \sum_{j \neq i} q_i$,
- *P(Q)* : Price depending on quantity,
- c_i : Constant marginal cost of player i,

In Stackelberg model, the sequential games are offered. In sequential games, first the problem is solved for the follower players and then the problem is solved for the leader player. First order condition (FOC) for profit maximization of the given q_{-i}:

$$\frac{\partial \Pi_i}{\partial q_i} = 0 \Leftrightarrow a - 2bq_i - bq_{-i} - c_i = 0$$

3.13

According to Cournot reaction function, the optimal output allocation for player i can be written as follows.

$$q_i = r_i(q_{-i}) = \frac{a - bq_{-i} - c_i}{2b} = \frac{a - c_i}{2b} - \frac{1}{2}q_{-i}$$

3.14

Then, the optimal output allocations can be written according to Cournot reaction function, Equation 3.14, for the quadruple game model as follows.

$$q_1 = \frac{a - c_1}{2b} - \frac{1}{2}(q_2 + q_3 + q_4)$$

$$q_2 = \frac{a - c_2}{2b} - \frac{1}{2}(q_1 + q_3 + q_4)$$

$$q_3 = \frac{a - c_3}{2b} - \frac{1}{2}(q_1 + q_2 + q_4)$$

$$q_4 = \frac{a - c_4}{2b} - \frac{1}{2}(q_1 + q_2 + q_3)$$

3.15

Each player produces in the *n*-player oligopoly as follows.

$$q_i^n = \frac{a - b_q - c_i}{b} = \frac{a - c_i}{b} - \frac{n}{n+1}\frac{a - \bar{c}}{b} = \frac{1}{n+1}\frac{a}{b} + \frac{n(\bar{c} - c_i) - c_i}{(n+1)b}$$

3.16

For simplicity, assume that player have identical marginal costs $c_i = \bar{c} = c$. Then,

$$p = \frac{1}{n+1}a + \frac{n}{n+1}c \to c \; as \; n \to \infty$$

3.17

In the calculations, the difference between the marginal costs of the players was taken so that the increase in total costs would be distributed to the cost of each unit output.

$$q_i^n = \frac{1}{n+1}\frac{a - c}{b} \to 0 \; as \; n \to \infty$$

3.18

$$\Pi_i^n = (p - c)q_i^n = \left(\frac{1}{n+1}a + \frac{n}{n+1}c - c\right)\frac{1}{n+1}\frac{a - c}{b}$$

$$= \frac{1}{(n+1)^2}\frac{(a - c)^2}{b}$$

3.19

Then we can calculate the output for the leader player according to the Stackelberg model as follows. Here let's assume that player 1 is the leader player so it moves first, other players observes the move and then adapts. Let us now, for simplicity, the display of the output formula that allows maximizing the leader player's profit, the other players are considered like a single player as 'q_{-i}'. Then, the formula can be written as follows.

If the rational other players observe the quantity q_1, and then they (q_{-i}) will choose the quantity as follows.

$$q_{-i} = r_{-i}(q_1) = \frac{a-c}{2b} - \frac{1}{2}q_1$$

3.20

Then, the total output can be written as follows.

$$q_1 + q_{-i} = \frac{a-c}{2b} + \frac{1}{2}q_1$$

3.21

Then the price will be as follows.

$$p = a - b(q_1 + q_{-i}) = a - \frac{a-c}{2} - \frac{b}{2}q_1 = \frac{a+c-bq_1}{2}$$

3.22

The leader player anticipates the price, and expects to make the profit which is given as follows.

$$\Pi_1\big(q_1, r_1(q_{-i})\big) = \left(\frac{a+c-bq_1}{2} - c\right) \times q_1 = \frac{a-c-bq_1}{2} \times q_1$$

3.23

The output allocation of the leader is derived from Equation 3.23 and the followers' output allocation is derived from Equation 3.20 as follows.

$$q_1 = \frac{a-c}{2b}$$

$$q_{-i} = \frac{a-c}{4b}$$

3.24

Then the price formula can be written again as seen in Equation 3.21 as follows.

$$p = \frac{a+c-b\frac{a-c}{2b}}{2} = \frac{a-c}{4}$$

3.25

Note that if the followers cannot observe the quantity selection, it will not be Nash equilibrium, because the followers can react optimally while the leader player should produce the following output. The equation is derived from Equation 3.14 based on Equation 3.20

$$q_1 = r_1(q_{-i}) = \frac{a-c}{2b} - \frac{1}{2}\,q_{-i} = \frac{a-c}{2b} - \frac{a-c}{8b} = \frac{3}{8}\frac{a-c}{b}$$

3.26

Then the total quantity would be as follows.

$$Q = \frac{5}{8}\frac{a-c}{b}$$

3.27

Then the price can be written as follows.

$$p = a - \frac{5}{8}(a-c) = \frac{3a+5c}{8}$$

3.28

According to the Stackelberg-Nash Equilibrium, the profit of the leader is derived from Equation 3.26 and 3.28 and the profit function for the leader can be written as follows.

$$\Pi_1 = \left(\frac{3a+5c}{8} - c\right)\left(\frac{3}{8}\frac{a-c}{b}\right) = \frac{9}{8^2}\frac{(a-c)^2}{b}$$

3.29

The profit function of the followers can be written referring Equation 3.19 as follows.

$$\Pi_2 = \frac{1}{9}\frac{(a-c)^2}{b}$$

$$\Pi_3 = \frac{1}{16}\frac{(a-c)^2}{b}$$

$$\Pi_4 = \frac{1}{25}\frac{(a-c)^2}{b}$$

3.30

It should be noted that the profit of the leader must be at least as large as in the Cournot model because the leading player could have always obtain the Cournot model profits by choosing the Cournot quantity, which is given in Equation 3.24, to which other players would have replied with it's the Cournot quantity in Equation

3.24 since the followers reaction curve in the Stackelberg model is the same as in the Cournot model.

As a conclusion, the leader player knows that the followers will reduce the quantity (q_{-i}) by increasing q_1. The decision is irreversible. Otherwise the leader player would undo its choice and we would end up in the Cournot model again. Anderson and Engers (1992) note that the Stackelberg model leads to a more competitive equilibrium than the simultaneous move game, the Cournot model.

From the Stackelberg model, the following points can be deduced.

- $q_1 > q_2$: the leader produces more,
- $p > c$: there will be dead weight loss,
- $\Pi_1 > \Pi_2$: the leader has higher profits, there is an advantage of being the first to choose.

3.4 Cost Calculations in the Container Transportation Network

Stopford (2009) mainly divides the annual costs for operating a fleet in two categories: (1) annual costs of operating fleet; and (2) annual costs of maintaining and financing fleet. At this point, the differences between vessel size, type, management method and other related variables, which affect the annual maintenance and financial costs, will not be considered when calculating the annual costs of maintaining and financing fleet; for the reason to assume the annual costs of maintaining and financing fleet as equal for each unit of container.

Looking at the annual costs of operating container fleet, Table 3-1 can be drawn to display cost expenditures during the container fleet operation.

Table 3-1 Operational cost expenditures of container transportation

Annual Costs of Operating Fleet	
Operating Costs	Crew Costs
	Stores
	Maintenance
	Insurance
	Administration
Voyage Costs	Fuel Consumption
	Speed
	Port Charges
Cargo Handling Costs	Cargo Handling Equipment
	Stevedore Costs
Hinterland Transportation Costs	Feeder Service
	Inland Transportation

Source: Adapted from Stopford (2009)

For the optimum container transportation network, the main objective is to minimize the total transportation cost from point A to B. It can be formulated as to be give cost minimization as follows.

$$TC = OC + VC + CHC + HTC$$

3.31

Where:

- TC : Total transportation cost;
- OC : Operating cost;
- VC : Voyage cost;
- CHC : Cargo handling cost;
- HTC : Hinterland transportation cost;

By calculating the annual transportation cost of a fleet, Stopford (2009) and Aymelek (2016) includes the capital cost expenditure, but in our study it will be ignored by assuming that the capital cost per unit will be same on each container transportation network. Then, the objective function[2] depending on constraints can be written as follows.

$$Min\,TC = \sum_{i \in I}^{n} \left(c_{cr_i} + c_{st_i} + c_{mnt_i} + c_{ins_i} + c_{adm_i}\right) + \sum_{i \in I}^{n} \left(c_{fc_i} RT_i + c_{pd_i} RT_i + \gamma_{ik}\right) + \sum_{i \in I}^{n} \left(p_{ch} x_{c_{il}}\right) + \sum_{j \in J}^{n} c_j^* \quad \textbf{3.32}$$

Where:

- c_{cr_i} : The crew cost for containership *i* in a year,
- c_{st_i} : The store cost for containership *i* in a year,
- c_{mnt_i} : The maintenance cost for containership *i* in a year,
- c_{ins_i} : The insurance cost for containership *i* in a year,
- c_{adm_i} : The administration cost for containership *i* in a year,
- c_{fc_i} : The fuel cost for containership *i* in a year,
- c_{pd_i} : The port dues for containership *i* in a year,
- RT_i : The number of round trips sailed by containership *i*,
- γ_{ik} : The costs of tug, pilotage and canal dues applied for containership *i* at round trip *k*,
- p_{ch} : The handling price per container,
- $x_{c_{il}}$: The number of containers handled at port *l* delivered with containership *i*,
- c_j^* : The cost for hinterland transportation per container *j*,

In Equation 3.32, $i(=1,\dots,n) \in I$ represents the set of containership in the network, $j(=1,\dots,m) \in J$ is the set of containers will be delivered to the point within hinterland, $k(=1,\dots,p) \in K$ is the set of round trips that are made by containership *i* in a year, and $l(=1,\dots,r) \in L$ is the set of ports in the network serving to same hinterland (competition) area.

[2] For assumptions and sources please see Appendix A and Appendix B.

3.4.1 Operating Costs

As seen in Equation 3.31, the objective function actually covers expense items under 4 different headings. Let's examine these cost items in more detail.

$$OC = c_{cr} + c_{st} + c_{mnt} + c_{ins} + c_{adm}$$

3.33

The operating costs cover crew costs, stores, repairs and maintenance costs, insurance and administration cost as in Table 3-2.

Table 3-2 Ship operating costs

Operating Costs	
Crew Costs	Crew wages
	Travel, insurance etc.
	Provision
Stores	General cabin stores
	Lubricants
Maintenance	Routine Maintenance
	Breakdowns
	Repairs
	Spares
Insurance	Hull & machinery & war risks
	P&I
Administration	Registration costs
	Management fees
	Sundries

Source: Stopford (2009), Greiner (2011)

3.4.2 Voyage Costs

$$VC = c_{fc} + c_{pd} + \gamma$$

3.34

Where, VC represents voyage costs, c_{fc} is the fuel costs for main engines and auxiliaries, c_{pd} port and light dues and γ represents the total fee charged for tug and pilotage services and canal dues.

Speed is an important factor which affects directly the cost as the consumption of fuel increases exponentially when the speed increases (Notteboom and Cariou, 2009). According to Stopford (2009), the fuel cost can be counted 47% of the total transportation cost and he notes that sailing at lower speeds results less amount of fuel consumption due to the reduces water resistance and the relationship between speed (V) and fuel consumption (F) is given with the cube rule as follows.

$$\left(\frac{V}{V_0}\right)^a = \frac{FC}{FC_0}$$

3.35

Where; V_0 represents the reference speed, while F_0 is fuel consumption (tons/day) at V_0 and a symbolises a constant which has a value of about 3 but it can change according to vessel type and engine type (Barrass, 2004, Stopford, 2009, Kontovas and Psaraftis, 2011).

Daily fuel consumption by the main engine in tonnes is formulated by (Buxton, 1985) as follows.

$$DFC = EP \times SFC$$

3.36

Where:

- DFC : Daily fuel consumption in tons/day
- EP : Engine power in SHP (Ship Horse-Power) or kW (kilowatt)
- SFC : Specific fuel consumption in tons/SHP or tons/kW

SFC depends on a number of conditions such as the steaming condition, hull roughness, fouling, propeller condition, ship age and environmental factors etc. However, the container shipping has a specific characteristic about vessel speed allocation due to its liner shipping feature. Because the liner shipping has to be offer regular schedules with a strict number of vessels for the customers. Therefore, the schedule is drawn depending on the average speed of vessels in the fleet which is used on a route.

Saving from roundtrip costs related to operate vessels at the optimum SFC, and a general approach is to operate at optimum power load both to reduce fuel consumption and maintenance costs (MAN, 2011). The total roundtrip bunker cost can be derived from Equation 3.36 as follows.

$$RBC = [(FC_{ME} \times p_{fME}) + (FC_{SAux} \times p_{fAux})] \times t_S + [(FC_{PAux} \times p_{fAux})] \times t_P$$

3.37

Where:

- RBC : The total roundtrip bunker cost
- FC_{ME} : The main engine specific fuel consumption (tonnes/ SFC – day)
- p_{fME} : The main engine fuel price ($/tonnes)
- FC_{SAux}: The auxiliary engine/s specific fuel consumption at sea (tonnes/ SFC – day)
- p_{fAux} : The auxiliary engine/s fuel price ($/tonnes)
- t_S : Days at sea per roundtrip
- FC_{PAux} : The auxiliary engine/s specific fuel consumption in port (tonnes/ SFC – day)
- t_P : Days in port per roundtrip

3.4.3 Cargo Handling Costs

When it is looked at cargo handling cost, it can be explained that cargo handling cost can be obtained by the sum of loading and discharging costs and the cost of any container claim may arise.

$$CHC = p_{ch}x_c = L + DIS + CL$$

3.38

Where CHC represents cargo handling costs depending on L is cargo loading charges, DIS is cargo discharge costs and CL is cargo claims.

3.4.4 Hinterland Transportation Cost

Last but not least, hinterland transportation cost is considered as a part of total transportation cost for the last consumer delivery. This cost expenditure covers the costs of transportation after containers left the main discharging port to go towards the last destination. In addition to inland transportation cost, offshore and hub-spoke port system may incur another port handling cost which is considered to be part of the hinterland transportation cost. Hinterland transportation cost also incurs from the cost in other transportation modes (short sea shipping, road and rail) up to the last destination.

$$HTC = c_j^* = ht_{rd} + ht_{rw} + ht_{sss} + p_{ch_{sp}}$$

3.39

Where HTC represents hinterland transportation cost, ht_{rd} is the road mode hinterland transportation cost, ht_{rw} is the railway mode hinterland transportation cost, ht_{sss} is the short sea shipping mode hinterland transportation cost, and $p_{ch_{sp}}$ is the cargo handling price at spoke port may arise when offshore or hub-spoke container port system is applied.

3.5 Nash Equilibrium for Non-cooperative Games

The basic concepts of Nash equilibrium for non-cooperative finite games are defined by Nash (1951). In this section we define the basic concepts and set up standard terminology and notation for four players' non-cooperative games.

$$\Gamma = \{(N), (S_i)_{i\in N}(u_i)_{i\in N}\}$$

3.40

Where:

- N : A finite set of players; $N=\{1,\dots,n\}$,
- S_i : A set of pure strategies for each player $i \in N$; $S=\{s_{i1},\dots,s_{imi}\}$,
- u_i : A payoff function for each player $i \in N$,

If $N=\{1,\dots,n\}$, then $S = \prod_{i\in N} S_i$ is the space of possible pure strategies in Γ game. The payoff function of player i is denoted by u_i: $S \rightarrow \mathbb{R}$ where $S=S_1*S_2*\dots*S_N$ is the Cartesian products of all sets S_i.

Let's suppose that player i has m^i pure strategies. Then, the following equation represents the number of pure strategies in the game.

$$\sum_{i=1}^{n} m^i$$

3.41

Where:

- m^i : The pure strategies for each player $i \in N$,

The pure strategies combinations in the game are mathematically represented as follows.

$$\prod_{i=1}^{n} m^i$$

3.42

The combination of pure strategies for the set of players $i \in N$ is denoted by $S_i = \{s_i^j | j \in m_i\}$ with $M = \sum m_i$. Then the pure strategies combinations can be represented for the purpose of representation of the game as follows.

$$(s_1^1, s_2^1, \dots, s_{n-1}^1, s_n^1) := 1$$

$$(s_1^1, s_2^1, \dots, s_{n-1}^1, s_n^2) := 2$$

$$\vdots \qquad \vdots$$

$$(s_1^{m^1 1}, s_2^{m^2}, \dots, s_{n-1}^{m^{n-1}}, s_n^{m^{n-1}}) := (M-1)$$

$$(s_1^{m^1}, s_2^{m^2}, \dots, s_{n-1}^{m^{n-1}}, s_n^{m^n}) := (M)$$

3.43

For example, it is possible to suppose that a game with 4 players and each has 2 pure strategies which is denoted by n = 4 and $m_1 = m_2 = m_3 = m_4 = 2$. Then, the total number of pure strategies in the game is calculated as 8 and the number of pure strategy combinations in the game is calculated as 16. Briefly, the combination of all pure strategies in the game could be shown as follows.

$$(s_1^1, s_2^1, s_3^1, s_4^1) \coloneqq Combination\ 1$$

$$(s_1^1, s_2^2, s_3^1, s_4^1) \coloneqq Combination\ 2$$

$$(s_1^1, s_2^1, s_3^2, s_4^1) \coloneqq Combination\ 3$$

$$(s_1^1, s_2^1, s_3^1, s_4^2) \coloneqq Combination\ 4$$

$$(s_1^1, s_2^2, s_3^2, s_4^1) \coloneqq Combination\ 5$$

$$(s_1^1, s_2^2, s_3^1, s_4^2) \coloneqq Combination\ 6$$

$$(s_1^1, s_2^1, s_3^2, s_4^2) \coloneqq Combination\ 7$$

$$(s_1^1, s_2^2, s_3^2, s_4^2) \coloneqq Combination\ 8$$

$$(s_1^2, s_2^2, s_3^2, s_4^2) \coloneqq Combination\ 9$$

$$(s_1^2, s_2^1, s_3^2, s_4^2) \coloneqq Combination\ 10$$

$$(s_1^2, s_2^2, s_3^1, s_4^2) \coloneqq Combination\ 11$$

$$(s_1^2, s_2^2, s_3^2, s_4^1) \coloneqq Combination\ 12$$

$$(s_1^2, s_2^1, s_3^1, s_4^2) \coloneqq Combination\ 13$$

$$(s_1^2, s_2^1, s_3^2, s_4^1) \coloneqq Combination\ 14$$

$$(s_1^2, s_2^2, s_3^1, s_4^1) \coloneqq Combination\ 15$$

$$(s_1^2, s_2^1, s_3^1, s_4^1) \coloneqq Combination\ 16$$

3.44

Where s_i^j denotes that j^{th} pure strategy of the i^{th} player.

With respect to the combination of each pure strategy, a player has an associated payoff, so the matrix of each player's payoffs is comprehended as an *M* length vector. For that matter, the input format of a non-cooperative game with 4 players and each player having m_i, $i = 1, 2, 3, 4$, pure strategies, so that the number of pure strategy combinations in the game is $M=16$, can be displayed as follows.

$$\begin{matrix} u_1^1 & u_2^1 & u_3^1 & u_4^1 \\ u_1^2 & u_2^2 & u_3^2 & u_4^2 \\ u_1^3 & u_2^3 & u_3^3 & u_4^3 \\ \vdots & \vdots & \vdots & \vdots \\ u_1^{15} & u_2^{15} & u_3^{15} & u_4^{15} \\ u_1^{16} & u_2^{16} & u_3^{16} & u_4^{16} \end{matrix}$$

3.45

Where u_i^j denotes that j^{th} utility profit payoff of the i^{th} player in a four-player game.

A mixed strategy of player i is taken as a probability distribution over the strategy set S_i and the set of player i is denoted by $\sum_i = \left\{\sigma_i \in \mathbb{R}^{m_i+} | \sum_{j=1}^{m_i} \sigma_i^j = 1\right\}$. For $\sigma_i \in \sum_i$, the assigned probability to pure strategy s_i^j is σ_i^j. The strategy set of the game can be given as $\sum = \prod_{i \in N} \sum_i$.

If a mixed strategy combination σ is played then the probability that the combination of pure strategies $s = \left(s_1^{j^1}, s_2^{j^2}, \ldots, s_n^{j^n}\right)$ occurs is given by $\sigma(s) = \prod_{i \in N} \sigma_i^{j^i}$. In a situation that the payoff assigned to player i is denoted by $u_i(\sigma) = \sum_{s \in S} \sigma(s) u_i(s)$, where $u_i(s)$ can be defined as the payoff of player i at the pure strategy combination s.

The mixed strategy combination σ can be replaced by (σ_{-i}, σ_i), when the mixed strategy vector for all players except i is denoted by σ_{-i}.

Equilibrium $s^* = (s_1^*, \ldots, s_n^*)$ is a strategy combination consisting of a best strategy for each of the n players in the game. Then the equilibrium or solution concept, F, can be written as $F: \{s_1, \ldots, s_n, u_1, \ldots, u_n\} \rightarrow s^*$. It is a rule that defines an equilibrium based on the possible strategy combinations and the payoff functions.

The best response of player i or best reply to the strategy s_{-i} chosen by the other players is the strategy s_i^* is called a Nash equilibrium of the game Γ that yields him the greatest payoff that is:

$$u_i(s_i^*, s_{-i}) \geq u_i(s_i', s_{-i}), \forall s_i' \neq s_i^*$$

3.46

Where:

- s_i^* : The best response strategy of player i,
- s_{-i} : The strategies chosen by other players in the game,
- s_i' : Any alternative strategy of player i,

The best response is strongly the best if no other strategies are equally good and weakly best otherwise.

The strategy combination s^* is Nash equilibrium if no player has incentive to deviate from his strategy given that the other players do not deviate. Then the Nash equilibrium can be formally written for the best response as follows.

$$\forall i, u_i(s_i^*, s_{-i}^*) \geq u_i(s_i', s_{-i}^*), \forall s_i'$$

3.47

Where:

- s_i^* : The best response strategy of player *i*,
- s_{-i}^* : The best response strategy of other players in the game,
- s_i' : Any alternative strategy of player *i*,

In other words it means that for each player *i*, he could not attain a better payoff than that at Nash Equilibrium, by changing only his own strategy. Here the sense of optimization for each player is to maximize his payoff when other playing by their Nash equilibrium strategies. Consequently, one attempts to minimize the gap between the optimal payoff and the best response obtained by possible strategy combinations.

Equilibrium point can be written for an *n*-tuple if and only if for every i.

$$u_i(s_i^*) = \max_{all\ s_{-i}^*} [u_i(s_i^*, s_{-i}^*)]$$

3.48

Thus an equilibrium point is an *n*-tuple s_i^* such that each player's mixed strategy maximizes his payoff if the strategies of others are fixed. Thus it can be said that each player's strategy is optimal against the strategies of the others.

Let's say that a mixed strategy σ_i uses a pure strategy s_i^j if $u_i(\sigma) = \sum_{s \in S} \sigma(s) u_i(s)$ and $\sigma(s) > 0$. If s_i^* and σ_i uses s_i^j, it can also say that s_i^* uses s_i^j. From the linearity of $u_i(s)$ in σ_i,

$$\max_{all\ s_{-i}^*} [u_i(s_i^*, s_{-i}^*)] = \max_j [u_i(s_i^*, s_i^j)]$$

3.49

It can be defined that $u_i^j(s_i^*) = u_i(s_i^*, s_i^j)$. Then the following condition for s_i^* to be equilibrium point.

$$u_i(s_i^*) = \max_j u_i^j(s_i^*)$$

3.50

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.

3.6 Data Collection

In the later sections of the thesis, an analysis based on case study is conducted in adaption with the given theoretical background and methodological definitions in the previous sections. Thus it is intended to provide an in-depth perspective on the practical applications of the theoretical contributions of the study. The data collection process is one of the basic research stages. This process is given in this chapter in details. In addition to this main stage, the reliability of data collection process is also crucial for the research to reflect the robustness and the practical reality and certain and verified the hypothetical estimates. In this section, the data collection procedures for the conducted case studies are also clarified separately under different categories. Finally, the data explanation is indicated to provide a better understanding between the data used and the results obtained from the case studies.

In this study, various data collection methods and steps are utilized to use for the analysis. Data is collected as follows.

- Row data and published secondary data from reliable data sources,
- Processes of recording data and observations,
- Assumptions made and assumed data.

3.6.1 Row and Published Data

Thanks to private connections, it was possible to get some data directly from the ports on the port operation process. Especially, the Venice Port Authority was very helpful in sharing the operational and financial information of offshore ports for this research. However, due to the confidentiality of some operational and financial information, unfortunately it was not possible to receive some data directly from the primary source. Thanks to access to some paid data resources such as Seaweb, some technical specs and operational data which especially about container ships, are given from Seaweb. When the requested data cannot be accessed, the study has been carried out through assumptions. In particular, the following main data resources have been used in the case study and they are referenced in the text and reference list of this thesis:

- Alphaliner,
- Clarkson,
- Colliers,
- Drewry Maritime Research,
- EU databases,
- EUROSTAT,
- IMO – International Maritime Organization,
- Liebherr – Crane technical specs and financial data,
- Lloyd's List,
- Maersk,
- OECD - The Organization for Economic Cooperation and Development,
- SeaWeb,
- Statista,
- UNCTAD - United Nations Conference on Trade and Development,
- World Bank,
- WPS – World Port Source,
- WSC – World Shipping Council,
- WTO – World Trade Organization.

Ports, where some data is received, are given below.

- APV - Venice Port Authority,
- HKMOA – Hong Kong Mid-Stream Operations Associations,
- Port of Hamburg,
- Port of Rotterdam,

- Port of Valencia,
- PSA Singapore.

3.6.2 Data Recording

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.

4 CASE STUDY: OFFSHORE BASED CONTAINER PORT GAME

Container ports play a critical role in the viability of international trade. Therefore, the market behaviours and allocation of the port service capacities are a great interest of the global trading partners. Historically, the container ports have undergone serious evolution, especially since the introduction of containers into the transport sector in the 1960s. During this time, the port hinterlands have expanded and the port handling amounts have increased greatly. In addition to all these, the goal of logistics delivering the right product to the right place and the right costumer, on the right time, with the right price, the right quantity and in the right condition brings serious obligations to the ports.

The container terminals serving containerized cargo increasing importance every day. When the world total container handling figures are examined as TEU based on years, it appears that the handling has doubled almost every 7 years (Esmer, 2010). For example, the 243 million TEU movements in all container ports in 2001exceeded 500 million TEUs in 2008. The container sector has a 7.8% growth rate according to 20 year average (Clarkson, 2015). This increase pushes the container terminal operators and the port administrations to constantly evolve.

Depending on the increase in the number of containers handled in the world, the container terminals are developed in terms of equipment and software technologies with the impact of factors such as the growth of ship’s length. For example, the dimensions of STS cranes used in the container terminals serving the main container ships and the speed of operations are increased. The equipment used at the back yard of ports for in-port transport and container storage is fully automated in order to reach the speed of STS cranes. This rapid development, however, cannot cope with congestions in the container terminals and prolonged ship waiting and order delivery times. Thus, the port industry was enforced to develop new perspective for the developing sector parameters and the complex port operations and the OCPS has begun to be developed as a new understanding of port operation.

It cannot be denied that Asia – Europe container route has a particular place among other main container routes, yet significant factors make the route more particular and increase the importance of container ports on the route. Also the transatlantic container route is one of major Europe connected container route (UNCTAD, 2017). The total merchandise exports and imports of Europe have the greatest figures in the world and those merchandise commodities are substantially carried by sea. Therefore it can be said that the ports and shipping elements have a critical role on this route. (WTO, 2016, UNCTAD, 2015).

According to UNCTAD's review of maritime transport in 2016, the lowest freight rates was reached as the sector was trying to overcome the issue of low demand and the presence of ULCVs in the market (UNCTAD, 2016). To cope with the issues, the container liner companies applied key measures including cascading, idling, slow steaming, consolidation and integration and the restructuring of new alliances (Lam, 2012).

In general a decrease tendency is seen at the rates of port growth but only the large ports showed a positive growth in 2015 (UNCTAD, 2016). It is mainly due to the fact that the applied measures by particularly the main container liner companies has increased interest on the large container ports (Notteboom, 2017). The largest container ports are located in the Northern Europe such as the Port of Rotterdam, the Port of Hamburg, and the Port of Bremerhaven and so on. However, the recent investments in Southern European and in the West Med ports make an indelible impression with a contribution to energy efficient transportation approach of port authorities (Notteboom, 2017). On the one side the largest container ports of the Northern Europe offer connectivity, capacity and accessibility for ULCVs, and on the other side the ports on Southern Europe offer to improve efficiency and optimize operations other than the largest container ports of the Northern Europe with the aid of infrastructural port investments (Notteboom, 2017).

Ever-increasing containership size and seeking for improved efficiency and optimized operations make the decision-making strategies important. How to choose the best port and thereby optimising container transportation routes depends on assessing the decision-making strategies. It is of great importance for policy makers and logistics practitioners to assess the potential of emerging trade routes and make the most appropriate route choices. For the seeking optimum route from Asia to Europe, China announced “one belt, one road” initiative in 2013. Thus China has given a fillip to the plan to achieve political and economic goals by designing a “21st Century Maritime Silk Road” in terms of the maritime transportation (Yang and Jiang, 2016).

According to the developed 21st century Maritime Silk Road, the Port of Venice and the North Adriatic Ports (Ravenna, Trieste, Koper and Rijeka) offer the shortest sea route from Asia to the Europe’s manufacturing destinations. As an alternative to the Port of Venice and the North Adriatic Ports, Piraeus (Greece) and Istanbul (Turkey) are the potential routes of the maritime and land Silk Road as European destination gateways (Xinhua, 2014). In “one belt, one road” strategy, while Istanbul is considering as the gateway of land Silk Road, Venice and Piraeus are considered as the gateways of maritime Silk Road. Figure 4-1 shows the potential routes of the maritime and land Silk Road.

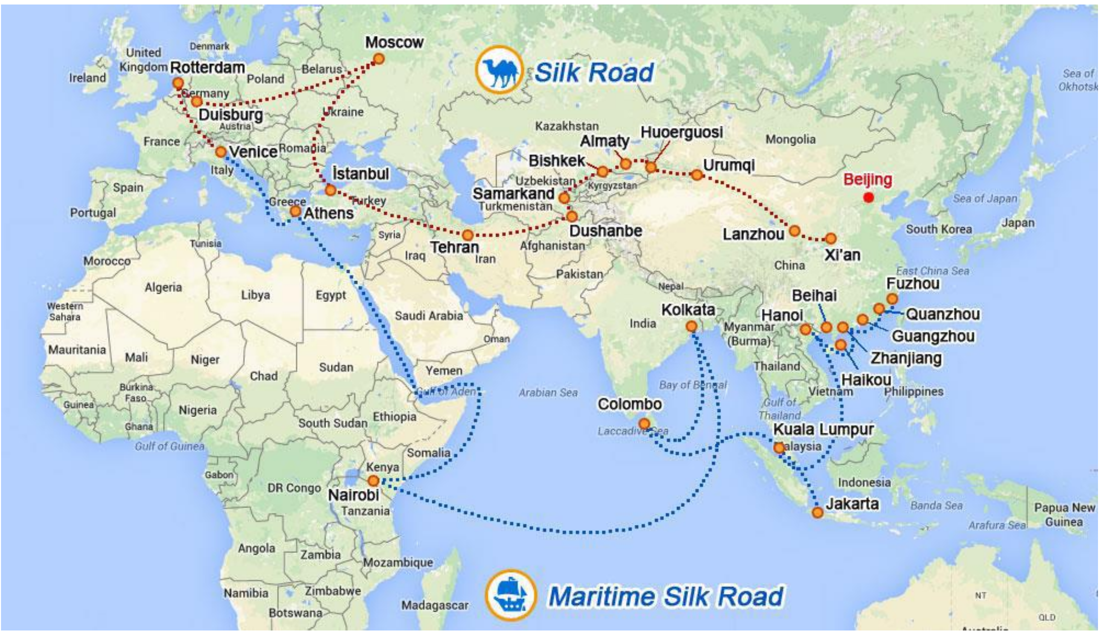


Figure 4-1 Map of Silk Road

Source: Xinhua (2014)

At this point, it can be considered that Athens (Piraeus, Greece) is a strong player against Venice. However, Athens offers a longer land leg against the longer and greener maritime leg of Venice, although Athens is offering a shorter sea route for cargoes which come from Asia. This situation is explained in detail by Costa (2016) as "Venice and the North Adriatic are at the right place to make the Maritime Silk Road greener and with the best time/cost ratio".

As addition to optimising container routes, this case study also seeks to examine the changing container port competition dynamics with the adaptation of OCPS to the specific port competition area. This case study was designed as a study focused on offshore ports and ULCV. The aim of the case study is to be able to calculate the effect of offshore ports that have recently started to be implemented in the container sector on existing port competition among ports which are able to accommodate ULCVs. At this point, it can be said that this case study is important to see the strategic competition positions of the hinterland's leader ports with the effect of changing competition dynamics.

Four container ports are selected to set this case study and they handle more than 30 percent of top 20 ports' container throughputs in Europe. They are the Port of Rotterdam, the Port of Hamburg, the Port of Valencia and the Port of Venice. Due to their locations and the hinterland potentials, the ports of Rotterdam, Hamburg and Valencia ports have a high capacity of container handling. Although the Port of Venice is not one of the largest ports in container transport, it is one of the major port cities in Europe. However the Port of Venice has an aim to improve its position in the Europe container port competition thank to the investment in the OCPS by utilizing its advantageous location. The investment in OCPS may allow handling ULCVs and may also allow being a key port in the container transportation industry for the Port of Venice. Therefore, the Port of Venice can offer a significant alternative route by delivering containers comes from Asia to Europe's important industrial and big cities. Thanks to OCPS, the Port of Venice may take place among the few ports in Europe to be able to accommodate ULCVs. As shown in Figure 4-2, in 2015 the share of top 20 ports in TEUs of containers handled in each port.

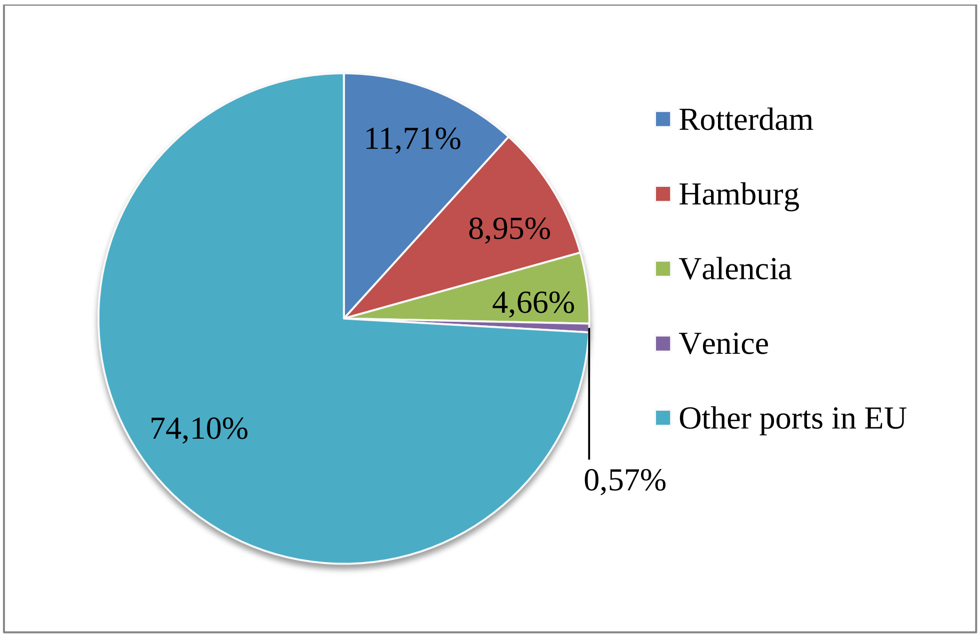


Figure 4-2 Shares of ports in the competition game in Europe, 2015

Source: Adapted from Eurostat (2016a)

Besides handling ULCVs, basic criteria in the selection of ports for the case study; the ranking of port countries in European countries' container throughputs list, the ranking of port within its own country ports excluding the Port of Venice because the Port of Venice is selected as one of the players in the competition due to it has an offshore container port project to accommodate the latest generation of container vessels. Also the draft constraint is another selection criterion for the selection of ports.

In this case, excepting the Port of Venice, other 3 ports are selected among the countries at the top in terms of container throughput by TEU in Europe. Table 4-1 gives the container throughputs of the main European countries.

Table 4-1 Container throughputs of the main European countries

Year	EU (28 countries)		Germany		Spain		Netherlands		Italy	
	Output (thousand)	% change	Output (thousand)	% change	Output (thousand)	% change	Output (thousand)	% change	Output (thousand)	% change
2006	74,225		13,800		12,329		10,063		7,850	
2007	83,195	12.1%	15,261	10.6%	13,536	9.8%	11,260	11.9%	8,539	8.8%
2008	81,942	-1.5%	15,672	2.7%	13,262	-2.0%	11,170	-0.8%	7,942	-7.0%
2009	69,790	-14.8%	11,919	-23.9%	11,677	-12.0%	9,925	-11.1%	7,223	-9.1%
2010	77,679	11.3%	13,092	9.8%	12,424	6.4%	11,202	12.9%	8,466	17.2%
2011	83,107	7.0%	15,240	16.4%	13,858	11.5%	11,447	2.2%	8,480	0.2%
2012	85,244	2.6%	15,290	0.3%	14,059	1.5%	11,523	0.7%	9,298	9.6%
2013	86,560	1.5%	15,563	1.8%	13,550	-3.6%	11,134	-3.4%	9,563	2.9%
2014	92,400	6.7%	15,918	2.3%	14,358	6.0%	11,756	5.6%	10,247	7.2%
2015	98,828	7.0%	15,193	-4.6%	14,347	-0.1%	11,719	-0.3%	11,456	11.8%

Source: Eurostat (2016a)

Therefore, in addition to the Port of Venice, other 3 ports are selected among German, Spanish and Dutch ports depending on the condition that one port from each country. In the selection of ports, as differ from the selection of the Port of Venice, other 3 ports are selected as the largest container ports of the determined countries. Therefore, the Port of Hamburg (Germany), the Port of Valencia (Spain), the Port of Rotterdam (Netherlands) and the Port of Venice are determined as the players of container port competition in this case study.

In addition to countries and ports' rankings in container throughputs, the draft of ports was another criterion for the selection of ports for the purpose of handling ULCVs. Therefore, the minimum draft has been taken 15 metres to be able to handle containerships which have more than 10,000 TEUs carrying capacity (Rodrigue et al., 2013). Table 4-2 gives the maximum draft values of the assigned ports.

Table 4-2 Assigned ports' max drafts

	Draft (m)
Hamburg	15.1
Valencia	17
Rotterdam	22.5
Venice	14.5

Source: SeaRates (2016)

According to Table 4-2, the Port of Venice is not providing the indicated condition. However, Venice Port Authority highlights that an offshore port is planned off the Malamocco port mouth with a natural depth of 20 metre (APV, 2013).

4.1 The Ports in the Competition

In this section some required geographical, technical and statistical information will be presented in relation to the selected ports in order to be able to recognize them. Thus familiarity with the ports will facilitate in order to analysis the location and the planned size and capacity of port.

4.1.1 The Port of Hamburg

The Port of Hamburg is located between the North Sea and the Baltic Sea at a latitude 53 32' N and a longitude 9 57' E. On this location, the Port of Hamburg is the largest seaport of Germany in 2015 with the high volume of cargo crossed the quay walls. The illustration of the Port of Hamburg on map is given in Figure 4-3.

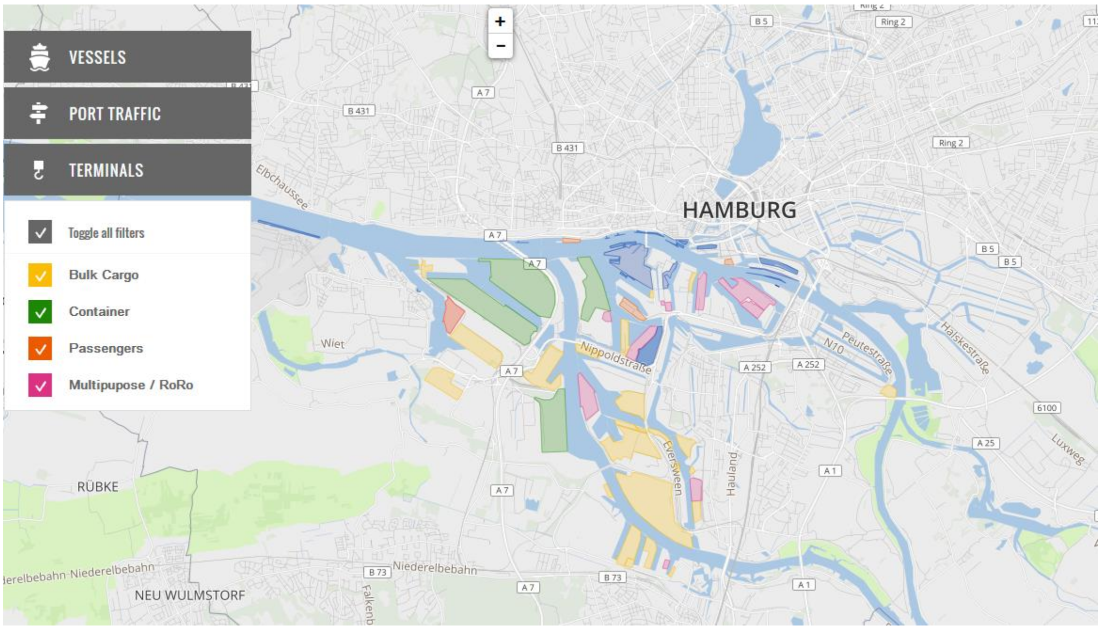


Figure 4-3 Port of Hamburg map

Source: Port of Hamburg (2016)

The port of Hamburg is an attractive port for many European producers and consumers thanks to its excellent hinterland network and connections to Europe. The Port of Hamburg's hinterland network is influentially supported by railway, inland waterway and roadway transportation mode alternatives. According to 2015 statistics, the Railway has emerged as the most important hinterland transport model and 45 per cent of the goods were transported by rail.

When focused on the liner services, it is noted that around 10,000 containerships call the Port of Hamburg every year. In 2015, 647 ULCVs called the Port of Hamburg.

The Port of Hamburg has adequate cargo handling capacity that makes possible to handle a huge number of ULCVs. The port is also one of the most important transhipment hubs of Northern Europe. The advantageous location of port in the entrance of the Kiel Canal where the port can provides feeder services to the significant destinations in Europe. The network corridors of the Port of Hamburg is given in Figure 4-4.

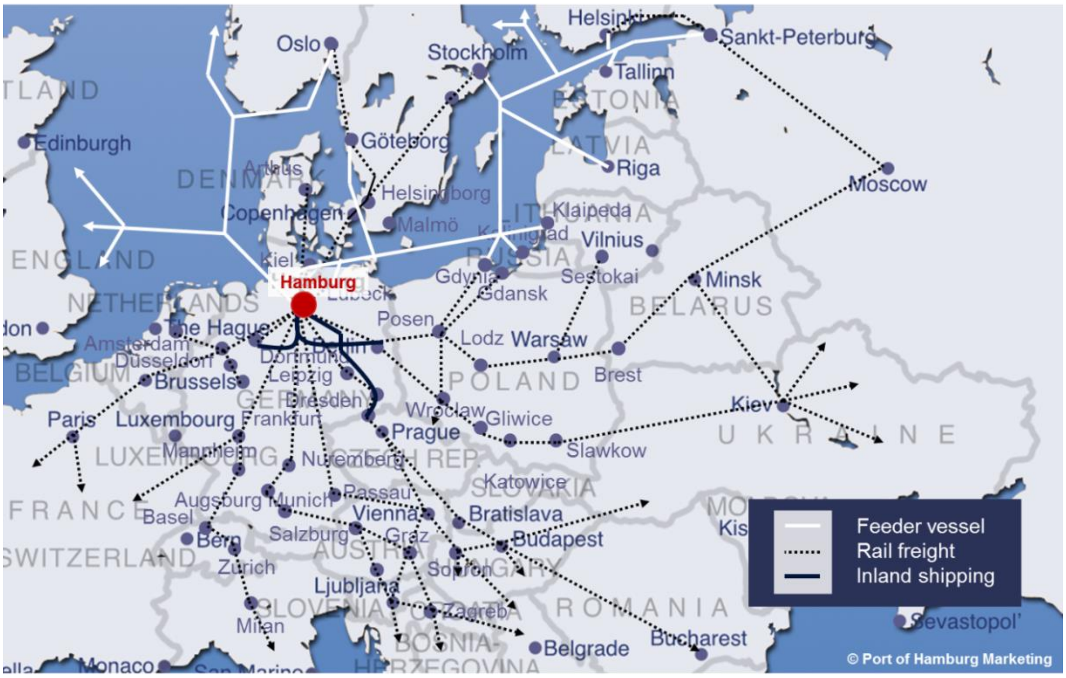


Figure 4-4 Network corridors of the Port of Hamburg

Source: Port of Hamburg (2016)

The port served for the container transportation industry with four state-of-the-art container terminals by handling 8.8 million TEU containers in 2015. The port of Hamburg has also capacity to handle 12 million TEU containers with the high performance handling capability of those four terminals. The 10-year container throughputs of the Port of Hamburg are given in Table 4-3.

Table 4-3 Container throughputs of the Port of Hamburg

Year	Incoming Containers	Outgoing Containers	Total (thousand)	% change
2006	-	-	8,878,000	
2007	-	-	9,914,000	12%
2008	-	-	9,767,000	-1%
2009	-	-	7,031,000	-28%
2010	-	-	7,906,000	12%
2011	-	-	9,035,000	14%
2012	-	-	8,891,000	-2%
2013	-	-	9,302,000	5%
2014	-	-	9,775,000	5%
2015	-	-	8,848,000	-9%

Source: Eurostat (2016a) and Port of Hamburg (2016)

4.1.2 The Port of Valencia

The Port of Valencia is located at the Western Mediterranean Sea at a latitude 39 26' N and a longitude 0 19' W. this location provide several advantageous such as very close commercial port property for the Suez-Gibraltar axis on the main routes from Asia to Northern Europe. Thus, the main shipping lines can have connections to Southern Europe destinations without departing so much from the scheduled route. Because of the geographical advantageous of the Port of Valencia, the shipping lines can provide direct influence for the southern Europe and the North African hinterlands. Thanks to the provided road and rail connection through the southern Europe, the port has efficient hinterland networks. The illustration of the Port of Valencia on map is given in Figure 4-5.

Figure 4-5 Port of Valencia map
Source: Port of Valencia (2016)

Due to the fact that the largest port of Spain, the Port of Valencia addresses a big part of Spain hinterland. The port can be also considered as a hub port for the area of Western Mediterranean and North African countries. This hub port capability of the port is reinforced connections with the main world ports through regular shipping lines.

The high level investments provide a continuous improvement in the regional and international container port competition for the Port of Valencia. The specialization of the Port of Valencia's terminals for the 2020 Horizon aims to focus on a combination of import/export and transit containers. The network corridors of the Port of Valencia is given in Figure 4-6.

Figure 4-6 Network corridors of the Port of Valencia
Source: Port of Valencia (2016)

There are three ports under the management of the Port Authority of Valencia. They are the Port of Valencia, the Port of Sagunto and the Port of Gandia. The ports controlled by the Port Authority of Valencia have handled 4.6 million TEU of container in 2015. The 10-year container throughputs of the Port of Valencia are given in Table 4-4.

Table 4-4 Container throughputs of the Port of Valencia

Year	Incoming Containers	Outgoing Containers	Total	% change
2006	-	-	2,615,000	
2007	-	-	3,049,000	17%
2008	-	-	3,606,000	18%
2009	-	-	3,654,000	1%
2010	-	-	4,211,000	15%
2011	-	-	4,332,000	3%
2012	-	-	4,471,000	3%
2013	-	-	4,328,000	-3%
2014	-	-	4,407,000	2%
2015	-	-	4,609,000	5%

Source: Eurostat (2016a) and Port of Valencia (2016)

4.1.3 The Port of Rotterdam

The port is located at West Coast of the city of Rotterdam, Netherlands at a latitude of 51 53' N and a longitude of 4 17' E. Thanks to accommodating largest containerships, the port offers an outstanding accessibility for ocean-going vessels with its leading position for throughput. The port of Rotterdam has Europe's largest container port throughput. The illustration of the Port of Rotterdam on map is given in Figure 4-7.

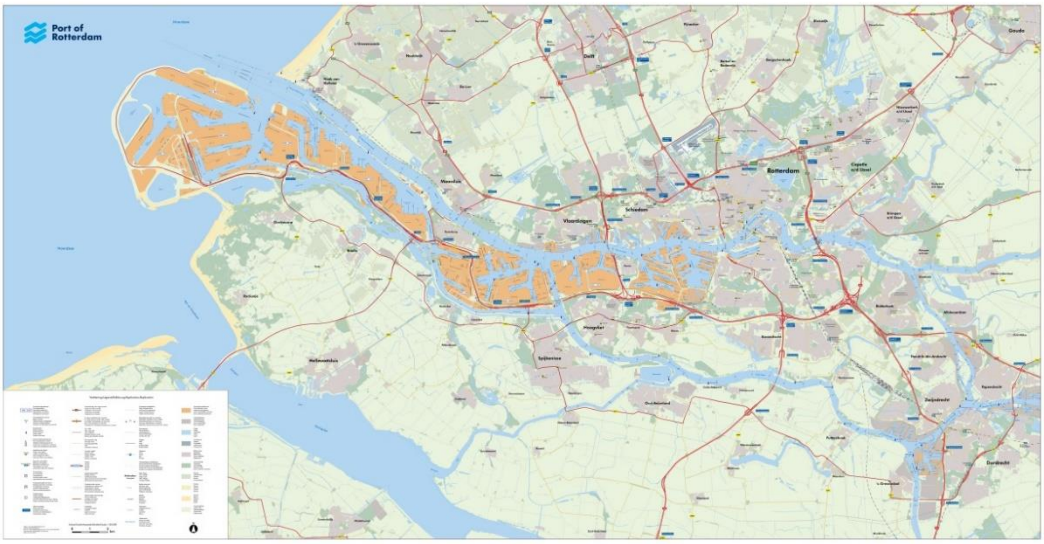


Figure 4-7 Port of Rotterdam map

Source: Port of Rotterdam (2016)

Rotterdam Port offers more than 1000 connections to ports worldwide. The Port of Rotterdam can be defined as both a main hinterland port and a transhipment port, due to the fact that the liner companies' main port of call and has a significant intermodal network. Thanks to the advanced transportation network, logistics operations can be operated smoothly, safely and quickly towards important industrial points in Europe via the Port of Rotterdam. The network corridors of the Port of Rotterdam is given in Figure 4-8.

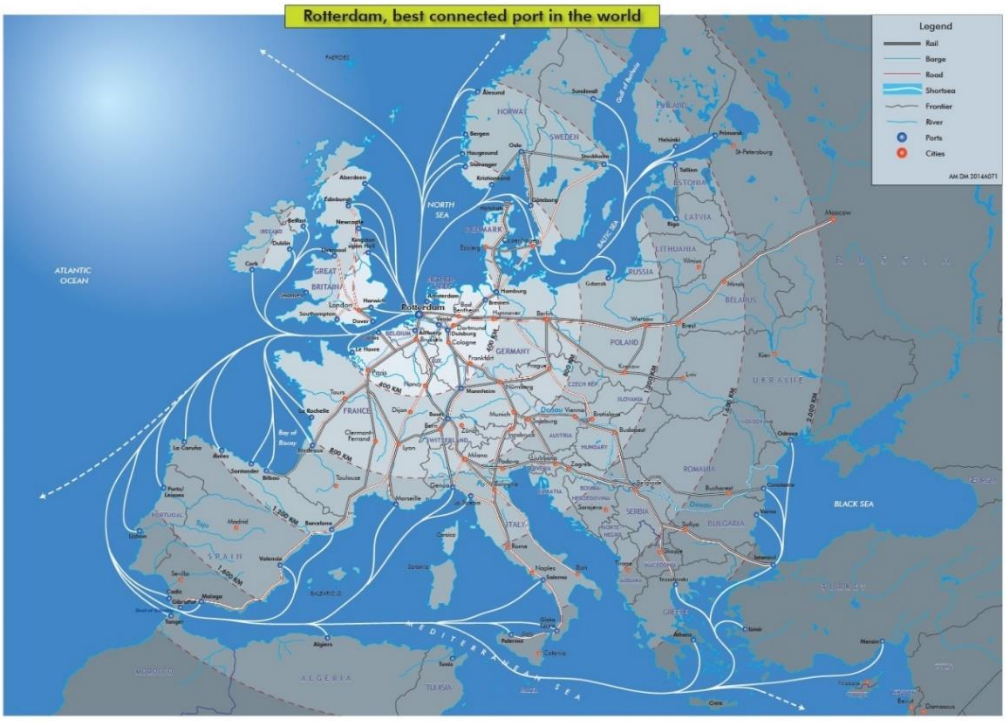


Figure 4-8 Network corridors of the Port of Rotterdam

Source: Port of Rotterdam (2016)

The Port of Rotterdam is the largest container port in Europe with its more than 12 million TEU handling volume annually. According to port statistics, the Port of Rotterdam could able to handle more than 12 million TEUs at 9 container terminals in years 2014 and 2015 (2016). The Port of Rotterdam can also handle the latest generation of container vessels. The 10-year container throughputs of the Port of Rotterdam are given in Table 4-5.

Table 4-5 Container throughputs of the Port of Rotterdam

Year	Incoming Containers	Outgoing Containers	Total	% change
2006	4,963,545	4,689,687	9,653,232	
2007	5,527,754	5,263,075	10,790,829	12%
2008	5,496,152	5,287,673	10,783,825	0%
2009	4,962,424	4,780,866	9,743,290	-10%
2010	5,692,211	5,455,361	11,147,572	14%
2011	6,099,586	5,777,314	11,876,900	7%
2012	6,078,355	5,787,561	11,865,916	0%
2013	6,032,414	5,588,631	11,621,045	-2%
2014	6,415,409	5,882,161	12,297,570	6%
2015	6,351,594	5,882,941	12,234,535	-1%

Source: Port of Rotterdam (2016)

4.1.4 The Port of Venice

The location of the Port of Venice is given by the Venice Port Authority (APV, 2013) that the port is located at the top end of the Adriatic Sea at a latitude of 45 26' N and a longitude of 12 20' E. The port has a strategic geographical location at the intersection of the main European transport corridors and of the Motorways of the Sea (MoS). The Port of Venice can act as the European gateway for Asia trade flows. The illustration of the Port of Hamburg on map is given in Figure 4-9.

Figure 4-9 Port of Venice map

Source: Port of Venice (2016)

The Port of Venice can act as the entry point to a vast area of Central Europe thanks to containerization's "window of opportunity" because of the strategic location of the Port of Venice in the Adriatic Sea. Thus the Port of Venice can provide access to North-Eastern Italy, Austria and Bayern in addition to Eastern Europe and some of the European Union's most dynamic markets. The Port of Venice can be also considered as a bridge to connect Central Europe with North Africa and the Middle East. The network corridors of the Port of Venice can be given as a part of core network corridors of Europe in Figure 4-10.

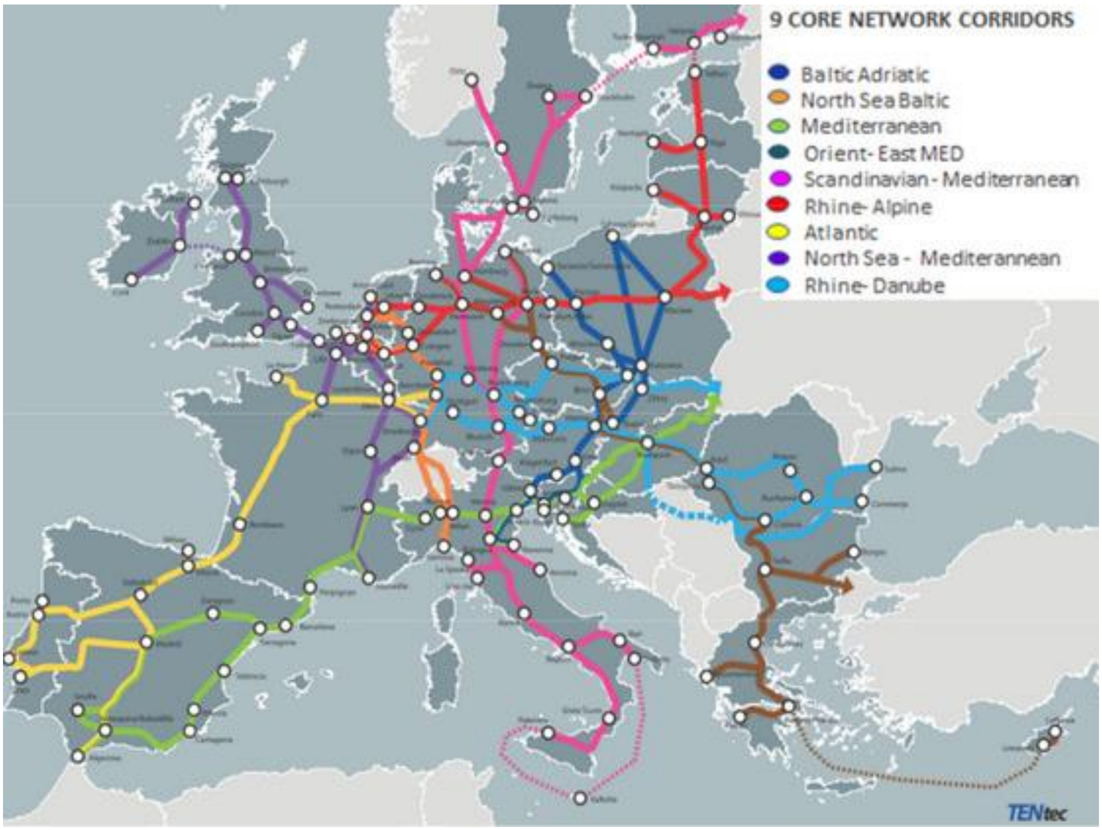


Figure 4-10 Network corridors of the Port of Venice

Source: Port of Venice (2016)

The Port of Venice is one of main ports in the Adriatic Sea for container operations. So it can be said that the successful strategy can create opportunity for the Port of Venice to exploit transhipment system. Owing to the developments that took in the container industry, the container port competition has increased in the European area. The Venice Port Authority then planned to improve the Port of Venice's infrastructures to facilitate the future with the following projects (APV, 2013).

- A new container terminal at Marghera,
- A Motorways of the Seas terminal at Fusina,
- An offshore terminal to enable access to ships with a draft up to 20 metres.

The 10-year container throughputs of the Port of Venice are given in Table 4-6.

Table 4-6 Container throughputs of the Port of Venice

Year	Incoming Containers	Outgoing Containers	Total	% change
2006	167,095	149,547	316,642	
2007	184,322	145,190	329,512	4.1%
2008	204,031	175,041	379,072	15.0%
2009	197,282	172,192	369,474	-2.5%
2010	207,419	186,494	393,913	6.6%
2011	238,609	219,754	458,363	16.4%
2012	237,589	192,304	429,893	-6.2%
2013	246,669	199,759	446,428	3.8%
2014	249,515	206,553	456,068	2.2%
2015	301,014	259,287	560,301	22.9%

Source: Port of Venice (2016)

According to the analysis of ports, it can be seen that the Port of Venice has a special situation although the port do not have so high volume of container handling capacity in comparison with other ports in this case. This situation is that an OCPS was planned by the Authority of Venice Port but President of Venice Port Authority is in belief that such a project is unsustainable for the Adriatic region. The reason behind this idea is that the total container capacity of the entire Adriatic Region, not just the Port of Venice, will not reach 6 million TEU by 2030 and mega-ships will not prefer the regional ports due to they favour the transhipment ports (Dell'Antico, 2017). Analyses and other project-based studies carried out in the previous port administration term have shown that an offshore port to be built in Venice would provide a significant added value for the region and European container network with the contribution of advantageous state of the region (Costa, 2016, Rowland, 2015). The Port of Venice is also seen as a gateway of maritime Silk Road along with the Port of Piraeus in Greece in the scope of “one belt one road”(Yang and

Jiang, 2016). Thus the Port of Venice can use its location effectively for the container transportation from Asia to Europe hinterland.

4.2 Location Analysis of the Ports

The location analysis is intended to determine the positions of the ports designated for the case in the new competitive environment due to the inclusion of the new offshore based container transportation system. The analysis is conducted in order to assess the ports in terms of transportation time and cost depending location and local traffic of the ports. The generated transportation network for this analysis includes the transport of containers loaded from an Asian port to the selected cities and regions through four European ports identified as well as the transfer of container with alternative hinterland transportation modes.

In the generated transportation network, the Port of Singapore is considered as the last call port on the Asia leg of network, the designated four European ports for this case are generating the Europe leg of network. The representation of the proposed container transport network from Asia to Europe and the used route are simply given in Figure 4-11 with the aid of legends.

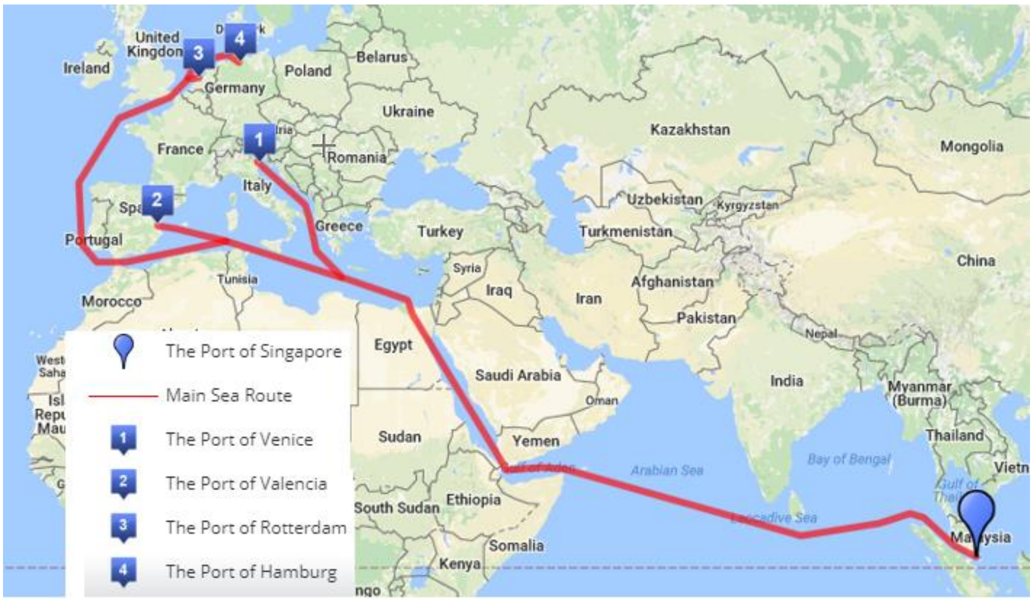


Figure 4-11 Network map

Source: Created by author on ScribbleMaps (2017)

In practice, in the context of intercontinental container transportation, the vessels complete a round-trip by calling numerous ports. The largest container shipping company Maersk-Line carries out its Asia-Europe services with minimum 9 port calls and they can reach up 15 port calls (MAERSK, 2017b). In this case, it is assumed that no other port of call should be planned between the designated ports. The other port of calls on the round trip are planned to be either before the last port of call in Asia or after the destination port in Europe. The aim of which is to establish direct voyages between the last port of call in Asia and the designated European ports. In this way, the influence of the ports, which will be located between the two target-ports, on the Asia-Europe direct container transportation network can be abolished. Therefore it is envisaged that the effect of the container transhipments through the destination ports identified in Europe on the door-to-door container network can be seen plainly. Taking this direct voyage plan into consideration, the container vessels raise anchor from the last port of call in Asia and travel to the ports in Europe via the Suez Canal by taking the shortest route.

In this defined container transportation network, the containers are transferred to the final transportation stage of the network through alternative transport modes (trucks, trains and inland waterway vehicles-barge, feeder vessel) at the ports identified in Europe to be delivered to the target cities located in Europe. All the ports and transport vehicles are assumed to have the same technical descriptions in order to obtain a comparable travel time when the entire defined route is elaborated. In addition, the ports are considered to serve the same hinterlands, and the travel times from the same destination for each designated port are compared. The time calculations are made by ignoring waiting time and idle time that may occur during transportation and other operations. It means that the analysis ignores the waiting for canal passages, the time at anchorage, for pilotage and any idle at loading and discharging port during the sea passage of main container vessel. It is also assumed that the idle time of trucks, trains and inland waterway services are ignored.

In the analysis, comparisons were also made with respect to different speed data. It has been investigated at which speed more optimal transport network can be obtained. At seaway stage, the analysis is conducted at the speed range between 13-25 knots for the main container vessels. The speed range of 13-25 knots is technically feasible but the tendency of container liner companies is to operate containerships at optimum speed in the consideration of two factors which are keeping stable commercial services, and fuel saving approaches (Rodrigue et al., 2013). Therefore, the operation speed for the main containerships has been taken 19 knots by considering fuel saving and practices in the container transportation industry according to the study of Rodrigue et al. (2013) who define 4 speed ranges as follows. Normal speed range: 20-25 knots, slow steaming speed range: 18-20 knots, extra slow steaming speed range: 15-18 knots and minimal cost speed range: 12-15 knots. In terms of the transportation time, the increasing speed provides time saving in total transportation but it causes extra cost due to more fuel consumption as seen the defined speed-fuel consumption relationship in Equation 3.35. Figure 4-12 represents the fuel consumption changes regarding to ship size and speed.

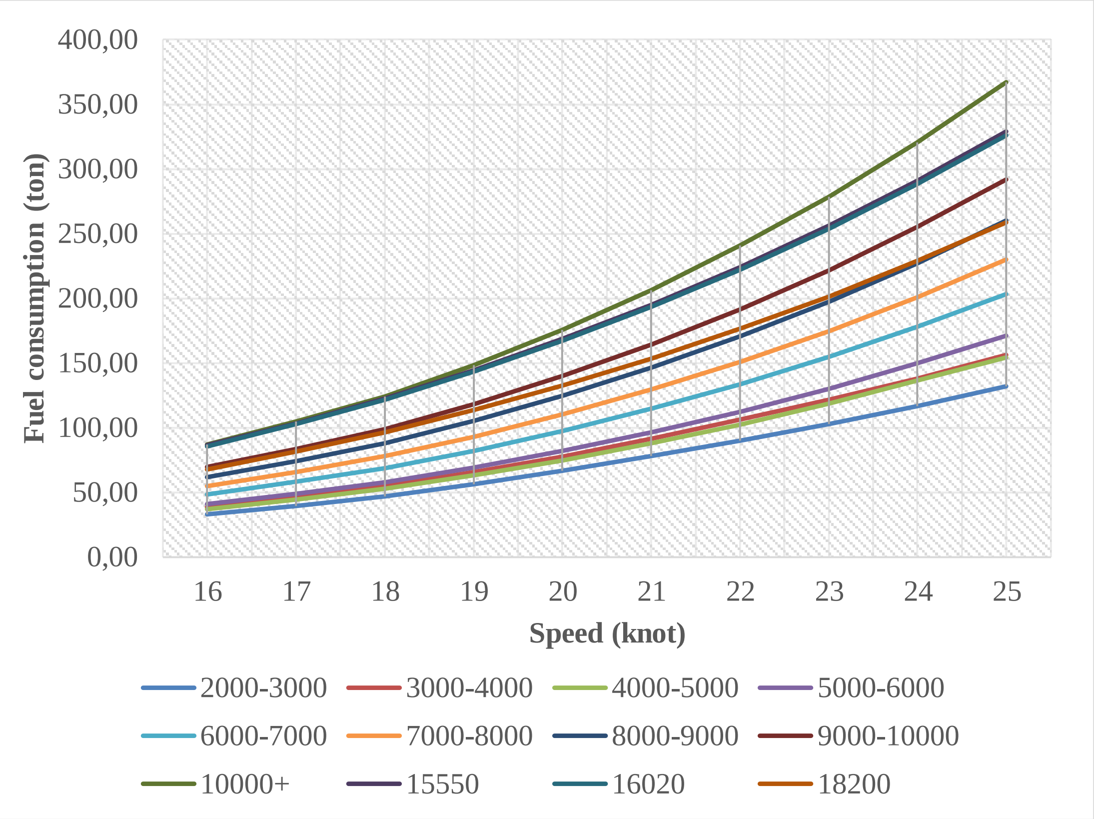


Figure 4-12 Fuel Consumption by Containership Size and Speed

Source: Adapted from Notteboom and Cariou (2009)

The speeds of vehicles vary depending on traffic and road conditions at hinterland connections. For this reason, in consideration of the general conditions, a certain average speed criterion has been introduced for the vehicles which are transporting to the hinterland. For example, the average speed for trucks used to reach the containers to the final destinations is taken as 50 km / h by considering stop-and-go and urban and rural traffic combinations (Statista, 2017a, Statista, 2017b, EU, 2017a).

In fact that this analysis covers the door-to-door container transportation network in addition to the inter-port transport network. At this point, the cities and regions, which are dominated by important cities and regions of Europe in terms of economy and population density, are chosen as the final destination of door-to-door container transportation network. A pre-elimination is carried out for the selection of final destinations according to the geographical and strategic importance of them. After pre-elimination, the final destinations are classified under three different categories. As a result of elimination process, the container transportation network analysis is conducted for 29 cities in total under three categories. They are located in the accessible hinterland of the determined European ports. Those of categories are namely: (1) the top 10 EU capital cities in terms of the countries' population on the ports' hinterland, (2) the top 9 regions in terms of GDP (Gross Domestic Product)'s of regions on the ports' hinterland, and (3) the top 10 lowest manufacturing-cost regions on the ports' hinterland.

4.2.1 Time and Cost Analysis for the Major Capitals in Europe

The network is designed in form of the voyage of containers begins at the major port city of Asian - Singapore and will end up in 10 major European capitals. The determined major European capitals are represented in Table 4-7.

Table 4-7 Assigned ports and the major capitals in Europe, group 1

Port				Final Destinations	
Departure Port		Arrival Port		Capital Cities	
				1	Berlin
				2	Paris
				3	Rome
	Singapore	1	Venice	4	Madrid
		2	Valencia	5	Warsaw
		3	Rotterdam	6	Bucharest
		4	Hamburg	7	Amsterdam
				8	Brussels
				9	Athens
				10	Prague

In Table 4-7, the ports and destinations are categorized within groups. In the table, the dark blue column represents the Port of Singapore, the blue column represents the arrival ports, and the red column represents the determined capital cities in Europe. The assigned ports and destinations are geographically illustrated on the map in Figure 4-13 excluding the Port of Singapore. However, the Port of Singapore has shown with a dark blue colour-paddle in Figure 4-11 to able to supply visibly more focused illustration on Europe section of the network. The blue markers in numbers from 1 to 4 also symbolize the arrival ports at the Europe leg of network and the white markers in numbers from 1 to 10 symbolize the final destinations on the Europe hinterland. Here, the red dashed line represents the Port of Venice's hinterland network, and the yellow dashed line, the green dashed line and the blue dashed line represents the Port of Valencia, the Port of Rotterdam and the Port of Hamburg, respectively.

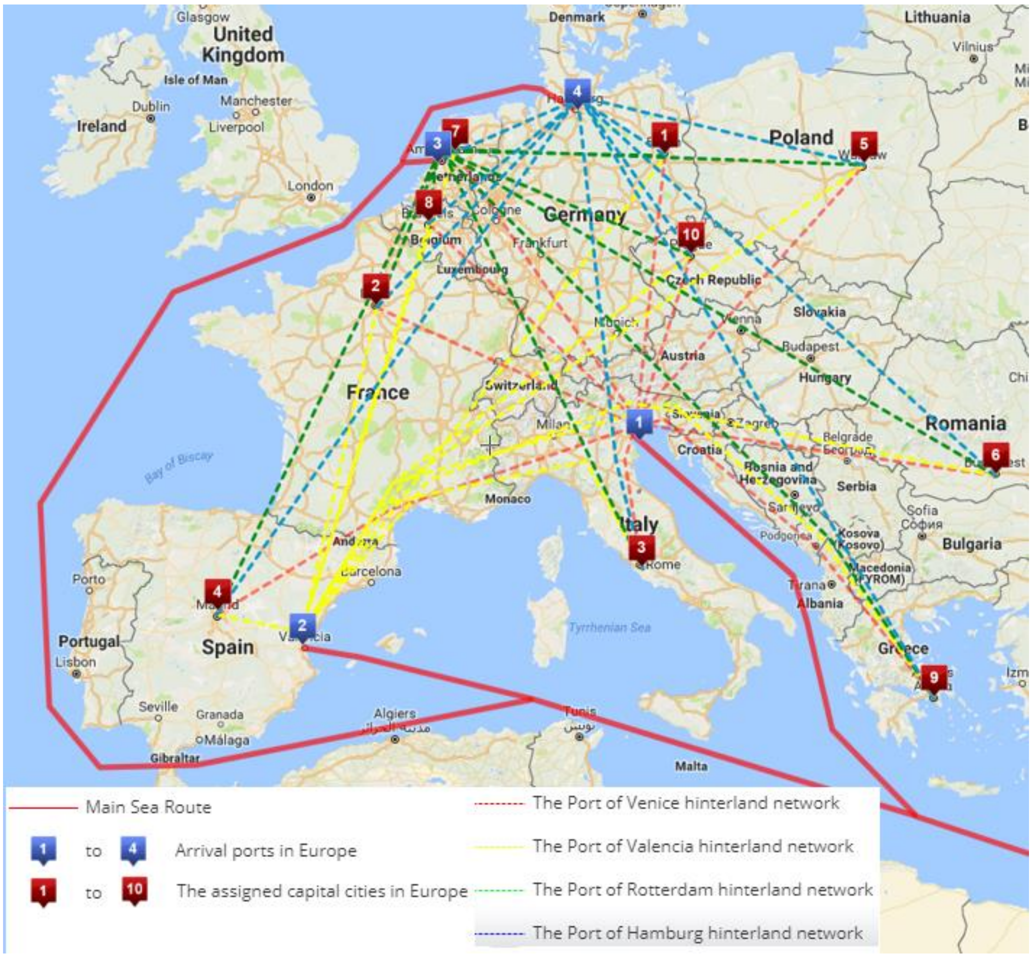


Figure 4-13 Arrival ports' hinterland network for the major capitals in Europe
Source: Created by author on ScribbleMaps (2017)

Within the specified criteria for the conducted case study, the transportation times from the Port of Singapore to the major European capitals are represented in Figure 4-14. It is obviously seen from the results obtained that the Port of Venice offers a more advantageous container transportation network compared to the other designated ports. The main reason for obtaining these results can be shown that the Port of Venice can provide the shortest sea route due to its location for the containers coming from Asia. The proposed maritime transport times at a 19-knot ship speed are compared, the Port of Venice can offer roughly 1, 4 and 5 days shorter routes for the Port of Valencia, the Port of Rotterdam and the Port of Hamburg, respectively. Thus, the Port of Venice has a significant advantage in terms of total transportation time, even if it has disadvantageous in the roadway section. According to the results obtained, the Port of Venice can provide to reach containers to all the designated capitals in the shortest time except for the city of Madrid. Even this is valid for the capital cities such as Berlin, Amsterdam and Brussels which are within a few hours' distance to the port of Rotterdam and the Port of Hamburg.

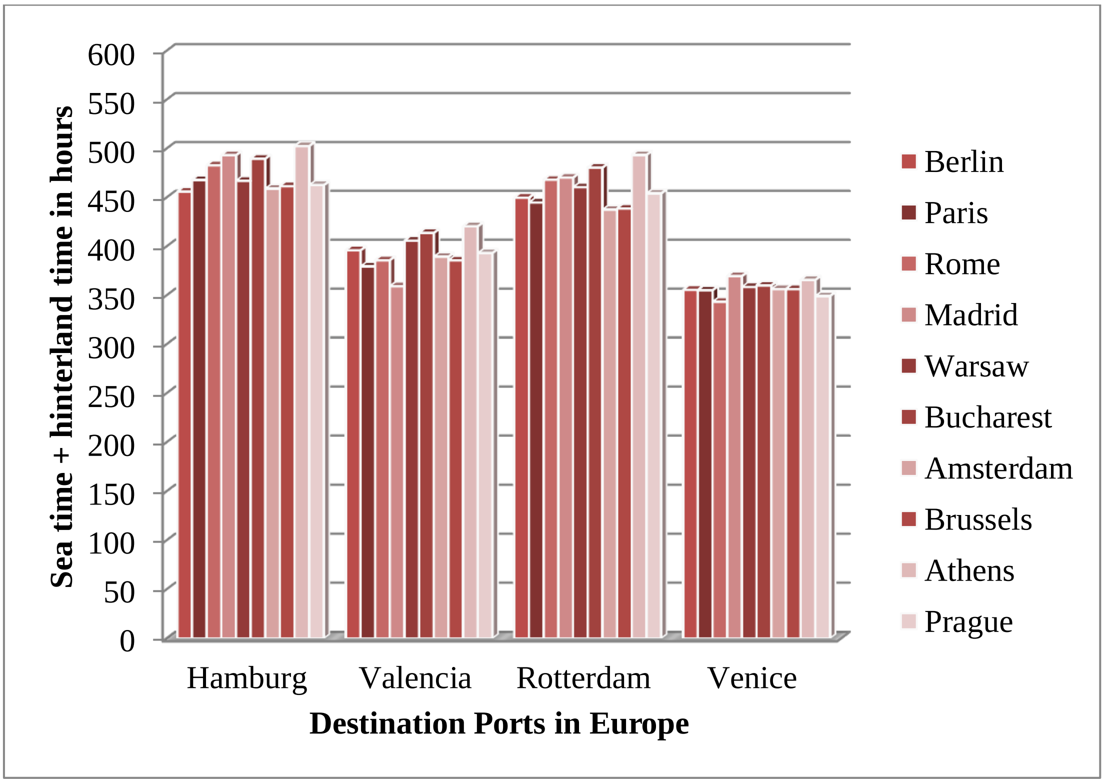


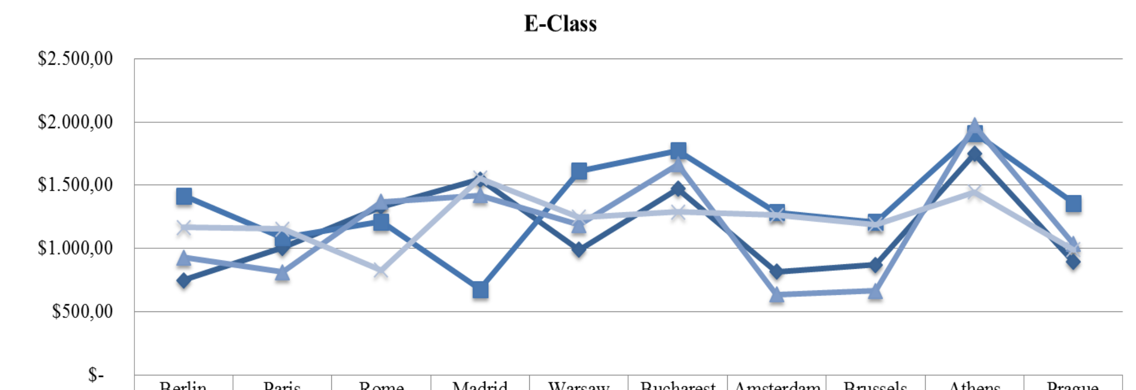
Figure 4-14 Transportation time analysis for the selected major capitals in Europe

It is clear that the ports of Venice and Valencia offer much better rates than the ports in northern Europe in terms of total transport times. In this case it is possible to say that the ports of Venice and Valencia have the best times in terms of total transportation time, while the times of Rotterdam and Hamburg are far behind them for Asian freight. It can be said that the ports of Venice and Valencia have a significant advantage over the ports of northern Europe in terms of the total transport times of Asian containers. As previously mentioned, the delays, waiting and idle times were not taken into account when these results were obtained. Thus obtaining more realistic results depends on all the operational periods in the transportation process which loading, unloading, custom services, transfers and so on.

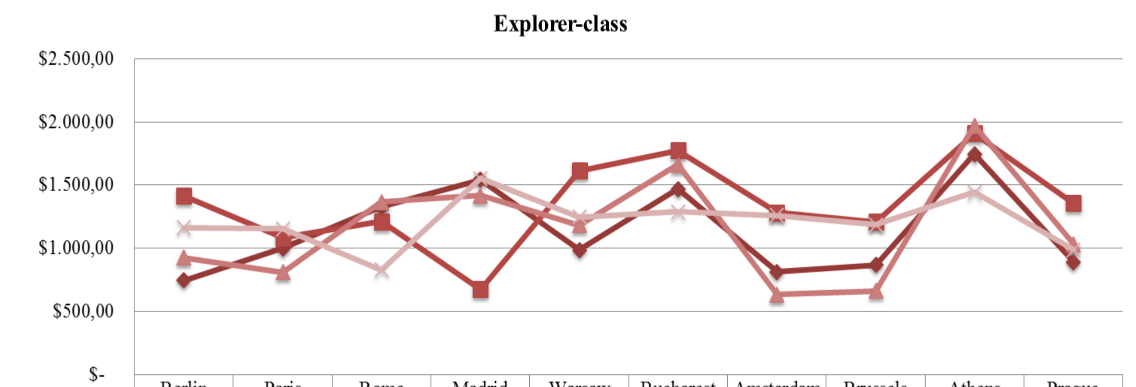
In terms of total transport times, the ports of Venice and Valencia obtain really surprising and positive values even for the most northern capitals selected for this case. Especially, the Port of Valencia offers the longest roadway distance in total for the destinations and it is longer than the closest competitor (the Port of Venice) by more than 8,000 km. However, the Port of Valencia may offer shorter total transportation times for the assigned destinations thanks to the shorter sea leg of network.

It cannot be denied that a higher share of the highway in the total duration of transport provides a significant advantage for the containers traded on the ports of Venice and Valencia. However, it cannot be also ruled out that high road use rates will be disadvantageous in terms of transportation costs. The improvement of transportation costs depends on the efficient use of the vehicles and resources used, as well as the most effective application of operational solutions. In terms of the total transportation cost, operational solutions can be effective to create more sustainable transportation network design. The technical specifications of vehicles used through the network have also obvious impact on the improvement of transportation cost. ULCVs, which are developed in terms of technical and productivity, enable transportation to be more economically and efficiently transported on the sea leg. However, in order to be able to see the effect of the vessels on the efficiency and to see the port competition in terms of costs, analysis is carried out for vessels with different dimensions and technical data. So, three different types of ULCVs are used to able to see the impact of technical specs of those vessels on the total transportation cost.

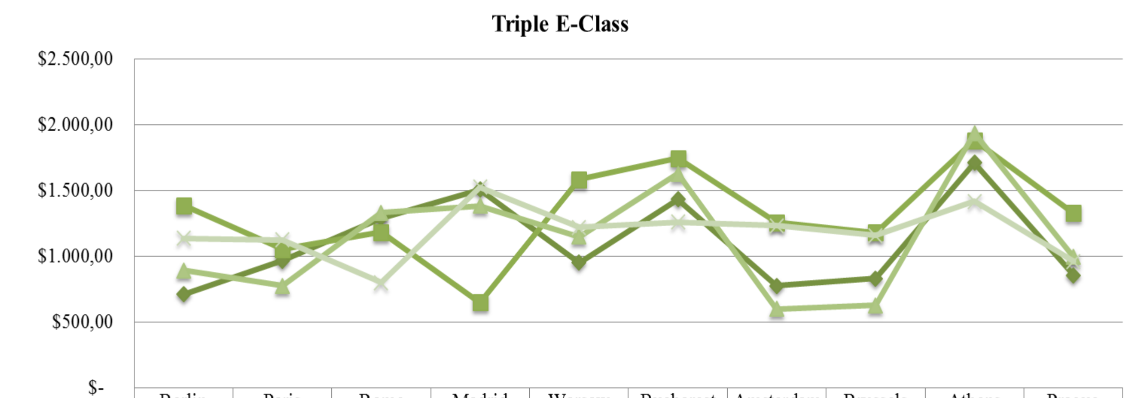
The following graphs in Figure 4-15 give the total transport costs for the three different types of container vessels operating in the container network from Asia to the designated European capitals as a result of the analysis carried out. The types of vessels used are known as E-class, Explorer Class and Triple E-Class with 15,500, 16,000 and 18,000 TEU carrying capacities, respectively. The obtained cost values are given in 3 separate charts according to the specifications of vessels. The obtained figures give the costs for a container which is loaded in Asia and transported to the designated European cities.



	Berlin	Paris	Rome	Madrid	Warsaw	Bucharest	Amsterdam	Brussels	Athens	Prague
Hamburg	$748,55	$1.005,16	$1.329,89	$1.547,52	$989,74	$1.472,55	$815,81	$870,65	$1.748,87	$893,78
Valencia	$1.418,29	$1.085,47	$1.213,76	$679,24	$1.614,75	$1.775,31	$1.286,78	$1.210,53	$1.912,46	$1.359,39
Rotterdam	$929,69	$812,49	$1.370,28	$1.420,99	$1.186,11	$1.665,92	$637,88	$666,11	$1.974,48	$1.033,98
Venice	$1.165,78	$1.155,26	$831,00	$1.555,33	$1.248,78	$1.290,28	$1.262,61	$1.188,46	$1.446,33	$990,36



	Berlin	Paris	Rome	Madrid	Warsaw	Bucharest	Amsterdam	Brussels	Athens	Prague
Hamburg	$745,35	$1.001,96	$1.326,69	$1.544,32	$986,54	$1.469,35	$812,61	$867,45	$1.745,67	$890,58
Valencia	$1.415,86	$1.083,05	$1.211,33	$676,82	$1.612,32	$1.772,88	$1.284,35	$1.208,11	$1.910,04	$1.356,96
Rotterdam	$926,60	$809,40	$1.367,19	$1.417,90	$1.183,02	$1.662,83	$634,79	$663,02	$1.971,39	$1.030,89
Venice	$1.163,48	$1.152,97	$828,70	$1.553,04	$1.246,48	$1.287,98	$1.260,32	$1.186,17	$1.444,03	$988,07



	Berlin	Paris	Rome	Madrid	Warsaw	Bucharest	Amsterdam	Brussels	Athens	Prague
Hamburg	$708,15	$964,76	$1.289,49	$1.507,12	$949,34	$1.432,15	$775,41	$830,24	$1.708,46	$853,38
Valencia	$1.386,17	$1.053,35	$1.181,64	$647,12	$1.582,63	$1.743,18	$1.254,65	$1.178,41	$1.880,34	$1.327,27
Rotterdam	$890,46	$773,26	$1.331,05	$1.381,76	$1.146,88	$1.626,69	$598,65	$626,88	$1.935,25	$994,75
Venice	$1.135,13	$1.124,61	$800,35	$1.524,69	$1.218,13	$1.259,63	$1.231,96	$1.157,81	$1.415,68	$959,71

Figure 4-15 Total transportation costs for the designated capitals in Europe by three different vessel types[3]

[3] For the details of calculations, assumptions and sources please see Appendix A and Appendix B.

The graphs obtained show that the economy of scale has the effect on total transportation costs depending on the ship characteristics changing. Thanks to the growing ship capacities, the fuel, personnel and port costs per unit container are decreasing. The container ship with the largest capacity for all the designated destinations offers transportation at a lower unit cost. The cost results obtained are calculated in accordance with the equations in section 3.4. These costs are calculated as ship costs (operating costs and voyage costs), port charges excluding cargo handling, container handling costs and other possible container operation costs, administration costs and inland transportation costs and the results are obtained. However, events such as unexpected strike, accident etc. have been ignored because they could create extra cost that would not be predicted by size. The data used in calculations have been tried to be used in the most up-to-date manner possible.

In Table 4-8, the cost of the designated ports is given in an order for each selected European capital according to Figure 4-15. A coefficient is given to each port on the basis of the costs they incurred according to the obtained order in Table 4-8. The coefficient scores obtained from the designated cities for each of the designated ports are shown in Table 4-9. According to the total score obtained in the case study, the container transportation for the major capitals of Europe at minimal cost can be achieved through the Port of Hamburg. The Port of Hamburg offers a door-to-door transportation with the lowest cost among other ports determined by the total score of 31 points. The Port of Hamburg is followed by the Port of Rotterdam with 27 points, the Port of Venice with 25 points and finally the Port of Valencia ports with 17 points.

When the scores obtained are examined in detail, it is not right to say that the Hamburg port has the lowest cost of transport for each capital city. However, the Port of Hamburg is offering transportation for 3 capital cities (Berlin, Warsaw and Prague) at the lowest cost which is proved to be the most powerful player for these cities. Although the ports of Rotterdam and Venice also offer the lowest costly transportation for 3 capitals (the Port of Rotterdam for Paris, Amsterdam and Brussels; the Port of Venice for Rome, Bucharest and Athens), the port of Hamburg has the highest score in total with the second lowest costly transportation opportunity for the five capitals (Paris, Bucharest, Amsterdam, Brussels and Athens).

Table 4-8 Sorting of ports by total transportation costs for the designated capitals in Europe

	Berlin	Paris	Rome	Madrid	Warsaw	Bucharest	Amsterdam	Brussels	Athens	Prague
1st Cheapest	Hamburg	Rotterdam	Venice	Valencia	Hamburg	Venice	Rotterdam	Rotterdam	Venice	Hamburg
2nd Cheapest	Rotterdam	Hamburg	Valencia	Rotterdam	Rotterdam	Hamburg	Hamburg	Hamburg	Hamburg	Venice
3rd Cheapest	Venice	Valencia	Hamburg	Hamburg	Venice	Rotterdam	Venice	Venice	Valencia	Rotterdam
4th Cheapest	Valencia	Venice	Rotterdam	Venice	Valencia	Valencia	Valencia	Valencia	Rotterdam	Valencia

Table 4-9 Coefficients of the ports according to their total transport costs for the designated capitals in Europe

	Hamburg	Valencia	Rotterdam	Venice
Berlin	4	1	3	2
Paris	3	2	4	1
Rome	2	3	1	4
Madrid	2	4	3	1
Warsaw	4	1	3	2
Bucharest	3	1	2	4
Amsterdam	3	1	4	2
Brussels	3	1	4	2
Athens	3	2	1	4
Prague	4	1	2	3
Total	**31**	**17**	**27**	**25**

While the Port of Hamburg is providing transportation opportunity for 5 capitals of as the second lowest-cost port that enables the port to be the lowest costly port in total, similar situation can be said for the Port of Rotterdam. Because, the Port of Rotterdam is the second most cost-effective port in total ahead of the Port of Venice with a 2-point different thanks to the opportunity which can be offered by the Port of Rotterdam for 3 capital cities (Berlin, Madrid and Warsaw). The Port of Venice can offer the second most cost-effective transportation opportunity for just one capital (Prague). This can be also applied for the Port of Valencia (Rome).

As the most cost-effective third port, the Port of Venice can offer the third lowest costly transportation for the 4 capitals (Berlin, Warsaw, Amsterdam and Brussels), while the other ports can offer the third lowest cost transportation opportunity for the two capitals (the Port of Hamburg for Rome and Madrid; the Port of Rotterdam for Bucharest and Prague; and the Port of Valencia for Paris and Athens).

Among the selected ports for this case study, the Port of Valencia is determined as the most costly port for the designated capitals. The Port of Valencia can offer the most costly transportation for the 6 capitals (Berlin, Warsaw, Bucharest, Amsterdam, Brussels and Prague), the Port of Rotterdam and the Port of Venice can offer the most costly transportation for the two capitals (The Port of Rotterdam for Rome and Athens; and the Port of Venice for Paris and Madrid). The Port of Hamburg does not offer the most costly transportation for any capital city.

4.2.2 Time and Cost Analysis for the High-GDP Regions in Europe

As a second part of total transportation and cost analysis, this part is designed for 9 regions that make the most contribution to GDP. In this part, the total transportation time and cost analysis of the container transport network to distribute the containers from Asia to the designated 9 high GDP regions as in the first part (Eurostat, 2017c, Eurostat, 2017b, Eurostat, 2016c, Eurostat, 2016b). The reason for the selection of 9 target regions in this group is that the tenth region is analysed in the first group.

Table 4-10 shows the regions or cities from Eurostat’s urban audit program (Eurostat, 2016c). As in section 4.2.1, in this stage of case study, the Port of Singapore is assigned as last departure port on Asia side and likewise in section 4.2.1, the same four ports are also assigned as the arrival ports for Europe side.

Table 4-10 Assigned ports and high-GDP regions in Europe, group 2

Port				Final Destination	
Departure Port		Arrival Port		High-GDP regions	
				1	Ruhr
				2	Randstad
				3	Barcelona
	Singapore	1	Venice	4	Milan
		2	Valencia	5	Frankfurt
		3	Rotterdam	6	Munich
		4	Hamburg	7	Vienna
				8	Lisbon
				9	Stuttgart

In Table 4-10, the dark blue column represents the Port of Singapore, the blue column represents the arrival ports, and the green column represents the high-GDP regions. The locations of assigned ports and regions have also been illustrated on the map in Figure 4-16. The hinterland network for the assigned regions is also shown in the following figure. The determination of regions as a final destination has been made according to the provided data from Eurostat (2016c) which identifies agglomerations using the Urban Audit's Functional Urban Area. The selection of these agglomerations has been among top 15 regions in EU in terms of GDP. Other 6 of regions has been eliminated due to they had been used in group 1 of this case study.

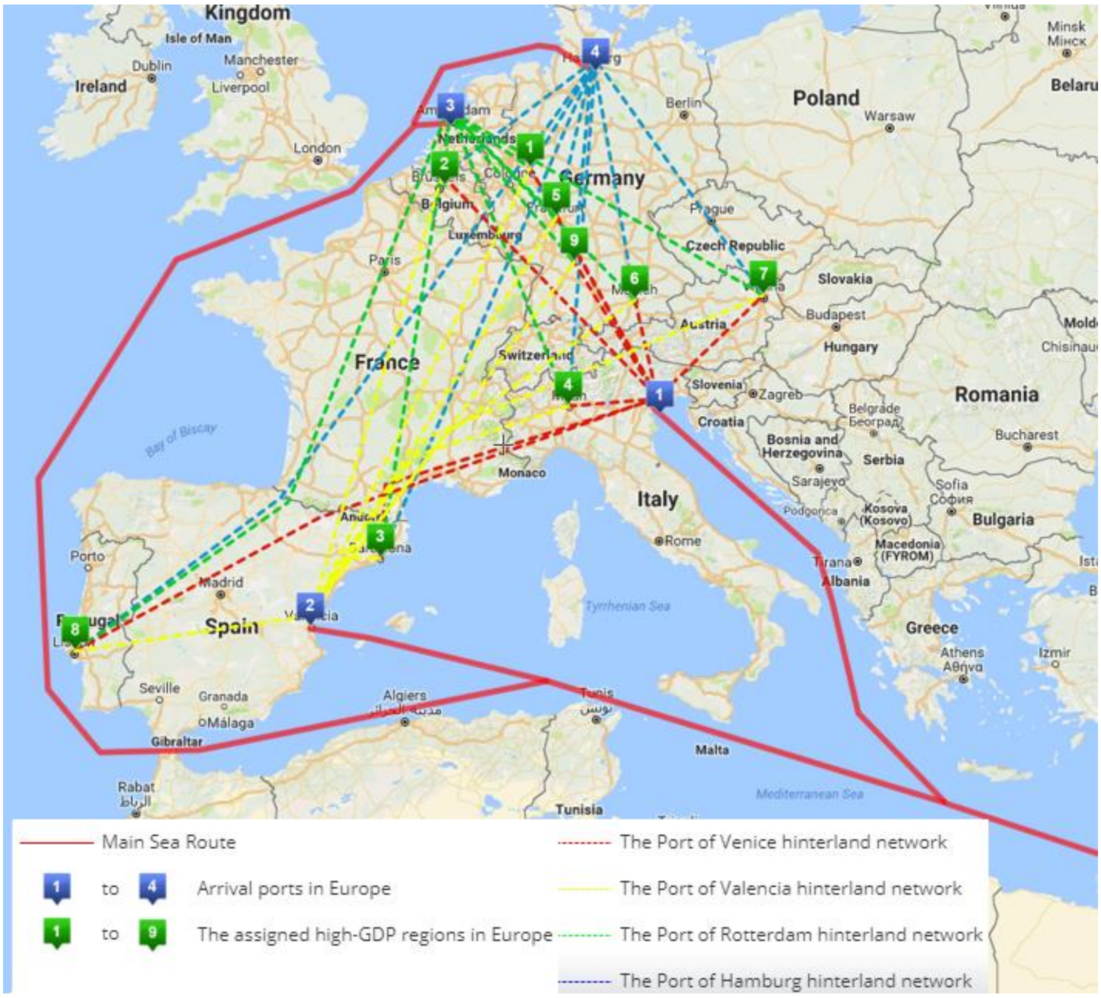


Figure 4-16 Arrival ports' hinterland network for the high-GDP regions in Europe

Source: Created by author on ScribbleMaps (2017)

Within the specified criteria for the conducted case study, the transportation times from the Port of Singapore to the high-GDP European regions are represented in Figure 4-17. As it is in section 4.2.1, it is obviously seen from the results obtained that the Port of Venice offers a more advantageous container transportation network compared to the other designated ports. However, the Port of Valencia can offer the shortest total transportation time for Barcelona and Lisbon. The short maritime route for European Hinterland brings the Port of Venice to a position which provides important advantage in terms of total transportation time. According to the results obtained, the Port of Venice can provide shorter total transportation time to reach containers to the designated other high-GDP regions in group 2. Even this is valid for the regions such as Rhine-Ruhr, Randstad and Frankfurt which are within a few hours' distance to the port of Rotterdam and the Port of Hamburg.

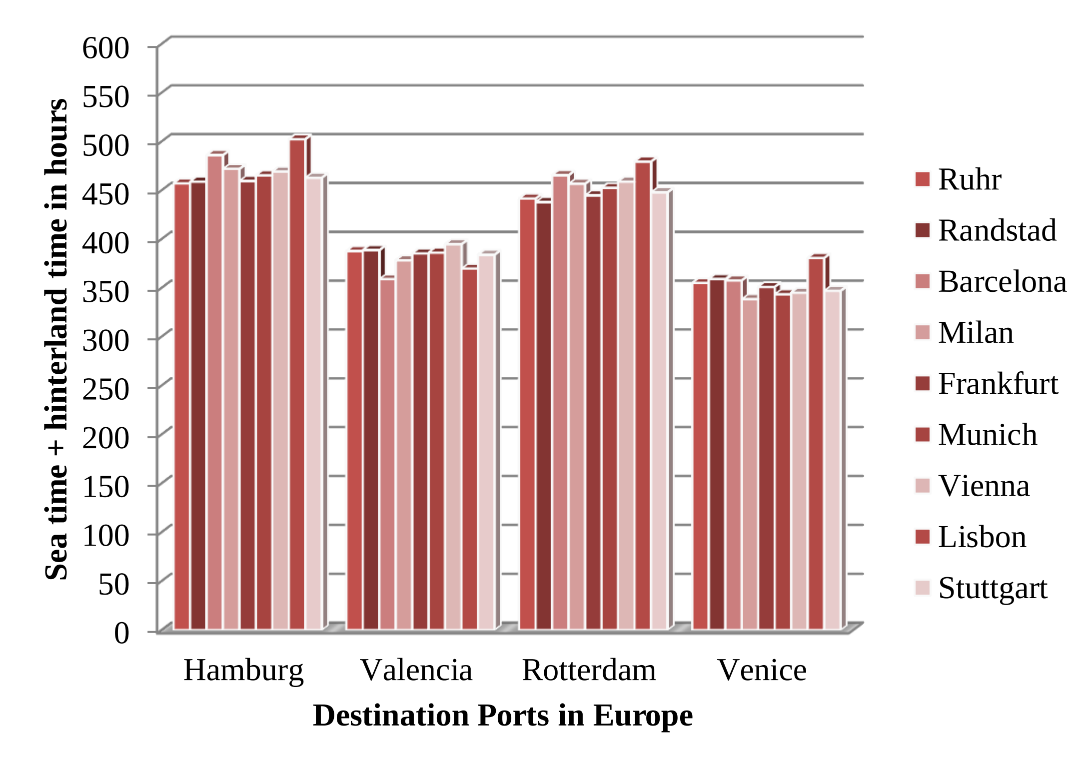
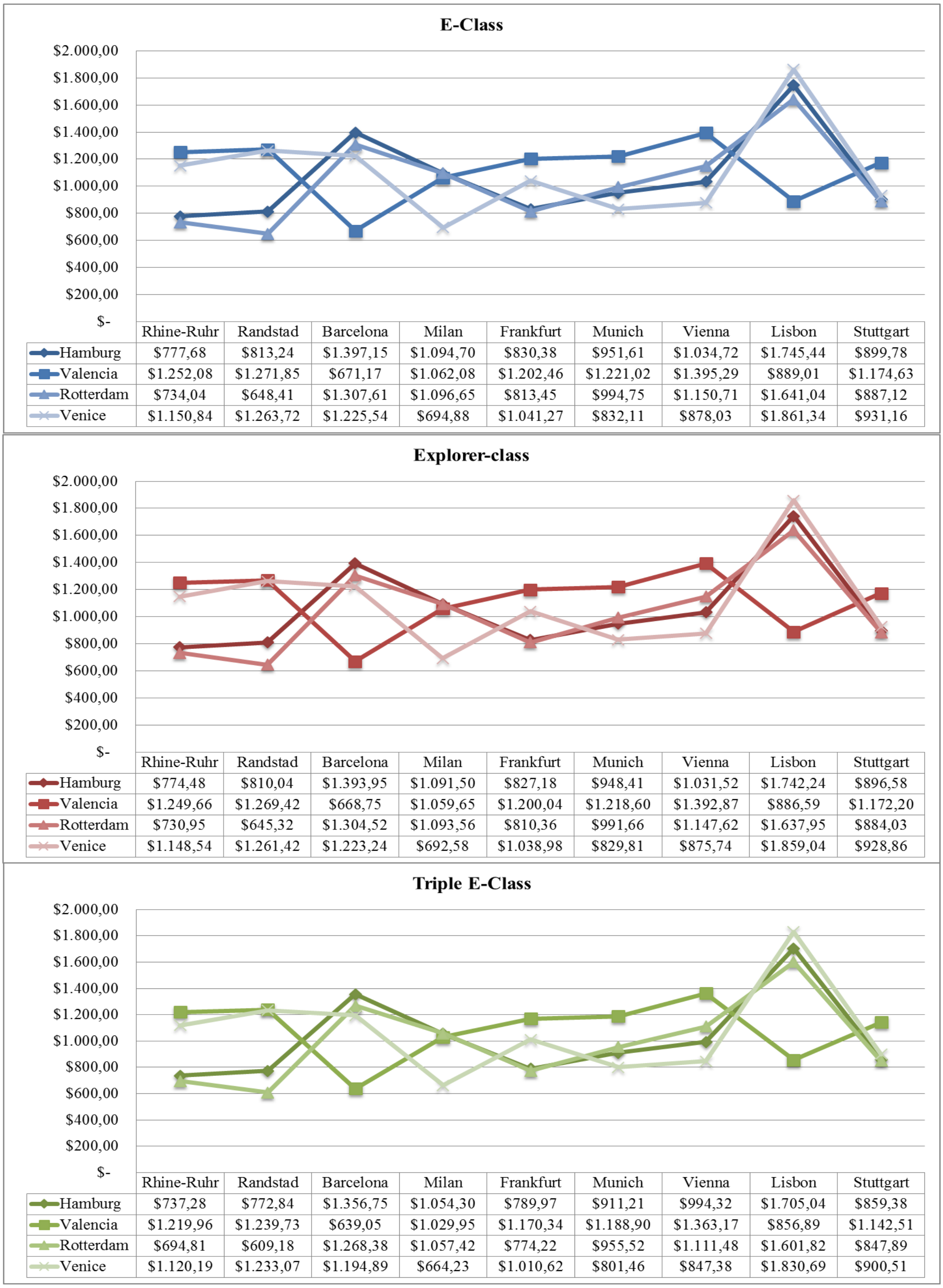


Figure 4-17 Transportation time analysis for the designated high-GDP regions in Europe

It is clear that the ports of Venice and Valencia offer much better rates than the ports in northern Europe in terms of total transport times. In this case it is possible to say that the ports of Venice and Valencia have the best times in terms of total transportation time, while the times of Rotterdam and Hamburg are far behind them for Asian freight.

By specifying again, in terms of ship characteristics as under all conditions determined, this analysis is carried out by observing the same details as in section 4.2.1. The graphs in Figure 4-18 give the total transport costs for the three different types of container vessels operating in the container network from Asia to the designated high-GDP European regions as a result of the analysis carried out. The types of vessels used are known as E-class, Explorer Class and Triple E-Class with 15,500, 16,000 and 18,000 TEU carrying capacities, respectively. The obtained cost values are given in 3 separate charts according to the specifications of vessels.



E-Class

	Rhine-Ruhr	Randstad	Barcelona	Milan	Frankfurt	Munich	Vienna	Lisbon	Stuttgart
Hamburg	$777,68	$813,24	$1.397,15	$1.094,70	$830,38	$951,61	$1.034,72	$1.745,44	$899,78
Valencia	$1.252,08	$1.271,85	$671,17	$1.062,08	$1.202,46	$1.221,02	$1.395,29	$889,01	$1.174,63
Rotterdam	$734,04	$648,41	$1.307,61	$1.096,65	$813,45	$994,75	$1.150,71	$1.641,04	$887,12
Venice	$1.150,84	$1.263,72	$1.225,54	$694,88	$1.041,27	$832,11	$878,03	$1.861,34	$931,16

Explorer-class

	Rhine-Ruhr	Randstad	Barcelona	Milan	Frankfurt	Munich	Vienna	Lisbon	Stuttgart
Hamburg	$774,48	$810,04	$1.393,95	$1.091,50	$827,18	$948,41	$1.031,52	$1.742,24	$896,58
Valencia	$1.249,66	$1.269,42	$668,75	$1.059,65	$1.200,04	$1.218,60	$1.392,87	$886,59	$1.172,20
Rotterdam	$730,95	$645,32	$1.304,52	$1.093,56	$810,36	$991,66	$1.147,62	$1.637,95	$884,03
Venice	$1.148,54	$1.261,42	$1.223,24	$692,58	$1.038,98	$829,81	$875,74	$1.859,04	$928,86

Triple E-Class

	Rhine-Ruhr	Randstad	Barcelona	Milan	Frankfurt	Munich	Vienna	Lisbon	Stuttgart
Hamburg	$737,28	$772,84	$1.356,75	$1.054,30	$789,97	$911,21	$994,32	$1.705,04	$859,38
Valencia	$1.219,96	$1.239,73	$639,05	$1.029,95	$1.170,34	$1.188,90	$1.363,17	$856,89	$1.142,51
Rotterdam	$694,81	$609,18	$1.268,38	$1.057,42	$774,22	$955,52	$1.111,48	$1.601,82	$847,89
Venice	$1.120,19	$1.233,07	$1.194,89	$664,23	$1.010,62	$801,46	$847,38	$1.830,69	$900,51

Figure 4-18 Total transportation cost for the designated high-GDP regions in Europe by three different vessel types[4]

[4] For the details of calculations, assumptions and sources please see Appendix A and Appendix B

The obtained values give the costs for a container loaded in Asia and transported to the designated high-GDP European regions. The graphs in Figure 4-18 are obtained as a result of the calculations made in accordance with the formulas in section 3.4, as in section 4.2.1.

In Table 4-11, the cost of the designated ports is given in an order for each selected high-GDP European region according to Figure 4-18. A coefficient is assigned to each port on the basis of the costs they incurred according to the obtained order in Table 4-11. These obtained coefficient score can be seen in Table 4-12. According to the total coefficient scored obtained in this part of the case study, the Port of Rotterdam can achieve to deliver containers to the high-GDP European regions at minimal cost in total. According to this case study, the Port of Rotterdam can achieve that with a total score of 26 points. The Port of Rotterdam is followed by the Port of Venice with 24 points, the Port of Hamburg with 23 points and finally the Port of Valencia ports with 17 points.

When the scores obtained are examined in detail, it can be said that the Port of Rotterdam can offer the lowest costly transportation for 4 high-GDP regions in Europe (Rhine-Ruhr, Randstad, Frankfurt and Stuttgart). While the Port of Venice can offer the lowest costly transportation for 3 high-GDP regions in Europe (Milan, Munich and Vienna), the Port of Valencia offers the lowest costly transportation for 2 high-GDP regions in Europe (Barcelona and Lisbon). The Port of Hamburg dominated the lowest costly transportation for the designated capitals, but the situation is completely different for the high-GDP regions because the Port of Hamburg cannot offer the lowest costly transportation for the high-GDP regions in Europe.

Although the Port of Hamburg cannot offer the lowest costly transportation for any region, it finds very close place to the first two ports by the collected scores. As a main reason of this, it can be said that the Port of Hamburg can offer the second lowest costly transportation for the 6 high-GDP regions which are Rhine-Ruhr, Randstad, Frankfurt, Munich, Vienna and Stuttgart. Other ports can offer the second lowest transportation for just one region (The Port of Valencia for Milan, the Port of Rotterdam for Lisbon, and the Port of Venice for Barcelona).

Table 4-11 Sorting of ports by total transportation costs for the designated high-GDP regions in Europe

	Rhine-Ruhr	Randstad	Barcelona	Milan	Frankfurt	Munich	Vienna	Lisbon	Stuttgart
1st Cheapest	Rotterdam	Rotterdam	Valencia	Venice	Rotterdam	Venice	Venice	Valencia	Rotterdam
2nd Cheapest	Hamburg	Hamburg	Venice	Valencia	Hamburg	Hamburg	Hamburg	Rotterdam	Hamburg
3rd Cheapest	Venice	Venice	Rotterdam	Hamburg	Venice	Rotterdam	Rotterdam	Hamburg	Venice
4th Cheapest	Valencia	Valencia	Hamburg	Rotterdam	Valencia	Valencia	Valencia	Venice	Valencia

Table 4-12 Coefficients of the ports according to their total transport costs for the designated high-GDP regions in Europe

	Hamburg	Valencia	Rotterdam	Venice
Rhine-Ruhr	3	1	4	2
Randstad	3	1	4	2
Barcelona	1	4	2	3
Milan	2	3	1	4
Frankfurt/Rhine	3	1	4	2
Munich	3	1	2	4
Vienna	3	1	2	4
Lisbon	2	4	3	1
Stuttgart	3	1	4	2
Total	**23**	**17**	**26**	**24**

As the most cost-effective third port, the Port of Hamburg can offer the third lowest costly transportation for the 2 high-GDP regions (Milan and Lisbon), while the Port of Venice ports can offer the third lowest costly transportation opportunity for the four high-GDP regions (Rhine-Ruhr, Randstad, Frankfurt, and Stuttgart). The Port of Rotterdam can offer for the three high-GDP regions (Barcelona, Munich and Vienna) and the Port of Valencia cannot offer the third lowest costly transportation opportunity for any region.

Among the selected ports for this case study, the Port of Valencia is determined as the most costly port for the designated capitals. The Port of Valencia can offer the most costly transportation for the 6 high-GDP regions (Rhine-Ruhr, Randstad, Frankfurt, Munich, Vienna, and Stuttgart). The Port of Hamburg, the Port of Rotterdam and the Port of Venice can offer the most costly transportation for the one capital (The Port of Hamburg for Barcelona, the Port of Rotterdam for Milan, and the Port of Venice for Lisbon).

4.2.3 Time and Cost Analysis for the Low Manufacturing-Cost Regions

As third part of section 4.2, another total transportation time and cost analysis is conducted for 10 low manufacturing-cost and these regions are named with the important cities of the regions (Colliers, 2013). These regions are selected among low manufacturing-cost regions which are located in Europe and close to Europe as well as located in the hinterland of the designated ports. As in sections 4.2.1 and 4.2.2, the total transportation time and cost for the containers departed from the Port of Singapore in Asia to arrive low manufacturing-cost regions as final destinations in Europe through the designated four ports as likewise above two sections. The designated ports and regions for this section of the case study are shown in Table 4-13.

Table 4-13 Assigned ports and low manufacturing-cost regions, group 3

Port				Final Destination	
Departure Port		Arrival Port		Low Manufacturing-Cost Regions	
				1	Kiev
				2	Istanbul
				3	Bratislava
	Singapore	1	Venice	4	Katowice
		2	Valencia	5	Sofia
		3	Rotterdam	6	Antwerp
		4	Hamburg	7	Lille
				8	Budapest
				9	Dusseldorf
				10	Venlo

In Table 4-13, the ports and final destinations have been categorized within groups and the dark blue column represents the Port of Singapore, the blue column represents the arrival ports, and the white column represents the low manufacturing-cost regions. The assigned ports and destinations are geographically illustrated on the map in Figure 4-19. The dark blue colour-paddle symbolizes the last departure port in Asia. The blue markers in numbers from 1 to 4 also symbolize the designated arrival ports in Europe and the white markers in numbers from 1 to 10 symbolize the low manufacturing-cost regions. In Figure 4-19, arrival ports' hinterland distribution for the low manufacturing-cost region can be seen to able to understand the geographical locations of the determined regions. It can be obviously seen that the low manufacturing-cost regions are mostly located on North and East Europe (Colliers, 2013).

It can be seen that some low manufacturing-cost regions are placed to North Europe where the regions are supported by major ports such as the Port of Rotterdam, the Port of Antwerp and the Port of Hamburg. The other determined regions are mostly located in East Europe due to cheap labour cost relatively the rest of Europe (Eurostat, 2017d).

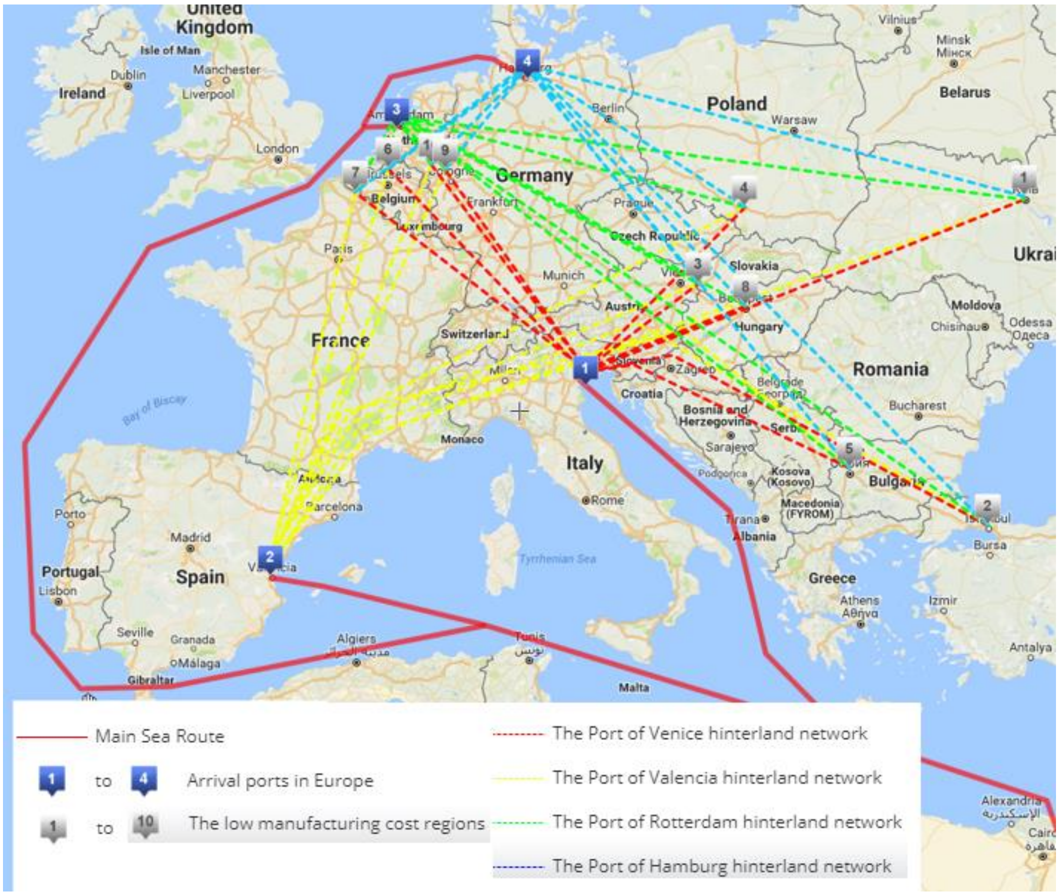


Figure 4-19 Arrival ports' hinterland distribution for the low manufacturing-cost regions

Source: Created by author on ScribbleMaps (2017)

Within the specified criteria for the conducted case study, the transportation times from the Port of Singapore to the low manufacturing-cost regions are represented in Figure 4-20. As it is in section 4.2.1 and in section 4.2.2, the Port of Venice is obviously able to offer shorter total transportation times for each designated low manufacturing-cost regions. This situation makes the Port of Venice is more advantageous in terms of time-effective container transportation network compared to the other designated ports. In terms of the total transportation time, as it is seen in section 4.2.1 and section 4.2.2, the Port of Hamburg and the Port of Rotterdam have longer total transportation time for door-to-door transportation in comparison with the Port of Valencia and the Port of Venice. The Port of Valencia can offer competitive total transportation times thanks to a shorter maritime transportation period although it has obvious advantageous in terms of highway transportation period especially for the region located in East Europe.

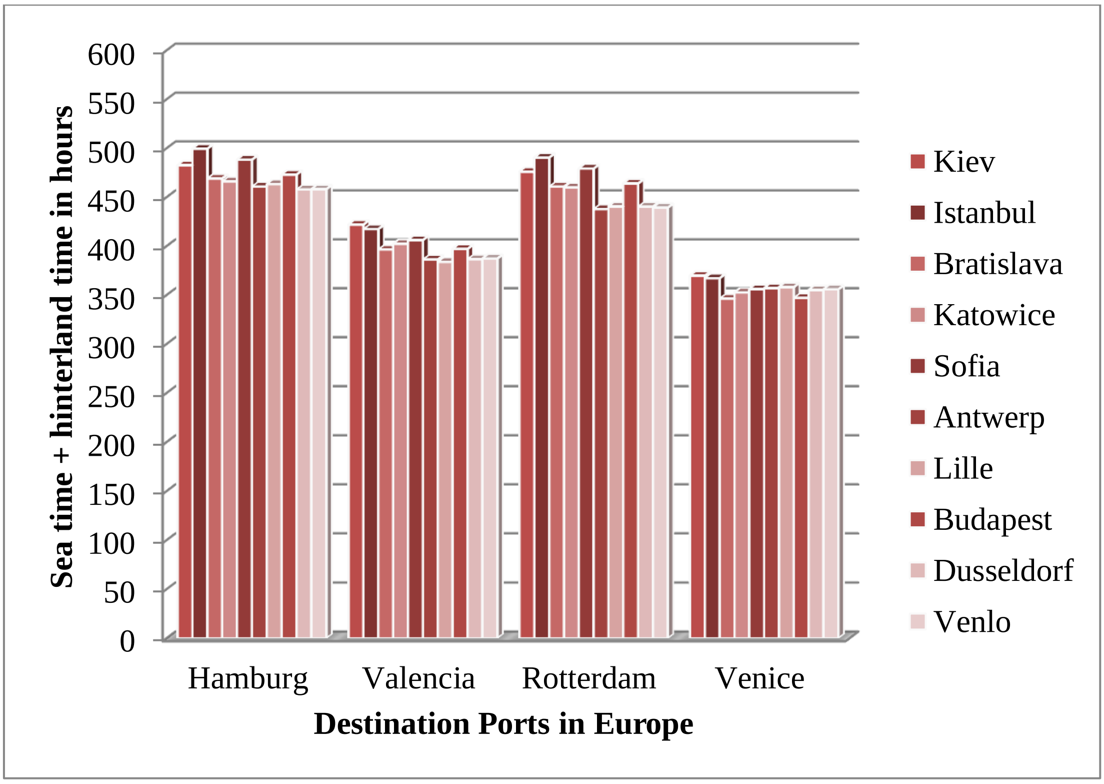
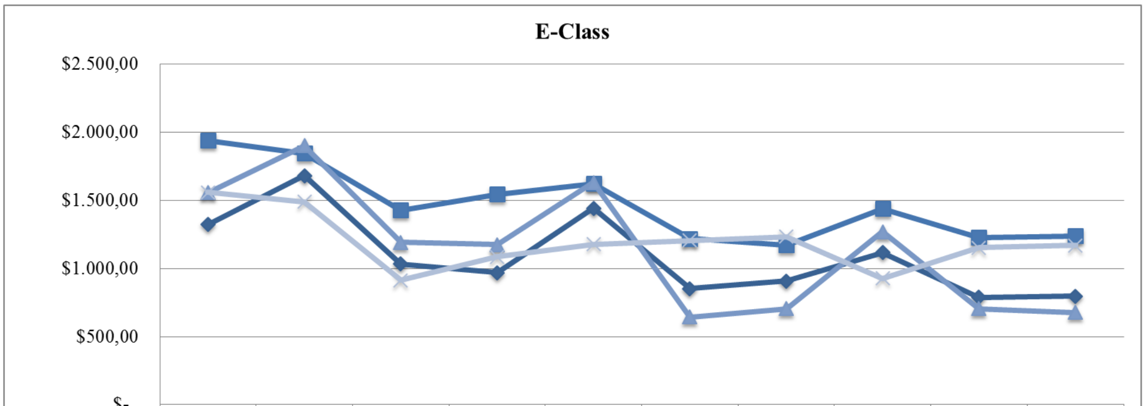


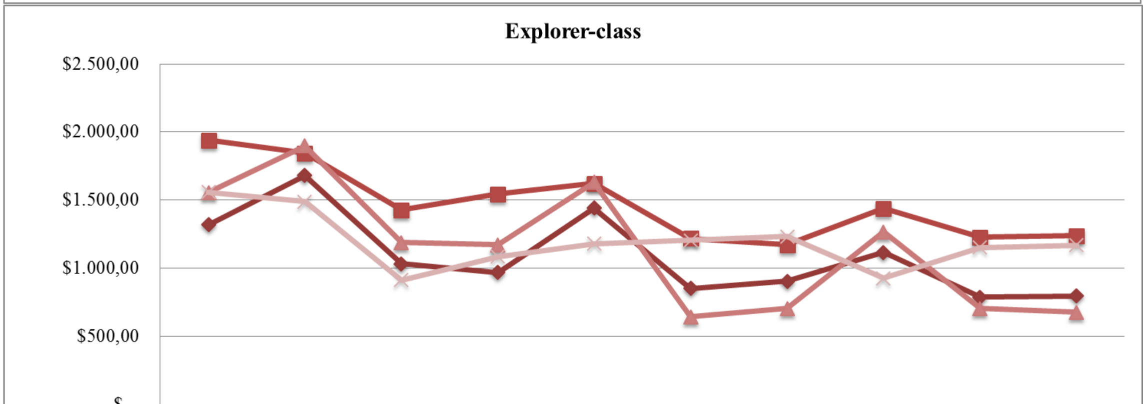
Figure 4-20 Transportation time analysis for the selected low manufacturing-cost regions

When all three sections under the total transportation time and total transportation cost analysis section, it can be seen that the Port of Venice can provides the shortest total transportation times for the specified container transportation network with a few exceptions because the Port of Valencia can obtain this advantage from the Port of Venice for only a few cities and regions in section 4.2.1 and in section 4.2.2. However, the Port of Rotterdam cannot get better total transportation times than the Port of Venice and the Port of Valencia. On the other hand, the Port of Rotterdam can obtain better total transportation times than the Port of Hamburg without any exception. In terms of ship characteristics as under all conditions determined, this analysis is carried out by observing the same details as in section 4.2.1 and section 4.2.2.

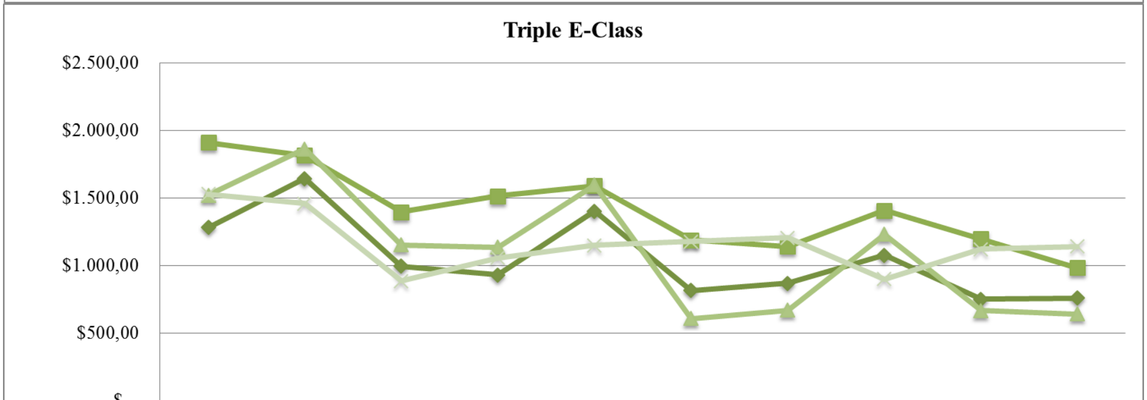
The graphs in Figure 4-21 give the total transport costs for the three different types of container vessels operating in the container network from Asia to the designated low manufacturing-cost regions as a result of the analysis carried out. The obtained cost values are given in 3 separate charts according to the specifications of vessels.



	Kiev	Istanbul	Bratislava	Katowice	Sofia	Antwerp	Lille	Budapest	Dusseldorf	Venlo
Hamburg	$1.322,18	$1.682,89	$1.033,44	$969,61	$1.443,42	$853,94	$907,92	$1.117,41	$789,68	$797,39
Valencia	$1.941,91	$1.848,32	$1.429,18	$1.544,96	$1.623,22	$1.221,42	$1.172,21	$1.440,48	$1.229,49	$1.239,98
Rotterdam	$1.557,81	$1.901,28	$1.191,85	$1.174,62	$1.633,87	$645,06	$706,77	$1.269,82	$704,86	$678,54
Venice	$1.559,21	$1.489,49	$914,56	$1.086,09	$1.180,16	$1.207,28	$1.235,50	$929,50	$1.152,50	$1.170,76



	Kiev	Istanbul	Bratislava	Katowice	Sofia	Antwerp	Lille	Budapest	Dusseldorf	Venlo
Hamburg	$1.318,98	$1.679,69	$1.030,24	$966,41	$1.440,22	$850,74	$904,72	$1.114,20	$786,48	$794,19
Valencia	$1.939,49	$1.845,90	$1.426,75	$1.542,53	$1.620,79	$1.219,00	$1.169,78	$1.438,05	$1.227,07	$1.237,56
Rotterdam	$1.554,72	$1.898,19	$1.188,76	$1.171,53	$1.630,78	$641,97	$703,68	$1.266,73	$701,77	$675,45
Venice	$1.556,91	$1.487,19	$912,26	$1.083,80	$1.177,87	$1.204,98	$1.233,20	$927,20	$1.150,20	$1.168,46



	Kiev	Istanbul	Bratislava	Katowice	Sofia	Antwerp	Lille	Budapest	Dusseldorf	Venlo
Hamburg	$1.281,78	$1.642,49	$993,04	$929,20	$1.403,02	$813,54	$867,52	$1.077,00	$749,28	$756,99
Valencia	$1.909,79	$1.816,20	$1.397,06	$1.512,84	$1.591,10	$1.189,30	$1.140,09	$1.408,35	$1.197,37	$983,27
Rotterdam	$1.518,58	$1.862,05	$1.152,62	$1.135,39	$1.594,64	$605,83	$667,54	$1.230,59	$665,63	$639,31
Venice	$1.528,56	$1.458,84	$883,91	$1.055,44	$1.149,51	$1.176,63	$1.204,85	$898,85	$1.121,85	$1.140,11

Figure 4-21 Total transportation cost for the designated low manufacturing-cost European cities by three different vessel types[5]

[5] For the details of calculations, assumptions and sources please see Appendix A and Appendix B

The obtained values in Figure 4-21 give the costs for a container which is loaded in Asia and transported to the designated low manufacturing-cost regions. The graphs in Figures 4-21 are obtained as a result of the calculations made in accordance with the formulas in section 3.4, as in section 4.2.1 and in section 4.2.2.

In Table 4-14, the cost of the designated ports is given in an order for each selected low manufacturing-cost region according to Figure 4-21. A coefficient is assigned to each port on the basis of the costs they incurred according to the obtained order in Table 4-14. These obtained coefficient score can be seen in Table 4-15. According to the total coefficient scored obtained in this part of the case study, the Port of Hamburg can achieve to deliver containers to the low manufacturing-cost regions at minimal cost in total. According to this case study, the Port of Hamburg can achieve that with a total score of 32 points. The Port of Rotterdam is followed by the Port of Rotterdam and the Port of Venice with 27 points and finally the Port of Valencia ports with 14 points.

When the scores obtained are examined in detail, it can be said that the Port of Hamburg can offer the lowest costly transportation for 2 low manufacturing-cost regions (Kiev and Katowice). Both of the ports, the Port of Rotterdam and the Port of Venice can offer the lowest costly transportation for 4 low manufacturing-cost regions (The Port of Rotterdam for Antwerp, Lille, Dusseldorf and Venlo; the Port of Venice for Istanbul, Bratislava, Budapest and Sofia). The Port of Hamburg has the highest score in terms total transportation times for the low manufacturing-cost regions in total, but it cannot dominate the low manufacturing-cost regions with the lowest costly transportation. The regions are dominated by the Port of Rotterdam and the Port of Venice. On other hand the Port of Valencia cannot offer the lowest costly transportation for the low manufacturing-cost regions.

Although the Port of Hamburg can offer the lowest costly transportation for only 2 regions, it finds the place at the top in total by the collected scores. As a main reason of this, it can be said that the Port of Hamburg can offer the second lowest costly transportation for the 8 remain low manufacturing-cost regions. The Port of Rotterdam and the Port of Venice can offer the second lowest transportation for just one region (The Port of Rotterdam for Kiev, and the Port of Venice for Katowice).

Table 4-14 Sorting of ports by total transportation costs for the designated low manufacturing-cost regions

	Kiev	Istanbul	Bratislava	Katowice	Sofia	Antwerp	Lille	Budapest	Dusseldorf	Venlo
1st Cheapest	Hamburg	Venice	Venice	Hamburg	Venice	Rotterdam	Rotterdam	Venice	Rotterdam	Rotterdam
2nd Cheapest	Rotterdam	Hamburg	Hamburg	Venice	Hamburg	Hamburg	Hamburg	Hamburg	Hamburg	Hamburg
3rd Cheapest	Venice	Valencia	Rotterdam	Rotterdam	Valencia	Venice	Valencia	Rotterdam	Venice	Valencia
4th Cheapest	Valencia	Rotterdam	Valencia	Valencia	Rotterdam	Valencia	Venice	Valencia	Valencia	Venice

Table 4-15 Coefficients of the ports according to their total transport costs for the designated manufacturing-cost regions

	Hamburg	Valencia	Rotterdam	Venice
Kiev	4	1	3	2
Istanbul	3	2	1	4
Bratislava	3	1	2	4
Katowice	4	1	2	3
Sofia	3	2	1	4
Antwerp	3	1	4	2
Lille	3	2	4	1
Budapest	3	1	2	4
Dusseldorf	3	1	4	2
Venlo	3	2	4	1
Total	**32**	**14**	**27**	**27**

As the most cost-effective second and third ports, the Port of Rotterdam and the Port of Venice can offer the third lowest costly transportation for the 3 low manufacturing-cost regions (The Port of Rotterdam for Bratislava, Katowice and Budapest; and the Port of Venice Kiev, Antwerp and Dusseldorf), while the Port of Valencia ports can offer the third lowest costly transportation opportunity for the 4 low manufacturing-cost regions (Istanbul, Sofia, Lille and Venlo). The Port of Hamburg cannot offer the third lowest costly transportation opportunity for any region.

Among the selected ports for this case study, the Port of Valencia is determined as the most costly port for the designated capitals. The Port of Valencia can offer the most costly transportation for the 6 low manufacturing-cost regions (Kiev, Bratislava, Katowice, Antwerp, Budapest and Dusseldorf). The Port of Rotterdam and the Port of Venice can offer the most costly transportation for the two regions (The Port of Rotterdam for Istanbul and Sofia; and the Port of Venice for Lille and Venlo). The Port of Hamburg cannot offer the most costly transportation opportunity for any region.

4.2.4 Results of Time and Cost Analysis

In the light of the results obtained from the time and cost analysis of the designated ports in the case study, it is shown in the following two maps illustrations which port can provide more advantageous container transport network serving the container from Asia to the designated cities and regions in terms of total transportation time and total transportation cost. The designated ports on both maps are marked with coloured pushpins. The destination cities and regions are also marked with paddles which have same colour with the port to indicate that those of cities and regions are in the hinterland of this port thanks to the advantageous state of port in terms of total transportation time and total transportation cost.

It can be seen from the markings made according to the results obtained that the Port of Venice stands out as the best network connection point in terms of the total transportation time for almost all of Europe except for just a few locations. This situation shows that the Silk Road plan in the scope of “one belt, one road” strategy, which is desired to be reintroduced by China, can be applicable at least in terms of total transportation time. In terms of the total transportation time, only the Port of Valencia can offer the best time for 3 locations, except for the Port of Venice, as it is seen in Figure 4-22.

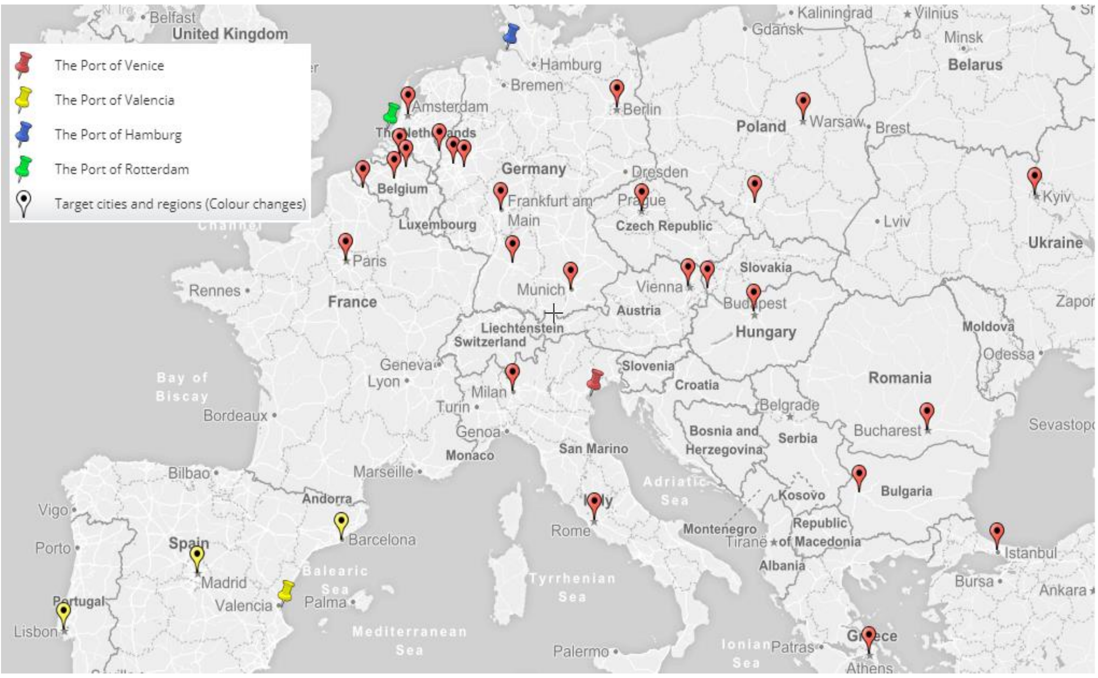


Figure 4-22 Hinterland of the designated ports in terms of the total transport time

Source: Created by author on ScribbleMaps (2017)

It seems that the situation of hinterland distribution of ports is more complicated when it is considered in terms of the total transportation cost. Compared to the total transportation time and cost for the defined container transport network, the Port of Valencia maintains its position in the competition by offering the best competitiveness values for the locations in Spain and Portugal. However, it is not possible to mention the same situation for the Port of Venice, since whilst the Port of Venice has the best figures almost for the designated locations all around Europe in terms of the total transportation time, the Port of Rotterdam can reach the best values for locations more than the Port of Venice. Interestingly, although the Port of Hamburg can allow transporting at the best cost figures for only 5 locations that is half of locations can reached by the Port of Venice and the Port of Rotterdam with the lowest transportation cost, it has the highest weight coefficient in total. As it is mentioned in the previous sections, the reason of the Port of Hamburg's the most competitive position in total is that it takes a place at the top in terms of the second lowest transportation for the most of the designated locations. The distribution of hinterlands according to the total transportation costs of the ports are given as in Figure 4-23.

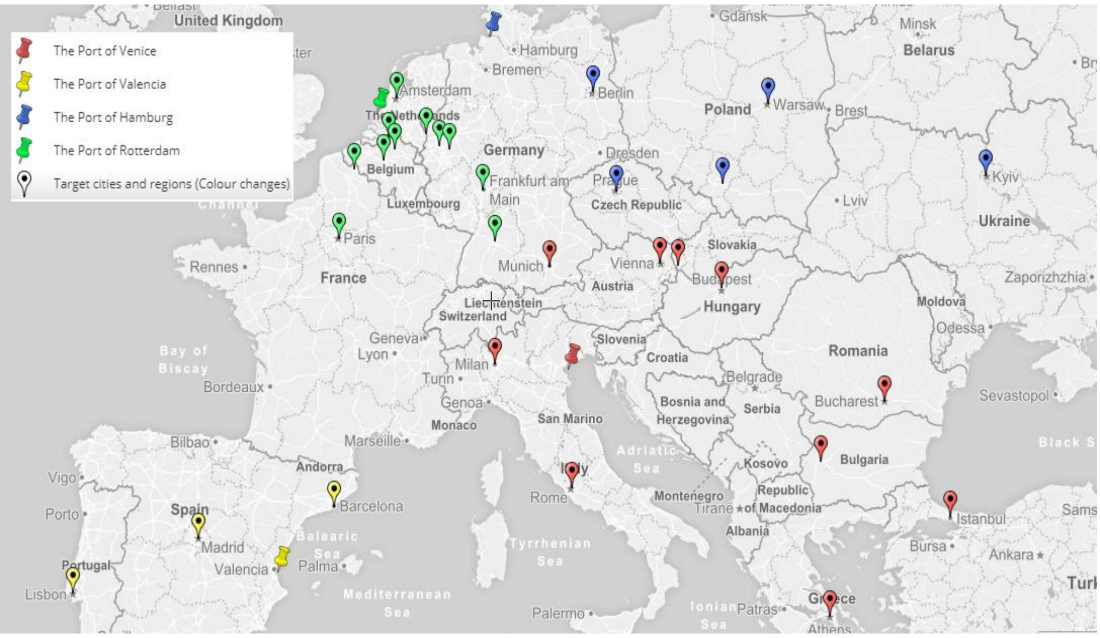


Figure 4-23 Hinterland of the designated ports in terms of the total transport cost

Source: Created by author on ScribbleMaps (2017)

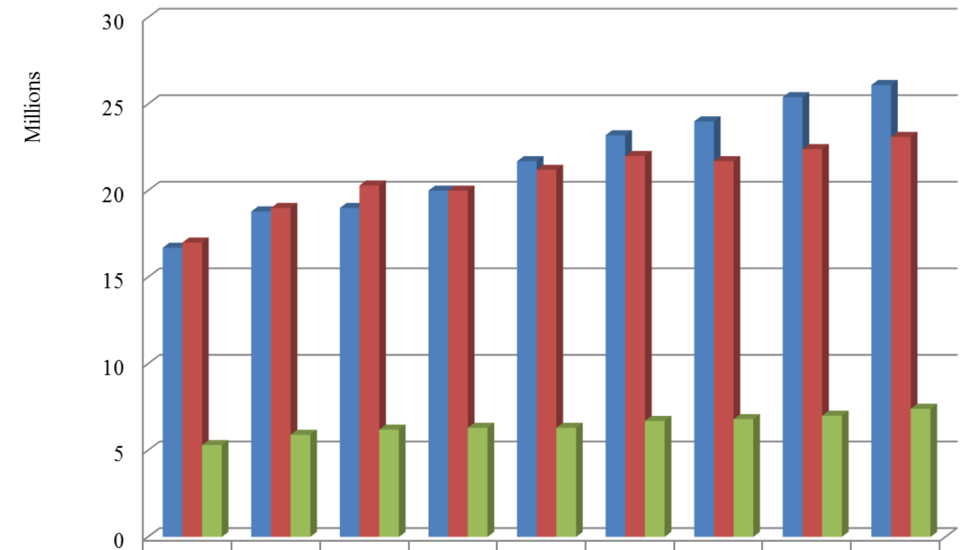
The coefficients obtained from the time and cost analysis of the ports given in Table 4-16 are used to obtain the percentage of the investment capacity utilization of the port to be constructed. It is assumed that the utilization rate of the port with the highest score is taken as 100% and the scores of the other ports are calculated according to this rate.

Table 4-16 Obtained time and cost scores and percentage display

	Group 1	Group 2	Group 3	Total score	%
Venice	25	24	27	76	88%
Valencia	17	17	14	48	56%
Rotterdam	27	26	27	80	93%
Hamburg	31	23	32	86	100%

4.3 Size and Capacity Analysis for OCPS

The size and capacity of a port depends on the quantity of cargo to be handled. Especially if this port is an offshore structure, the analysis of size and capacity is more important. Because it can be more difficult to physically improve offshore ports than conventional port in terms of static size and capacity. So deciding on the handling capacity of the offshore port requires deep current and long-term market analysis. When the container trade is analysed for Europe, the Asia-Europe route is one of the three main routes and has been growing continuously over the years. Adapted the data from UNCTAD (2014, 2015, 2016, 2017), more than 50 million TEU of containers are transported in these 3 routes annually. The development of containerized cargo flows in the main container routes the between years of 2009 and 2017 is given in Figure 4-24.

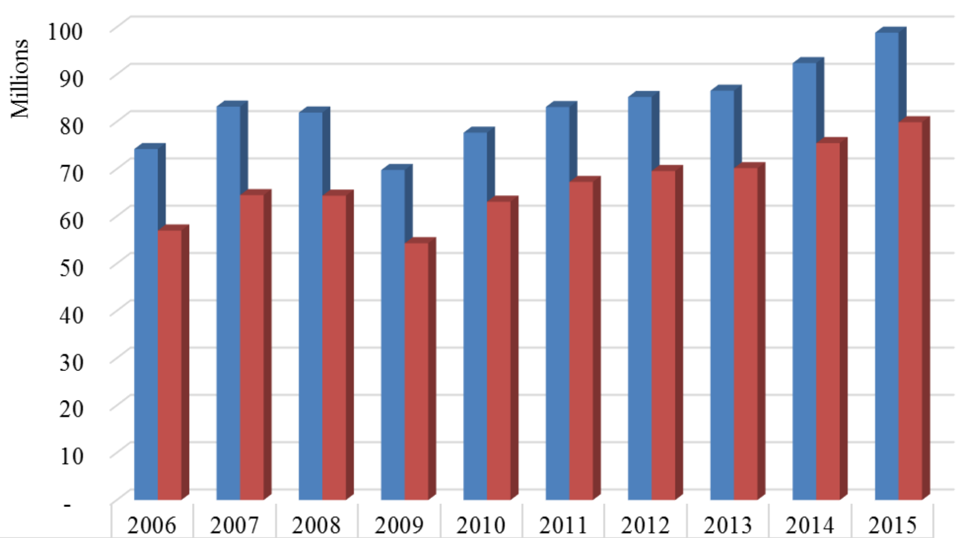


	2009	2010	2011	2012	2013	2014	2015	2016	2017
Trans-Pacific	16,7	18,8	19	20	21,7	23,2	24	25,4	26,1
Europe-Asia-Europe	17	19	20,3	20	21,2	22	21,7	22,4	23,1
Transatlantic	5,3	5,9	6,2	6,3	6,3	6,7	6,8	7	7,4

Figure 4-24 Containerized cargo flows in three major routes, 2009-2017

Source: Adapted from UNCTAD (2014, 2015, 2016, 2017)

Apart from the main routes, when it is looked at the all European Union ports and the top 20 ports in Europe between the years of 2006-2015, it is seen a similar growth curve with the main container routes (Eurostat, 2016a). However, there is no information relevant to the 2016-2017 data in the Eurostat data base. Therefore, estimates will be made according to the available data of the 10 years from 2006 to 2015. The development of containerized cargo flows in the all EU ports and also in the top 20 Europe ports for 10-year period between 2006 and 2017 are given in Figure 4-25.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU ports	74.225	83.195	81.942	69.790	77.679	83.107	85.244	86.560	92.402	98.828
Top 20 ports	56.989	64.483	64.363	54.306	63.093	67.267	69.569	70.181	75.483	79.897

Figure 4-25 Containerized cargo flows in EU ports and top 20 Europe ports, 2006-2015

Source: Adapted from Eurostat (2016a)

While two of the largest three container maritime trade routes are Europe-connected, the transatlantic container trade route has a trade volume about 30 percent of the Asia-Europe route. For this reason, it can be said that the investment opportunity for ports located on the Asian-European container trade route is more attractive. Therefore the competition between those of ports can be more complex and more player attractive. In this case, however, time and cost calculations have not been made for container services running on the transatlantic container route. The underlying reason of that is the ports in the America leg of route do not physically allow to handle the vessels used in the case study.

When looking at long-term past annual growth rates for the main Europe-connected routes, the Asia-Europe route seems to have achieved the growth with an average of 2.34 percent (UNCTAD 2014, 2015, 2016, 2017). The annual percentage change is 2.22 per cent, depending on the annual growth in the other Europe-connected container route, Transatlantic. As a result of the examined containerized cargo flows data between 2009 and 2017, the annual growth percentage changes starting from 2009 are given in Figure 4-26. In Figure 4-26, the data provided for 2017 are projected figures by UNCTAD.

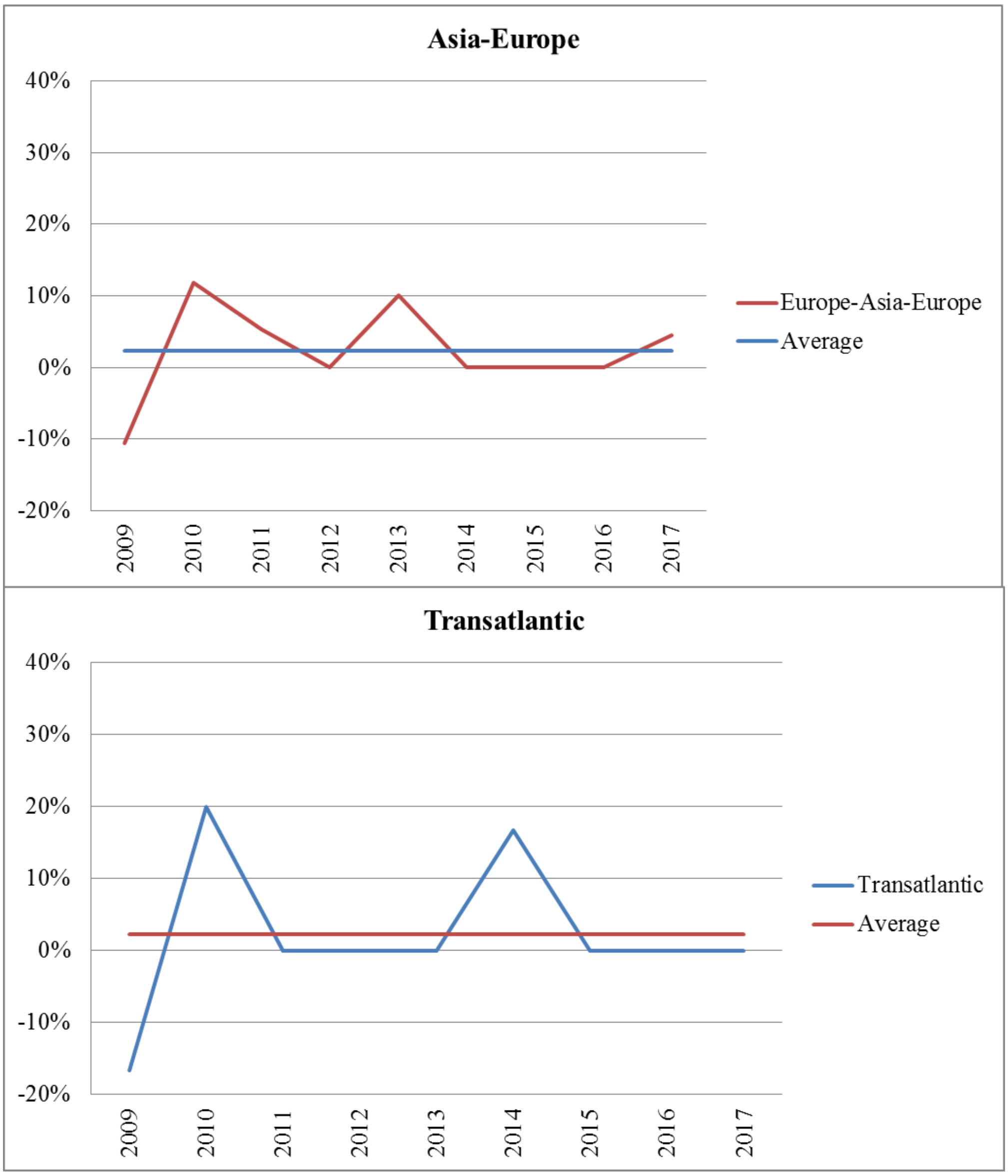


Figure 4-26 Annual percentage change in containerized trade and average growth rates for the major Europe container routes, 2009-2017

Source: Adapted from UNCTAD (2014, 2015, 2016, 2017)

In the light of the accessible last 9 years data, it seems that both of main container routes have similar average growth rates. But the situation is more positive for all ports in EU and top 20 ports. In this calculation, the average growth rate is estimated as 3.54 percent for all ports in EU and it is also estimated as 4.20 percent for the top 20 ports when the 2006-2015 data is taken in consideration as seen in Figure 4-27.

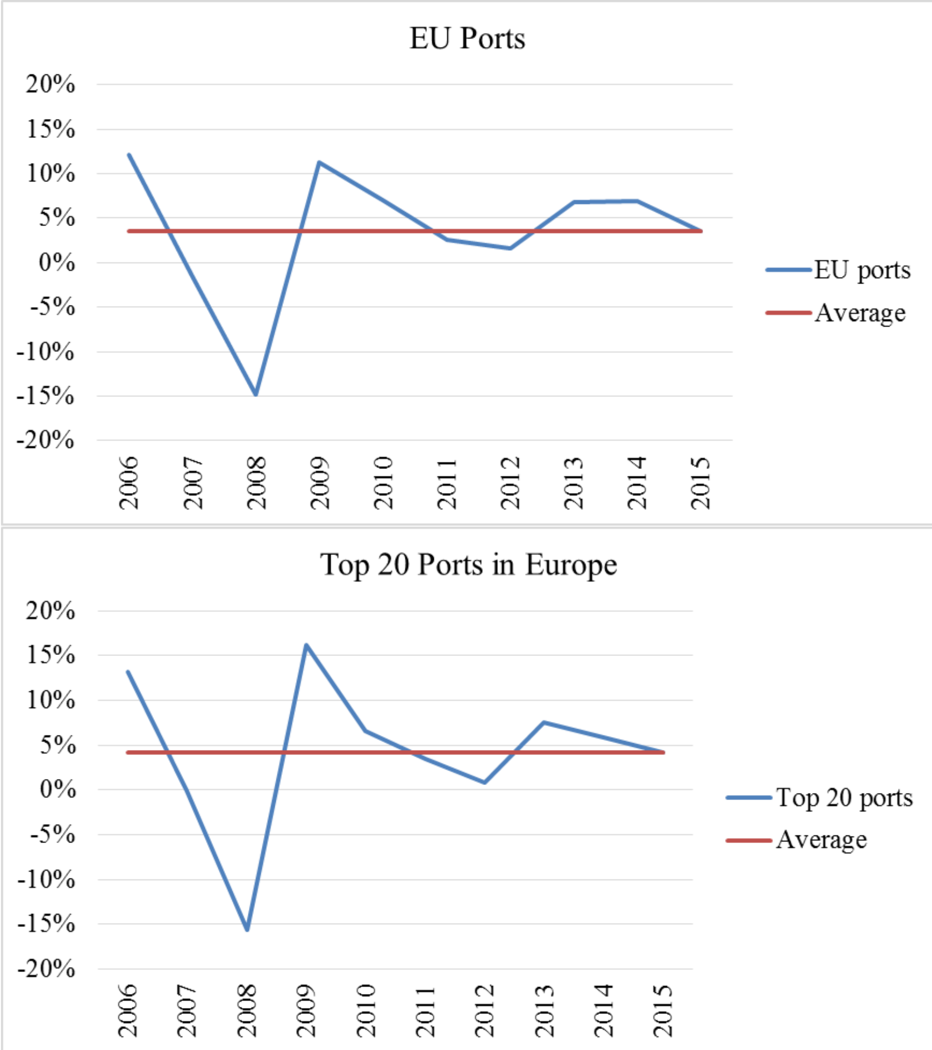


Figure 4-27 Annual percentage change in containerized trade and average growth rates for all EU ports and top 20 ports, 2007

Source: Adapted from Eurostat (2016a)

Assuming a 2.34 per cent of annual growth rate can be considered as a logical approach to decide on the determination of the size and capacity of port in Europe for the selected the route of Asia-Europe. However, the impact on the growth rate of the transatlantic route has also been taken into account when calculating the European container trade growth rate, in order to serve services with smaller ship sizes working in the transatlantic route. The growth rates of both European main routes are assumed to have grown with their own average growth rates in connection with past growth data. The average growth rates are accepted 2.34 for Asia-Europe route and 2.22 for transatlantic route without any crisis and similar situations that can negatively affect containerized cargo flows. The annual average growth rates and the development of containerized cargo flows for the two main lines according to these rates are given Figure 4-28. In this graph, 5-year forecasted containerized cargo flows are given on the primary axis while the average growth rates are given on the secondary axis.

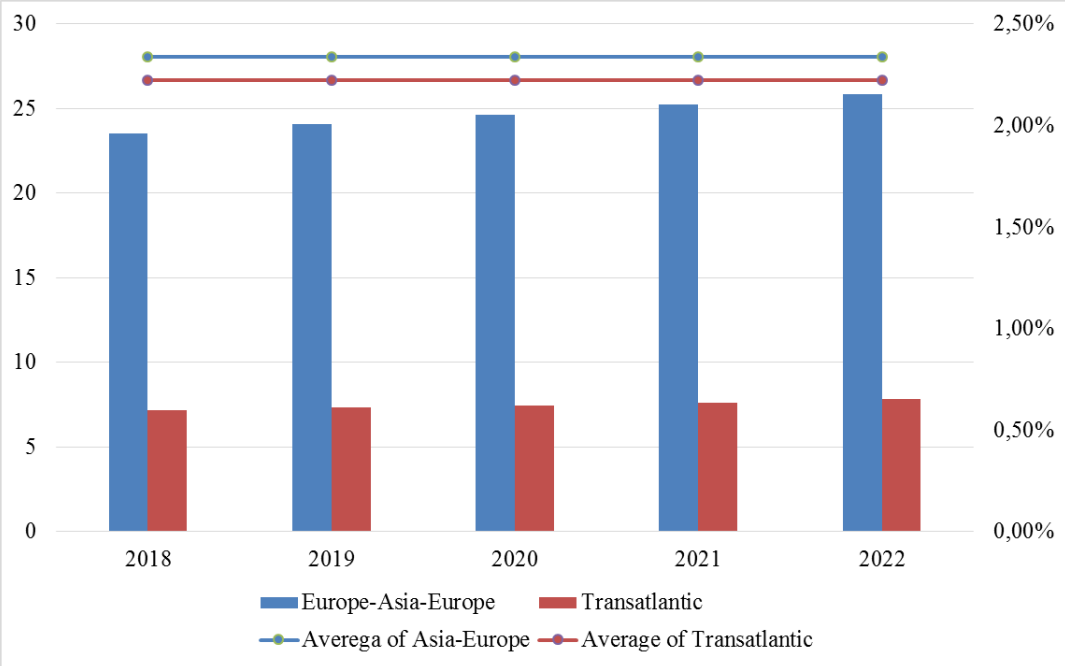


Figure 4-28 Growth rates for 5 years and the development of containerized cargo flows in two main Europe container routes, 2018-2022

Source: Adapted from Eurostat (2016a)

A similar calculation for the main two lines is conducted for the EU ports and top 20 ports. Accordingly, a 5-year forecast is made with a growth rate of 3.54 per cent for the EU ports while another forecast is made for the top 20 ports with a growth rate of 4.20 per cent according to the average growth rates obtained from Figure 4-27. The forecast has been done for a total of 7 years since the data is not available for 2016 and 2017. However, in practice the forecast covers the next 5 years. The annual average growth rates and the development of containerized cargo flows for all EU ports and top 20 ports according to these rates are given in Figure 4-29. In this graph, 5-year forecasted containerized cargo flows are given on the primary axis while the average growth rates are given on the secondary axis.

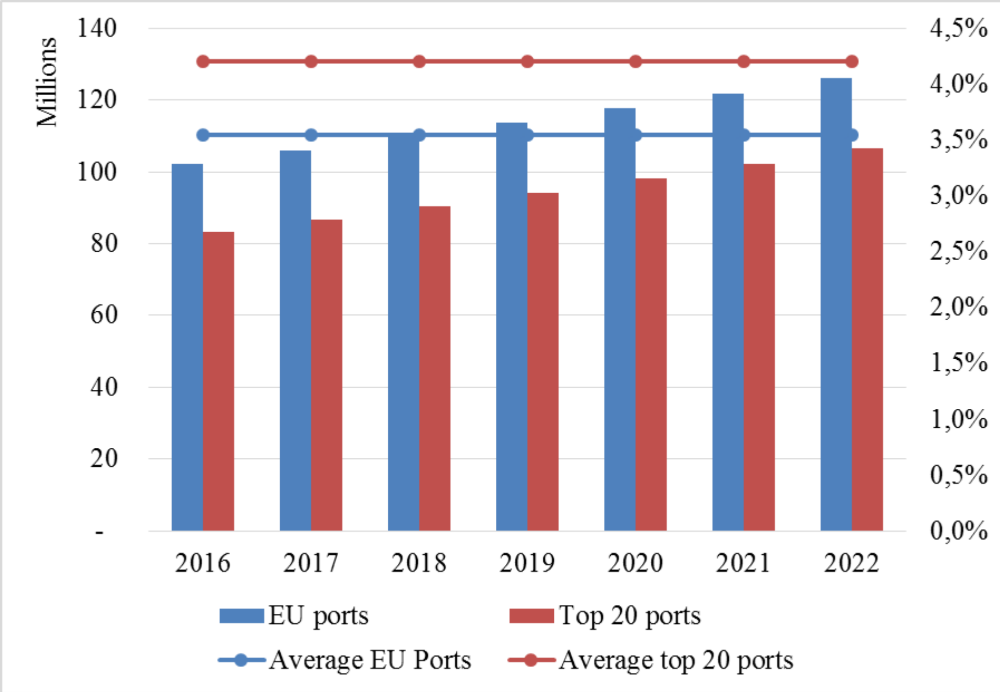


Figure 4-29 Growth rates for 5 years and the development of containerized cargo flows for all EU ports and top 20 ports, 2018-2022

Source: Adapted from Eurostat (2016a)[6]

Figure 4-30 gives the annual growth rates for years between 2007 and 2022 and the average growth rate for 2022 projection for all investigated levels. It is found that 4 annual average growth rate can be considered by decision makers for investment decisions when the obtained results in relation to the development of European containerized cargo flows are combined. The annual average growth rate of European containerized cargo flows as a strategic decision-making variant can be chosen at rates ranging from 2.22 to 4.2 percent of ports. The annual growth rates of Europe containerized cargo flows since 2007, there has been an increase trend in the European container flow up to the day. The impact of the crisis on growth has only been seen in 2009. For years between 2018 and 2022, a projection is developed in the light of past data as it is indicated with a black circle in Figure 4-30.

[6] The data had to be also projected for 2016 and 2017 due to data unavailability but it is actually estimated for 2018-2022

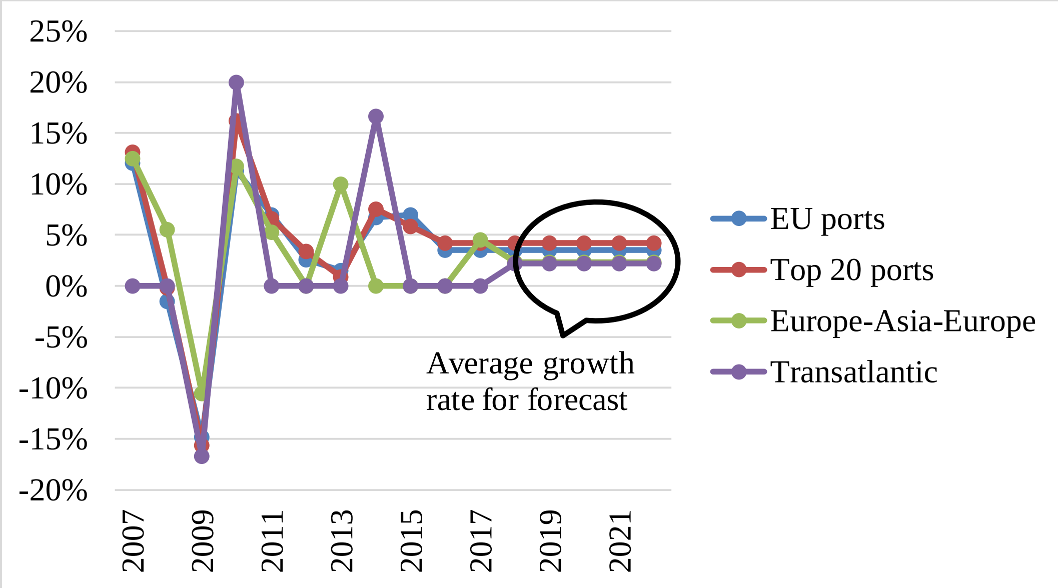
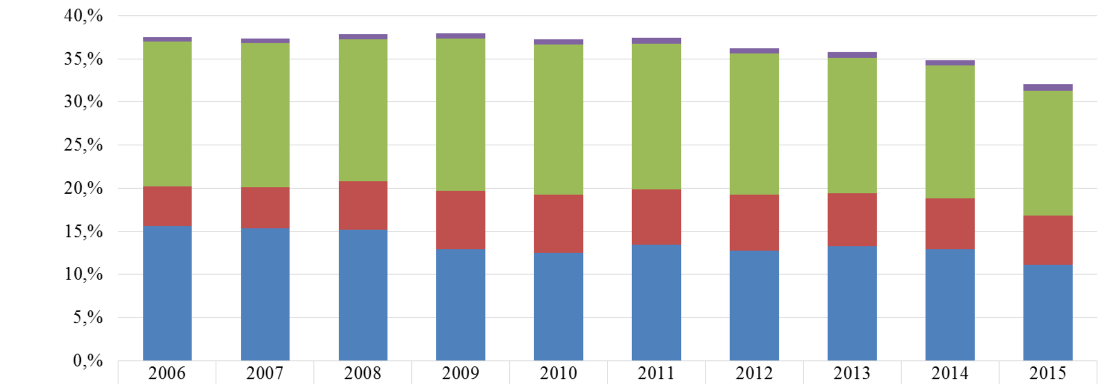


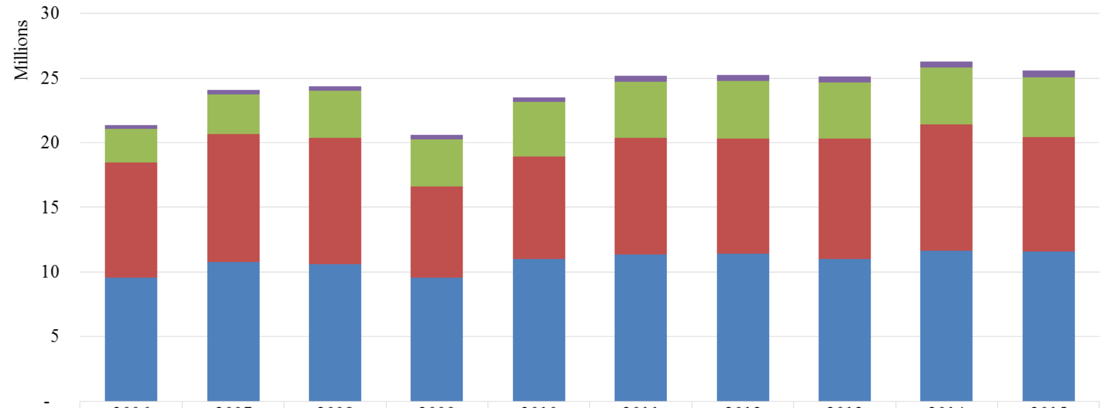
Figure 4-30 Annual percentage changes for years 2007-2017, and annual average growth rates for years 2018-2022

Source: Adapted from Eurostat (2016a) and UNCTAD (2014, 2015, 2016, 2017)

After examining the developments in the Europe container flows, it is seen that market share decreases of the ports used in the case study. When the 10-year market share of the ports used in the case between the years 2006-2015 is taken into consideration, the rate which was 28.8% decreased to 25.9% among all ports in EU from 2006 to 2015. But the same thing cannot be said in terms of port capacities used. Because the selected ports for the case has a rising trend in terms of the total handling capacity when the market share rate declines. The reason is that the containerized cargo flow growth rate in Europe is higher than the growth rates of selected ports in total. The share of these ports in Europe container market and the total amount of TEU-based handling are given in Figure 4-31 between the years of 2006-2015. The total container throughputs of these four ports are 25.6 million containers in 2015; it corresponds to 25.9 per cent of the total container flow in Europe.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Venice	0,6%	0,5%	0,6%	0,7%	0,6%	0,7%	0,6%	0,6%	0,6%	0,7%
Rotterdam	16,8%	16,7%	16,5%	17,6%	17,5%	16,9%	16,4%	15,7%	15,4%	14,5%
Valencia	4,6%	4,7%	5,6%	6,7%	6,7%	6,4%	6,4%	6,2%	5,8%	5,8%
Hamburg	15,6%	15,4%	15,2%	12,9%	12,5%	13,4%	12,8%	13,3%	12,9%	11,1%



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Venice	317.000	330.000	380.000	370.000	394.000	458.000	430.000	446.000	456.000	560.000
Valencia	2.615.000	3.049.000	3.606.000	3.654.000	4.211.000	4.332.000	4.471.000	4.328.000	4.407.000	4.609.000
Hamburg	8.878.000	9.914.000	9.767.000	7.031.000	7.906.000	9.035.000	8.891.000	9.302.000	9.775.000	8.848.000
Rotterdam	9.575.000	10.773.000	10.631.000	9.579.000	11.017.000	11.340.000	11.418.000	11.021.000	11.634.000	11.577.000

Figure 4-31 Container market share and container handling capacity of the selected ports, 2006-2015

Source: Eurostat (2016a)

It is assumed that these 4 ports aim to grow their total capacity as 2022 target, keeping their market share for 2015. According to the most optimistic scenario among the average growth rates obtained after the forecast, which is given in Figure 4-30, these 4 ports are expected to increase the total handling capacity by approximately 6 million TEUs by 2022. In that case these 4 ports will need an extra capacity of 1.5 million on average. It is also assumed that this capacity need is met by an offshore structure.

If an offshore port structure is designed according to this assumption, the stacking area is first calculated as Equation 3.4. The required stacking area for the required

1.5 million-TEU port capacity according to different variables is given Table 4-17. The results show that the required stacking area is associated with the stack height of the containers, but the dwell time and the stacking cranes used have a direct effect on the space required to store the containers. In this calculation, it is assumed that the average waiting period is 2 days, and RMGs (Rail Mounted Bridged Cranes) can stack up to 5 containers in each cargo area.

Table 4-17 Stacking area calculation

C_i Capacity (TEU)	Stacking Height	Dwell Time (day)	F (m^2/TEU)	r	m_i	A (m^2)	A (ha)
1000000	3	1	14	0,8	0,7	68493	6,8
1000000	4	1	11	0,7	0,7	61504	6,2
1000000	5	1	8	0,6	0,7	52185	5,2
1500000	3	1	14	0,8	0,7	102740	10,3
1500000	4	1	11	0,7	0,7	92256	9,2
1500000	5	1	8	0,6	0,7	78278	7,8
2000000	3	1	14	0,8	0,7	136986	13,7
2000000	4	1	11	0,7	0,7	123008	12,3
2000000	5	1	8	0,6	0,7	104371	10,4

In addition to container stacking area, an OCPS also needs area for operations, administration buildings, facilities and in-port transportation. As it is specified in section 3.2.2, the apron area is calculated in the form of 35m wide for 430m×430m port size. Accordingly the total required minimum area is 15.68 hectares but the total area of a port at size of 430m×430 is equivalent of 18.49 hectares. Table 4-18 gives the required terminal area for the proposed port capacity in details.

Table 4-18 Total required terminal area in ha

Terminal Areas		Area (ha)
Container Stacking Area		7,83
Apron Area		6,02
	Sub-total	13,85
Building and Facilities (approx. 5% of total)		0,73
Intern Transport Infrastructure (8% of sub-total)		1,11
	Total	***15,68***

Source: Adapted from Kurt (2015b), Ali (2005)

The total construction cost of the port structure is calculated according to the capacity and size assumptions. The items affecting the total construction cost are given in Table 4-19.

Table 4-19 Total construction costs for OCPS

		Cost Item	Cost in $	% Share
(1)	Terminal Modules	Main port structure	$ 124,962,816	23.7%
		Transport & Assembly	$ 24,992,563	4.7%
(2)	Equipment	Quay Cranes	$ 211,200,000	40.0%
		AGVs	$ 38,016,000	7.2%
		RMGs	$ 52,800,000	10.0%
		Supply Boats	$ 5,940,000	1.1%
(3)	Others	Administration building	$ 33,000,000	6.3%
		Facilities	$ 9,240,000	1.8%
		Ballast system	$ 10,560,000	2.0%
		Stability System	$ 17,160,000	3.3%
		Total	***$ 527,871,379***	***100.0%***

Source: Adapted from various resources (Ali, 2005, DLH, 2007, Kurt et al., 2015b, LIEBHERR, 2016)

Due to more advantages of concrete structures than steel structures, it is assumed that the structure is built with concrete material. The advantageous features of concrete are lower fabrication and maintenance costs, downtime and longer life of the material and motion behaviour (Berner and Gerwick, 2001, Sandvik et al., 2004). In that situation, the rough construction cost of the offshore structure is seen in the first cost section (1). This cost value is obtained for 20% concrete filling rate and 6.4 meters of structure draft. The second cost section (2) gives the cost of equipment to use in the container handling operations. Those of cost covers 32 quay cranes (STS), 96 automated guided vehicles (AGV), 32 rail mounted gantry cranes (RMG) and 3 supply and tug boats. As a third cost expenditure, other items can be given in section (3) such as administration buildings, facilities, and ballast and stability system of the structure if they are required. In total, an investment of USD 527.9 million is required for the construction of the determined offshore structure characteristics.

Figure 4-32 represents a basic structural design for an OCPS in the determined structural characteristics. The figure also shows the settlement of stacking area.

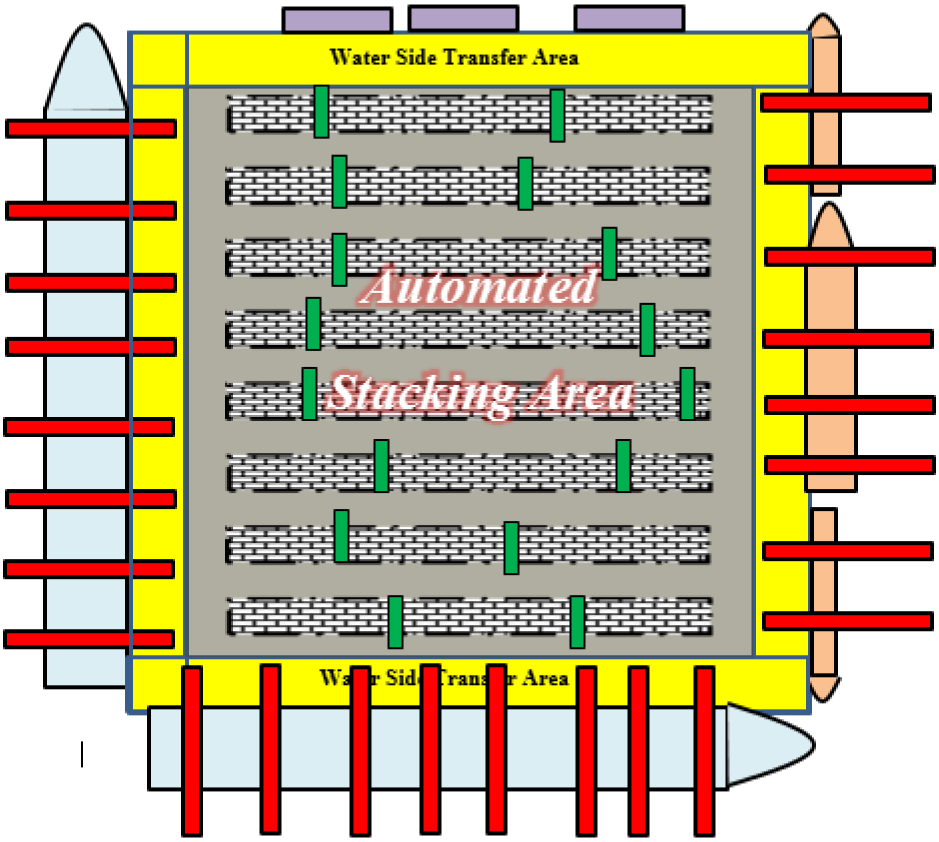


Figure 4-32 A basic structural design for OCPS and stacking area settlement

In addition to the construction costs, the operational costs of the port were also calculated, including annual energy costs and staff costs. The energy cost is calculated by assuming that the handling equipment is only operated with the electric energy. In addition, assuming that AGVs and RMGs are fully automated, the personnel costs for these vehicles are not calculated. The energy cost findings obtained are for 32 STSs, 96 AGVs and 16 RMGs with 6 KWh, 3KWh and 5KWh electric consumption per move, respectively. It is considered that there will be a total crane movement of 0.925 million for the 1.5 million TEU handling capacity port due to 0.7-percent ratio of FEU/TEU(Rodrigue et al., 2013). Also it is expected that 1×10^6 KWh electric can be annually consumed by administration buildings and 1,500 ton of MGO can be burned by 3 boats. The personnel costs are calculated for 3 shifts for 24/7 sustainable port operations. According to this offshore structure defined, the annual energy and personnel costs of the port are calculated as in Table 4-20.

Table 4-20 Annual energy and personnel costs for OCPS

		Annual amount	Unit	Price per Unit ($)	Cost ($)
Energy	Quay Cranes AGVs RMGs	12,950,000	KWh	$ 0.116	$ 1,502,200
	Buildings Lightings Facilities Utilities	1,000,000	KWh	$ 0.116	$ 116,000
	Personnel Tug (3)	1,500	Tonnes	$ 540.00	$ 810,000
	Total				***$ 2,428,200***
Personnel		**Number of staff**	**Salaries**	**Monthly Personnel Salaries**	**Annual Personnel Salaries**
	Quay Cranes' Operators	32	$ 4,620	$ 147,840	$ 1,774,080
	Boat Personnel (2 per Boat)	6	$ 5,280	$ 31,680	$ 380,160
	Administration	20	$ 3,960	$ 79,200	$ 950,400
	Maintenance	5	$ 4,620	$ 23,100	$ 277,200
	Others	3	$ 3,300	$ 9,900	$ 118,800
	Sub-total	66		$ 291,720	$ 3,500,640
	Total (3shifts)	***198***		***$ 875,160***	***$10,501,920***

Source: Adapted from various resources (Eurostat, 2017a, Ship&Bunker, 2017)

As shown in Table 4-19, an offshore construction investment requires approximately USD 527.9 million according to the described offshore structure features. This structure also requires approximately 12.9 million USD in annual energy and personnel costs in order to sustain the operations as seen in Table 4-20. The return period of this investment cost is one of the most economically important criteria for getting investment decision. So the return of this investment cost is calculated by considering different port handling fee scenarios. The results of this calculation are presented in Figure 4-33 as follows.

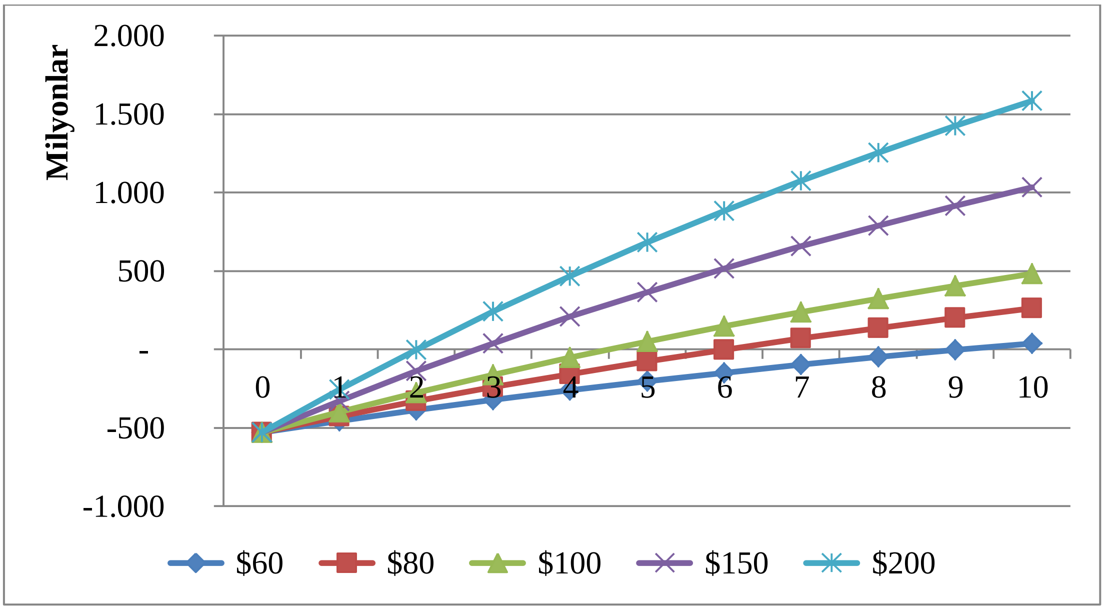


Figure 4-33 Return of costs for different port handling fee scenarios, 10-year period

For the designed offshore port, according to the calculations made, for the fully utilised port capacity, if a return is requested within 10-year period, a handling fee of $60 will be sufficient. However, if a handling fee of $200 is set, the return period can be reduced to 2 years. The cost figures in Table 4-19 and Table 4-20 are used while the interest rate for the construction investment is 6 percent per annum.

The calculation for the other three ports has been made for the cost of a 1.5 million capacity onshore port based on same technical and operational features with the designed offshore port. It is assumed that additional expenditure items are taken same for the three ports although they are different regions and they have different cost value. However, there are no significant cost differentiations amongst the three ports. For the conventional port cost calculation, the energy and personnel costs are assumed to be the same as offshore port investment. In the light of calculations and the defined assumptions, an additional cost of about $ 20 per TEU has emerged. The main reason affecting this cost increase is the high land prices. According to these calculations, the costs per TEU are shown in Table 4-21.

Table 4-21 also shows the capacity utilisation rate and the utilised capacity by TEU based on the scores given in Table 4-16. The following table also gives the average handling fee and the port handling cost per TEU as a result of the size and capacity analysis for the case of the 1.5 million TEU capacity increase strategy. Table 4-21 is a combined table of the results obtained from the calculations in section 4.2 and section 4.3.

Table 4-21 Features of the ports for operational approach

Properties	Venice	Valencia	Rotterdam	Hamburg
Total score	76	48	80	86
Capacity investment	1.500.000	1.500.000	1.500.000	1.500.000
Capacity Utilisation Rate	88%	56%	93%	100%
Capacity Utilisation	1.325.581	837.209	1.395.349	1.500.000
Average Handling Fee	$200	$200	$200	$200
Cost per TEU	$89,40	$161,55	$104,93	$99,00

For the given port models, the current average handling fee is identified as \$113.72/TEU. Thus, the market slope values of the ports are determined as $b_{venice} = 0{,}000065089$, $b_{valencia} = 0{,}000103058$, $b_{rotterdam} = 0{,}000061835$, $b_{hamburg} = 0{,}000057521$, and the a value is given as 200.

4.4 Quadrangular Competition Analysis of the Container Ports

To analyse the competition situation of container port market in Europe, a market scenario is generated. According to this scenario, a 5 year European containerized cargo flow growth forecast is made. The most optimistic growth forecast indicates that these ports need a capacity utilization increase of 23.43% by 2022 in total. This calculation is made based on the existing 2015 data available. This capacity utilization increase is assumed to be achieved with port investments in order to preserve the shares of the 4 ports determined in the European container market in accordance with this forecast. It is assumed that the Port of Venice will invest in an offshore based port and other competitors will extend their capacities thanks to a conventional port structure. It makes possible to invest an average capacity investment of 1.5 million TEU port structure.

In this scenario, the port handling fee will be taken $200 for each TEU. It is assumed that the expense items affecting the port handling fee during this five year period will remain static. The vessel operating costs, the voyage costs for the vessels, and the hinterland transportation costs are also assumed to be remained as same as the present which are used in that case. It is proposed that the Port of Venice is the leader who needs to take a rational action regarding capacity deployment decision-making due to its lower share in the Europe container market among other players. Then, the Port of Valencia is the first follower and the Port of Rotterdam and the Port of Hamburg are other followers. 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 container ports.

According to the defined scenario, each port in the competition has 2 strategic decision options to improve its competitiveness against the other rival in the game. Therefore, available strategies are given as in the following.

1. "yes", 1.5 million TEU capacity port investment is made,
2. "no", 1.5 million TEU capacity port investment is not made.

Hereunder the following pure strategy combinations can be created according to the combination alternatives in section 3.5.

$$\left(s_1^{yes}, s_2^{yes}, s_3^{yes}, s_4^{yes}\right) \coloneqq Combination\ 1(Move\ 4{:}\ 1, 1)$$

$$\left(s_1^{yes}, s_2^{no}, s_3^{yes}, s_4^{yes}\right) \coloneqq Combination\ 2\ (Move\ 4{:}\ 3,1)$$

$$\left(s_1^{yes}, s_2^{yes}, s_3^{no}, s_4^{yes}\right) \coloneqq Combination\ 3\ (Move\ 4{:}\ 2, 1)$$

$$\left(s_1^{yes}, s_2^{yes}, s_3^{yes}, s_4^{no}\right) \coloneqq Combination\ 4\ (Move\ 4{:}\ 1, 2)$$

$$\left(s_1^{yes}, s_2^{no}, s_3^{no}, s_4^{yes}\right) \coloneqq Combination\ 5\ (Move\ 4{:}\ 4, 1)$$

$$\left(s_1^{yes}, s_2^{no}, s_3^{yes}, s_4^{no}\right) \coloneqq Combination\ 6\ (Move\ 4{:}\ 3, 2)$$

$$\left(s_1^{yes}, s_2^{yes}, s_3^{no}, s_4^{no}\right) \coloneqq Combination\ 7\ (Move\ 4{:}\ 2, 2)$$

$$\left(s_1^{yes}, s_2^{no}, s_3^{no}, s_4^{no}\right) \coloneqq Combination\ 8\ (Move\ 4{:}\ 4, 2)$$

$$(s_1^{no}, s_2^{no}, s_3^{no}, s_4^{no}) \coloneqq Combination\ 9\ (Move\ 4{:}\ 8, 2)$$

$$\left(s_1^{no}, s_2^{yes}, s_3^{no}, s_4^{no}\right) \coloneqq Combination\ 10\ (Move\ 4{:}\ 6, 2)$$

$$\left(s_1^{no}, s_2^{no}, s_3^{yes}, s_4^{no}\right) \coloneqq Combination\ 11\ (Move\ 4{:}\ 7, 2)$$

$$\left(s_1^{no}, s_2^{no}, s_3^{no}, s_4^{yes}\right) \coloneqq Combination\ 12\ (Move\ 4{:}\ 8, 1)$$

$$\left(s_1^{no}, s_2^{yes}, s_3^{yes}, s_4^{no}\right) \coloneqq Combination\ 13\ (Move\ 4{:}\ 5, 2)$$

$$\left(s_1^{no}, s_2^{yes}, s_3^{no}, s_4^{yes}\right) \coloneqq Combination\ 14\ (Move\ 4{:}\ 6, 1)$$

$$\left(s_1^{no}, s_2^{no}, s_3^{yes}, s_4^{yes}\right) \coloneqq Combination\ 15\ (Move\ 4{:}\ 7, 1)$$

$$\left(s_1^{no}, s_2^{yes}, s_3^{yes}, s_4^{yes}\right) \coloneqq Combination\ 16\ (Move\ 4{:}\ 5, 1)$$

The Stackelberg-Nash quadrangular competition game, in which the port, that makes the initial investment decision according to the game strategy established, is the leader and the other competitors are followers, is applied for this case. This competition game is verified with Gambit which is open-source software for game theory graphical interface version 15.1.1 (Turocy, 1994-2014).

The obtained 16 combinations for the Stackelberg competition are shown in Figure 4-34 as extensive form in Gambit software. This is a screenshot from the version 15.1.1 of Gambit software. In this figure, all competitors are described with different colours and are shown on the left side of the figure. While the Port of Venice is shown in red, the Port of Valencia is depicted with yellow, the Port of Rotterdam is shown in green and the Port of Hamburg with blue. In the extensive tree model generated, each player's name and order is defined as having two strategic decision options. They are defined above as "Strategy 1" to make investment on an offshore structure and "Strategy 2" to not make investment on an offshore structure. The decision node connections and the payoffs for each strategy combination of the players are also included in the extensive tree model.

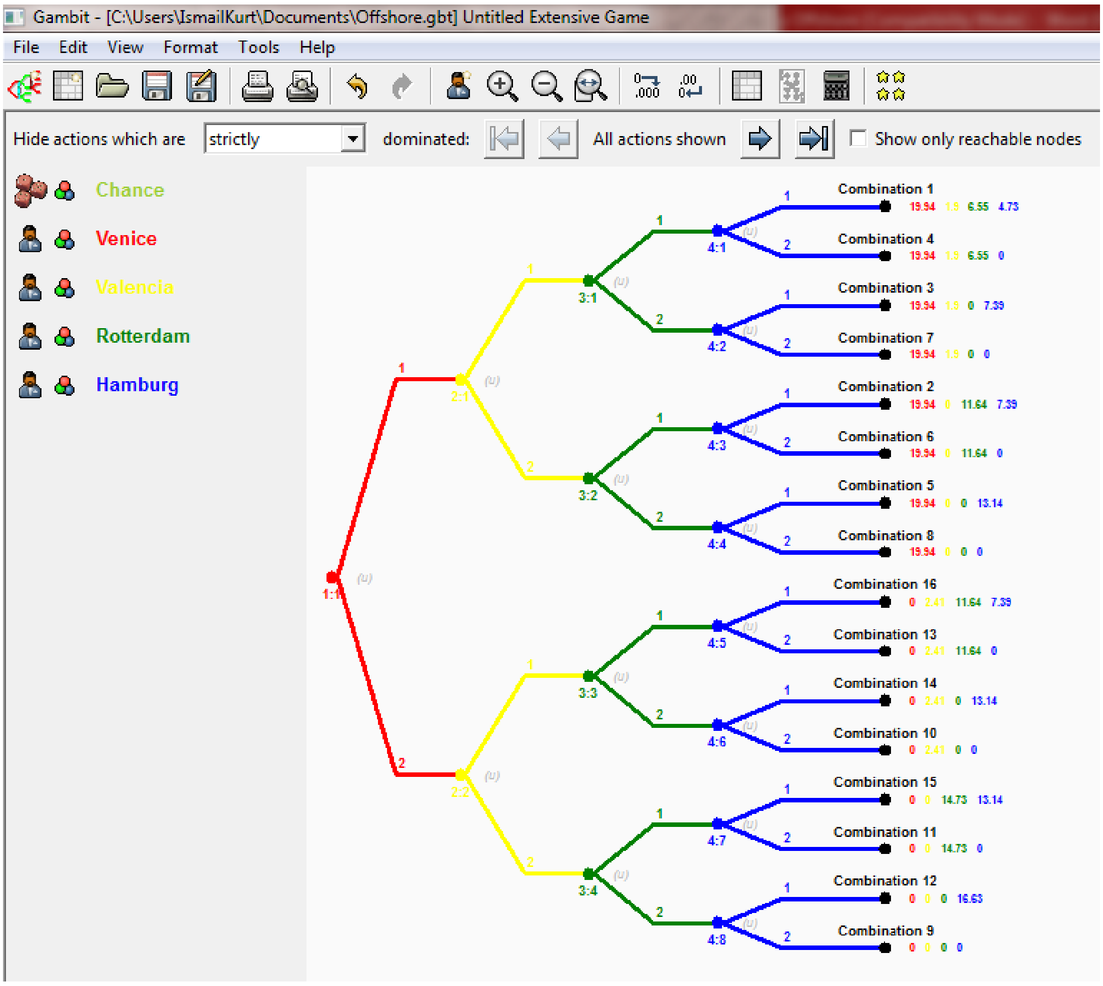


Figure 4-34 Extensive (tree) game illustration on the Gambit software for the designed competition game

After the combinations and strategies are shown on the software, the payoffs for each combination are defined in the Gambit software as the second step. The results of Nash equilibrium computed according to the defined payoffs are given in Figure 4-35. Accordingly, if optimal strategies are selected by the competitor ports, the maximum payoffs expected for each player are given on the left hand side of figure separately for each player. The strategic action to reach the maximum payoff is achieved in Combination 1. In this way, it can be said that the Port of Venice as leader of the game can make $19.94 additional profit per TEU and as the followers of game, the Port of Valencia, the Port of Rotterdam and the Port of Hamburg can make $1.9 profit, $6.55 profit and $4.73 profit per TEU, respectively.

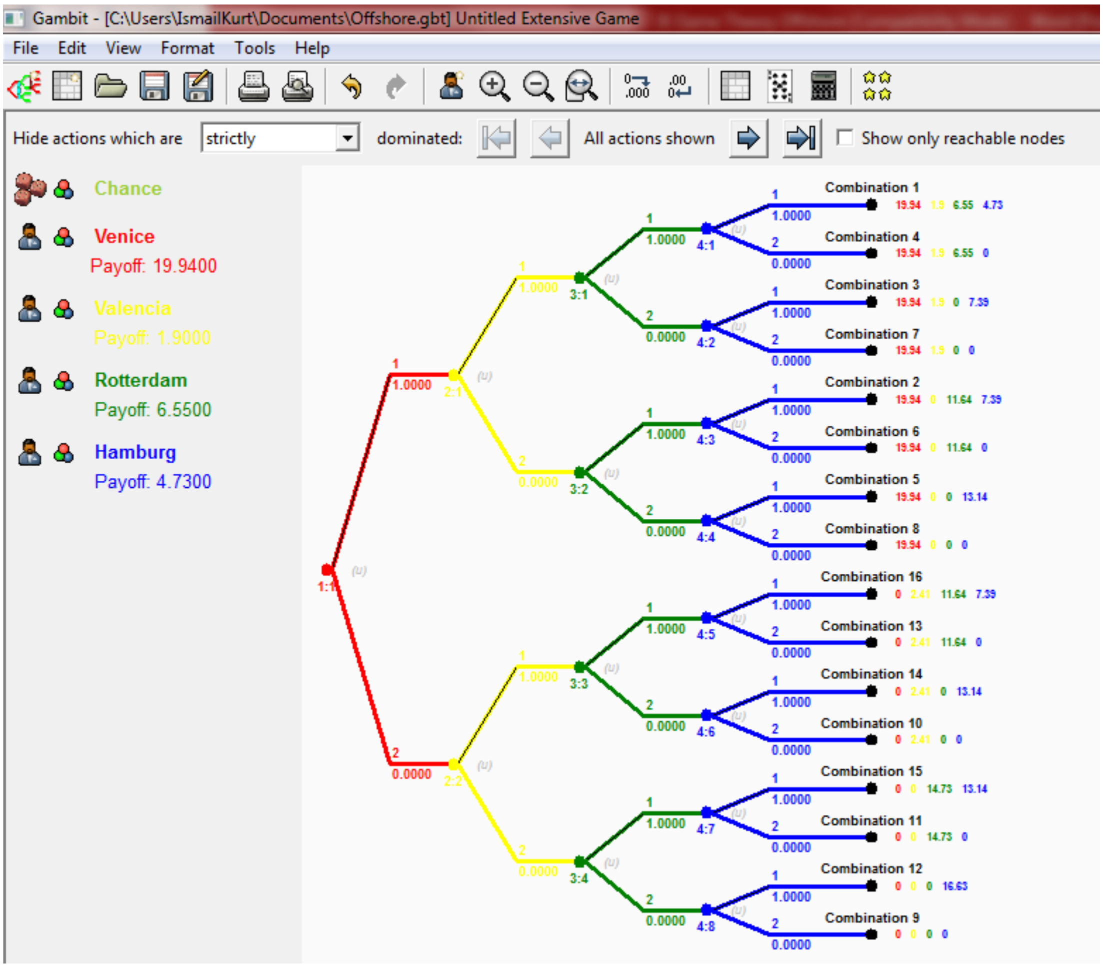


Figure 4-35 Obtained results from the Gambit software for the designed competition game

According to the defined game and expected payoffs, the investment to be made by all competitive ports in the game is foreseen. Thus, all ports can make profit by taking investment action. In this case, "Strategy 1" should be selected as the action strategy to achieve maximum profit in possible game combinations. Although the list of computed strategy is shown in a single row in software, it has been shown in two parts to be more visible in Figure 4-36. According to the obtained strategy profile, each port in the competition game should determine the strategy to take investment decision. Combination 1 is chosen as the best strategy for this competitive game, because it is profitable to invest for each port.

Profiles One equilibrium by logit tracing in extensive game

#	1: 1	1: 2	1: 1	1: 2	2: 1	2: 2	1: 1	1: 2	2: 1	2: 2	3: 1	3: 2	4: 1	4: 2
1	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000

Continues horizontally

1: 1	1: 2	2: 1	2: 2	3: 1	3: 2	4: 1	4: 2	5: 1	5: 2	6: 1	6: 2	7: 1	7: 2	8: 1	8: 2
1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000

Figure 4-36 List of computed strategy profiles

According to the chosen game model Stackelberg, if the port determined as leader competitor, which is the Port of Venice, does not select the strategy of investment, other ports cannot strategically decide investment decision. Figure 4-37 shows the movement of strategy decisions that could be taken. However, according to Stackelberg game theory, the leading player has to act first. Therefore, only the strategic movements in Combination 1 meet both the requirements of optimal result and the requirements of the Stackelberg game.

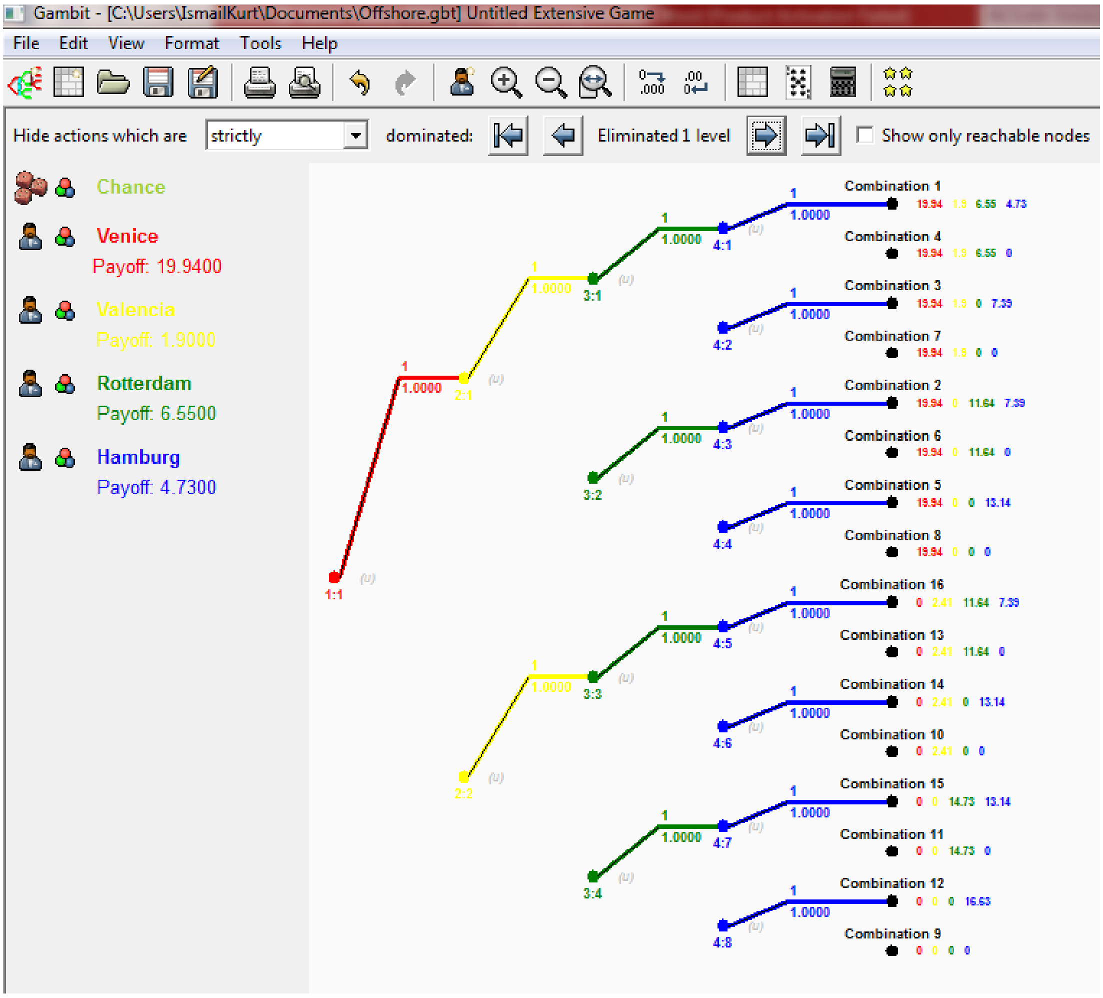


Figure 4-37 Illustration of rational actions taken by competitor ports in the Gambit software

Figure 4-38 gives the obtained optimal solutions from the Gambit software version 15.1.1. According to this, the first movement is made by the port of Venice. According to Stackelberg game strategy, the Port of Venice has the highest payoff. The followers set their strategic decisions after the strategic decision of the leader player. The followers give their strategic decisions, taking into account a lower profit rate than the leader player. In the designed game, each player receives an investment decision according to the optimal solution, and the profit ratios of the followers are less than the leader player.

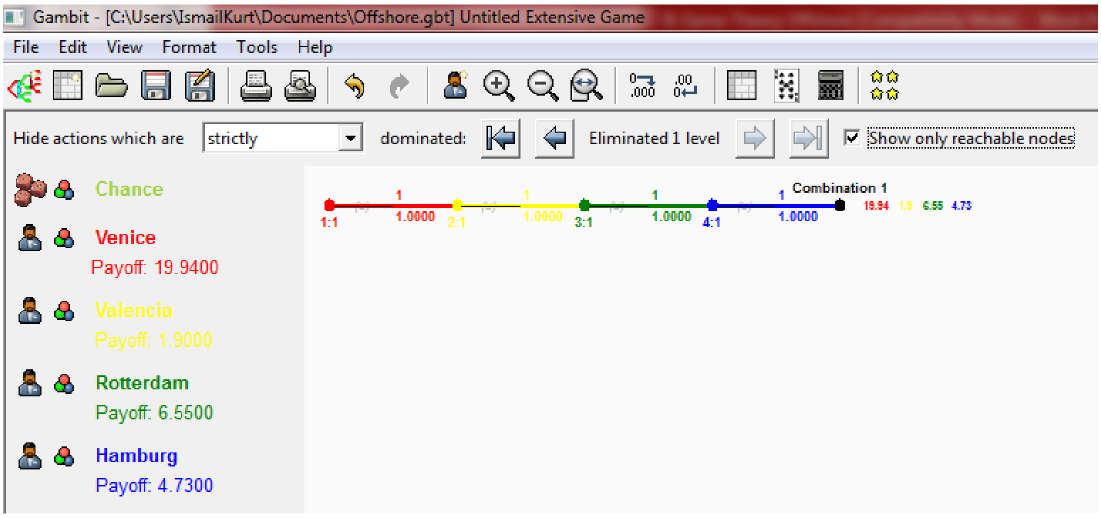


Figure 4-38 Illustration of optimal solutions obtained in the Gambit software

4.5 Sensitivity Analysis

As a consequence of evaluating the data by sticking to the data sources used in the case study, four different growing scenarios for European container trade have been obtained. According to different growth scenarios, this sensitivity analysis has been carried out to remove the questions that remain in mind as to what kind of investment strategy should be followed the ports in the case study. In the framework of the other three scenarios created in conjunction with Europe container trade growth scenario analysed in detail in the case study, it is analysed whether there is any change in the investment strategies carried out by the ports. An analysis was conducted to develop the investment strategy of the ports so that the total share of the designated ports (The Port of Venice, the Port of Valencia, the Port of Rotterdam and the Port of Hamburg) for each growth scenario among all ports in Europe remains same with the total share of the designated ports in 2017. This sensitivity analysis was carried out for 5 years for up to 2022 to be able to see the effect of the specified scenarios on the results. For these four scenarios, the total container capacity increases of the ports corresponding to the total shares of the four ports are given in Figure 4-39 according to years, so that the total share of the four ports among all port in Europe remains the same. Accordingly, the total capacities of the ports in the year 2022 actualise as 33.7 million for Scenario 1, 32.6 million for Scenario 2, 30.8 million for Scenario 3 and 30.6 million for Scenario 4.

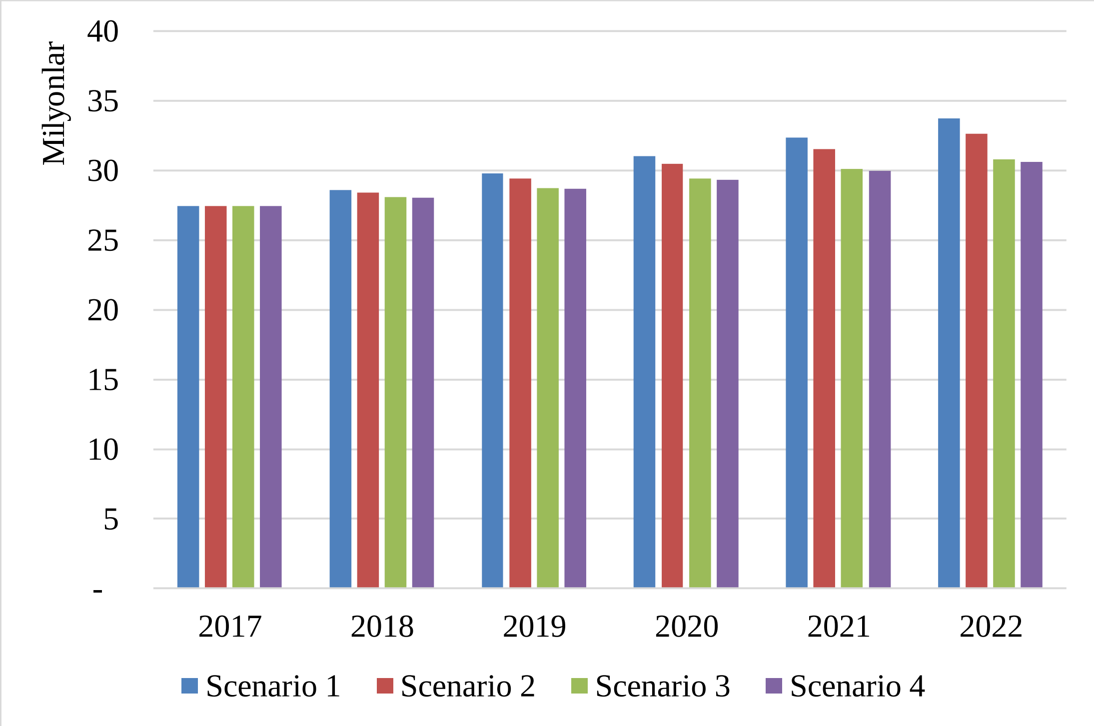


Figure 4-39 – Total container capacities of the ports for years 2017-2022

According to these four scenarios, the total capacity investment of the ports is changing in order to hold their total container throughput share for Europe container market at same level. The total capacity investment amounts by ports for each scenario are as shown in Figure 4-40.

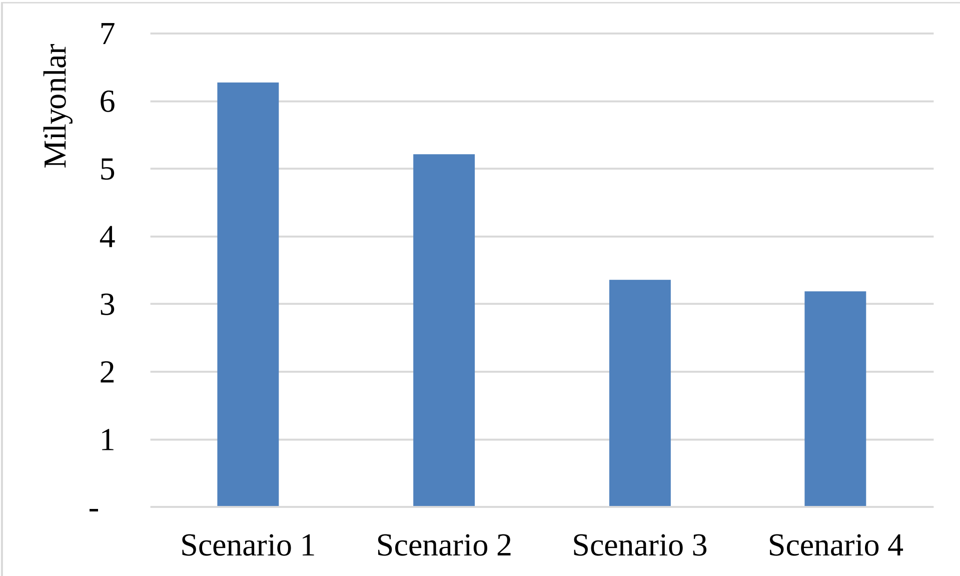


Figure 4-40 – Total capacity investment amounts

According to determined scenarios, when the required container handling capacity for 2022 compared to the container handling capacity for 2017, the 4 ports need to invest in a capacity expansion; for scenario 1 is approximately 6 million, for scenario 2 is approximately 5 million, for scenario 3 is approximately 3.5 million and for scenario 4 is approximately 3 million. It is assumed that each port receives an investment decision of one quarter of the total capacity investment for each scenario when it is accepted that each port invests in an equal amount of capacity increase while adhering to the game theory method used.

The capacity utilization of the ports is calculated taking into account the percentage distributions based on the coefficients obtained from the time and cost values for the hinterland distribution of the ports. The capacity utilization figures for each scenario are given in Table 4-41.

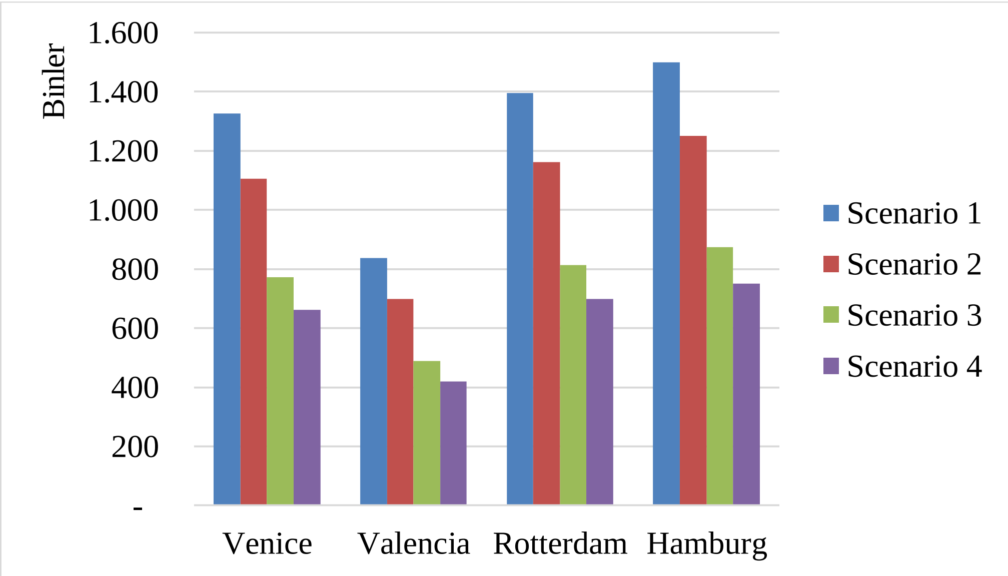


Figure 4-41 – Capacity utilization for each scenario

The capacity expansion investment is considered as an offshore container structure for the Port of Venice, it is treated as traditional container port structures for other ports as in the case study. It is assumed that the installation of OCPS for the Port of Venice is based on a 430m × 430m area for each scenario so that 400-metre ULCVs can be handled from four quays of the structure. According to the assumption made, the designated OCPS has sufficient physical space for the annual container throughput considered for each scenario. The cost calculations are made taking into account such adequate space, handling equipment, administration buildings and other necessary services and areas. In each scenario, OCPS has standardized measures since it is designed to be operable from four quays. However, considering this structure as a standard measure, the amount of idle space increases due to the decrease in capacity utilization. For this reason, it can be said that OCPS, which is built at 430m × 430m, offers more efficient operational functionality for capacity utilization of 1.5 million. The handling cost per TEU also varies depending on capacity utilization.

Based on the defined OCPS and conventional container port structures, the handling cost per TEU obtained for all ports in each scenario are given in Figure 4-42. Thanks to the advantage of offshore structure in construction costs, the Port of Venice offers the lowest container handling cost in scenarios except the scenario 4. However, in Scenario 4, the Port of Hamburg has more advantageous container handling costs due to reduced capacity utilization for the Port of Venice. Apart from the mentioned situation, the lowest handling costs are respectively given by the Port of Venice, the Port of Hamburg, the Port of Rotterdam and the Port of Valencia.

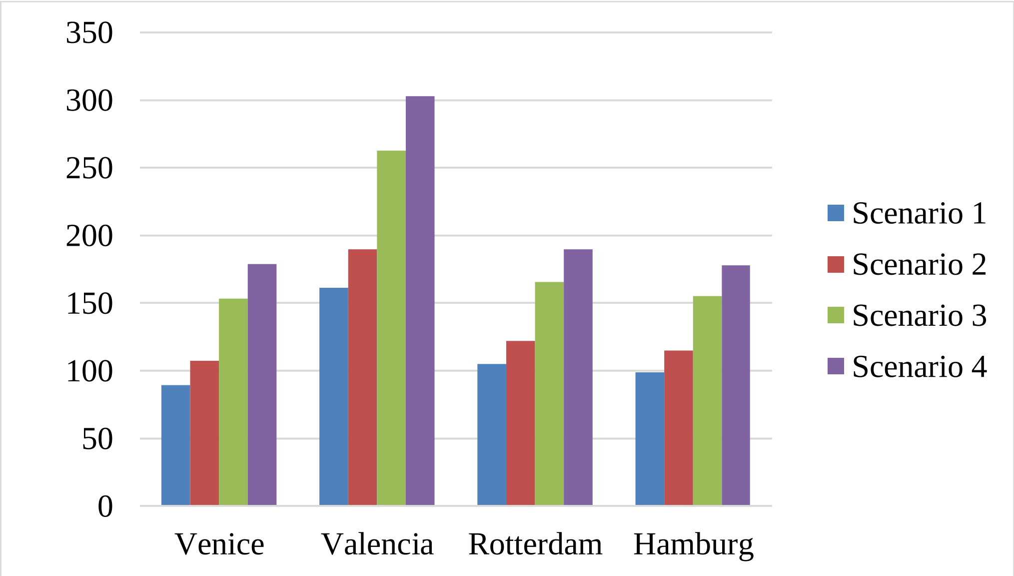


Figure 4-42 – Handling cost per TEU for each scenario

The total annual profits to be earned for the ports designated in each scenario are calculated as shown in Figure 4-43 according to the profit calculation made considering the $200 handling fee set in the case study. All ports except the Port of Valencia in each scenario close annual financial statement in positive level at the end of year. But the Port of Valencia have negative profitability data in scenario 3 and 4 due to insufficient capacity utilization. The profit-loss assessment shows that the increase in capacity utilization reflects on profit in positive meaning.

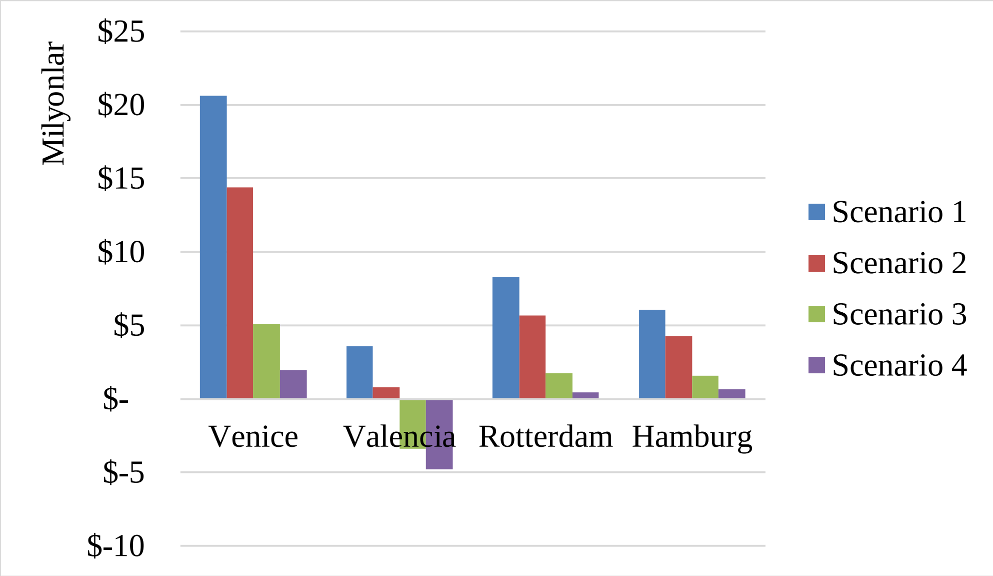


Figure 4-43 – Annual profits of the ports in each scenario

For $200 handling fee per TEU, the data obtained show that the profitability rate of the Port of Venice is higher than other ports. One of the most basic reasons for this is that the Port of Venice takes place in the leading position for capacity building investment. In addition, the reduction of marketing costs and the reduction of administrative costs as a result of earlier system adaptation than other players can be described as a benefit of defining the Port of Venice as a leading player.

In the same way, the total annual profit rate of the Port of Rotterdam is higher than the Port of Hamburg except scenario 4 because of the early investment in the capacity expansion of the Port of Rotterdam, although the Port of Rotterdam is disadvantageous compared to the Port of Hamburg in terms of the capacity utilization and the handling cost per TEU.

In assessment of the Port of Valencia, it can be said that the port has the lowest total annual profit as a result of insufficient capacity utilization. It is also possible to capture the positive profitability in only the scenarios 1 and 2. The Port of Valencia cannot obtain a positive profitability for the scenarios 3 and 4, and therefore it is more appropriate that Valencia port does not make investment decision if the scenarios 3 and 4 are realized.

4.6 Outline of the Case Study

In this case study, the aim was to illustrate numerical application and practicability of the generated methodology. Throughout this case study, a novel port competition analysis methodology was presented and tested for the selected ports in Europe. An integration of different port competition analysis perspectives was provided by applying hinterland analysis in terms of total transportation time and cost, the construction cost analysis of an OCPS and the game theory approach. For the game theory part of the analysis, the methodology developed in the chapter 3 was utilised for the complete information case of the Stackelberg game.

In the obtained data, the scenario 1 shows the most optimistic picture among the plotted scenarios. The scenario 1 shows that each port has the higher profitability than the other scenarios. The main reason for this is that the capacity utilization in scenario 1 is higher than other scenarios and therefore the handling costs per TEU are lower.

In the case study, the Port of Venice is found as the most profitable port, consequently the most competitive port. The primarily reason behind the fact that the most competitive port definition of the Port of Venice is the decrease in operational costs per TEU due to the investment in capacity increase in form of an offshore structure. In addition, the efficient use of the capacity obtained as a result of the investment made increases the profitability compared to other ports. Because the assumption of the Port of Venice as the leading player gives an advantage to the Port of Venice at the rate of profit. Scenario 4 shows that as a result of the decrease in capacity utilization, the Port of Hamburg leaves behind the Port of Venice at the handling cost per TEU. However, with the advantage of being a leading player, the Port of Venice can turn this disadvantage in its favour of profitability.

The other point obtained from this case study and sensitivity analysis is that the capacity utilization should be kept at a sufficient level. According to the plotted scenario, if the capacity utilization remains below a certain level as the scenario 3 and 4, it may cause to lose the ports' competitiveness completely and to suffer financial loss. It can be thought of as the easiest solution to increase the handling fee in order to avoid losses, but this time the player may come to a position where it cannot compete against its competitors in terms of handling fee. As a result, in this competitive analysis, the port investment costs, the time and cost values depending on location for hinterland distribution of ports, the port handling costs and the pricing strategies play an important role. The player who blends these criteria in the most appropriate way can find himself at the forefront of the competition among other competitors. The outcome of this chapter provides significant assistance to strategy development departments of the port administrations in order to measure their competitiveness level by considering complex port hinterland and cost analysis and tactical behaviours of the competitors.

The model used in case study has a design that can be used for other cases by port authorities. This model can be applied to each port authority's own case study by updating the data entries of the designed model by the port authorities according to their own ports and competitor ports and by defining the details of the specific case study.

The use of offshore structures in the case study of this study should not suggest that this model can only be used with offshore port applications. This model needs that the cost calculations to be adapted by the port authorities to the determined case study and to select suitable the game theory model for that case study so that the model can be used in all kinds of competition-based investment cases. In this way the port authorities can more easily see their competitive position in the case study which is created according to the definitions made in the model with the necessary details. Accordingly, thanks to the decision-making mechanism created, they can maximize the profits obtained while making investment decisions.

5 CONCLUSION

As it is known, the container ship dimensions have come to the level that can be called gigantic nowadays. The underlying idea of such a growth of ship dimensions is the transfer of the advantages of the scale economy to the container sector in a positive way to reduce unit transportation costs. If these mega-ships are operated on routes without any trouble in terms of container transportation demand, they can gain an important favour of economic. Otherwise, if these ships do not reach the required capacity, the financial losses will be much more than the smaller sized container ships. Therefore, when route selection is made, a suitable supply and demand environment for the operation of these vessels must be considered.

One of the main issues that these types of large vessels reveal in terms of the container port industry are the pressures on ports in terms of operation. Because of their dimensions, the required draft, the quay length, the crane handling height and width, and even the air draft limits are necessary to provide for the handling of these vessels. Port administrations have also made efforts to produce various technological and operational solutions in order to be able to cope with the effects of the vessels on the terminals. One of these solutions is the offshore port structures, which will remove especially the draft constraints. It is expected that the outcome of offshore port structures will be a significant effect on container port competition. Because it is inevitable to add a different operational understanding to the container sector due to its physical structure, and it is aroused curiosity about what the competitive position is between the ports with this different operational understanding. The offshore structures in terms of the features offered are a proposed model for responding to the developing container sector and the growing ship dimensions.

The purpose of this thesis is to examine the developing and growing container sector, the offshore port structure and the effects of offshore port structure on inter-port competition. During this examination, the history and development of containerization and container ports have been criticised in detail. The difficulties that are arisen due to the development of the container sector in terms of containerized cargo flow and vessel dimensions have been tried to be defined and the effects of ever-growing container ships on the container terminals have also been tried to define. The offshore port structures stand out as the proposed port concept to reduce these effects by providing dimension free container handling operations. For this reason, offshore port facilities have been subjected to a detailed examination under 3 main headings, namely, (1) strategic and economic aspects of OCPS, (2) structural aspects of OCPS and (3) operational aspects of OCPS.

The effect of offshore port structure, which is supposed to be newly adapted to the container sector, on the competition between the container ports of the port structure, what kind of position the offshore structures will have in the competition is not known exactly has made this study possible to examine the competition between the container ports. At this point, a detailed examination of container port competition has been made in terms of the level of competition between container ports and the dynamics affecting competition.

This thesis focuses on the development of new port structures mainly due to the development of the container industry. However, the examination of the competition between container ports with the adaptation of offshore port structures by applying the game theory method is a significant contribution of this study. The novelty of this thesis can be briefly explained in the light of the developing container sector that the examination of the offshore port structures' position in the container competition thanks to the application of game theory method. At this point, the offshore port structure, the competition between container ports and the application of game theory can be defined as the main stakeholders of this thesis.

A case-study approach was adopted to help understand how an OCPS can take position in the inter-port competition. For this case study, the container transport network between Asia and Europe, which will be constructed through an OCPS, was evaluated in terms of total transportation time and cost to the designated locations in Europe. This assessment was made to address the competition between the four ports determined by the criteria and assumptions set out in the case study. This competition game is built on the port investments that must be made in order to protect the share of ports in the growing European containerized cargo flow. The competition points with offshore port structure were also addressed to associate to offshore adapted inter-port competition, while the ports set strategic decisions for investment. Therefore, it is assumed that one of these ports determined to invest in an offshore port structure according to the determined capacity increase.

This thesis was undertaken to design an offshore container port adapted inter-port competition and evaluate the position of ports in the competition thanks to non-cooperative Stackelberg game theory strategy with Nash equilibrium solution method. In the specified case study, the obtained results have given that the situation of all competitor ports take the strategic investment decision for the designed and defined case conditions is the best strategy. The Port of Venice with an OCPS investment is designated as the leader to carry out the Stackalberg game and other competitor ports are designated as the followers. For the designated case study, the leader gained the highest payoff and other competitors also followed by the payoff values. It shows that the offshore port structure can have a strength position in the container transportation network. It can be said for this case that the offshore container structure has been able to achieve so thanks to the advantage of location and the cost of construction. At the same time it showed that the offshore structure has also an important potential to meet the expectations of the developing and growing container industry.

Overall, the study strengthens the idea that offshore port approach could be an alternative and a strong competitor for conventional container ports as offshore ports do not have dimensional constraints and can accommodate modern mega vessels easily and the existence of its cost related competitive aspects as analysed in this study. This research extends our knowledge of the offshore combined hub-and-spoke network, and will serve as a basis for future offshore-hub liner shipping network studies. Although, the study was limited by the absence of the offshore related real example or data in practice, further studies regarding the role of the offshore container port concept for network analysis research would be worthwhile.

In terms of the model used, the conclusions when the designed case study and sensitivity analysis are examined show that this model can be used in different case studies by determining suitable the game theory competition model which is applied depending on the structural and operational variables in the competition - based investment models. In terms of other studies, the flexible structure of the model allows it to cope successfully with the variability of inputs by defining the competition model appropriately.

As a conclusion, the offshore adapted inter-port competition analysis is a detailed case study. However, it is proved that the analysis methods used and the results obtained are compatible with the designed methodology and the results can be verified so that this research can be a guide role for other studies. As one of the objectives of this study, if the results are considered to be positive to meet the expectations of the real sector, the methodology and the analyses used will serve as a guide for industry stakeholders, strategic decision makers and entrepreneurs.

5.1 Limitations of the Current Study

Unfortunately, during this study has been encountered some limitations and restrictions. The most important of them has been faced as the issues to access the required data. The reason of that the commercial concerns of the companies and some of the data cannot be reached in a regular manner. For example, the access to the required data, that is to be used in the case study, has not been provided due to the management of a company has changed. For this reason, some assumptions have been tried to be made close to realistic values. As the amount of assumption made increases, the research is far from reality so and if it cannot be predicted, it is assumed from the data of other similar companies to try to obtain more realistic results.

The other issue is the variability of the information that is to be obtained such as fuel prices. In such cases, the long-term averages are used to make assumptions as well as the values that are sometimes used when they are accessed by referring the date and time.

A lot of information and data have been studied in this research. However, due to the limited finance of the study, all data cannot be retrieved directly from Seaweb and similar databases. Therefore, free but limited data sources have been used for research.

5.2 Recommendations for Further Research Work

It would be interesting to assess the effects of the practical inter-port competition implementation with offshore container port system on the container transportation network. However, more research is also required to better understand the practical implementation of the inter-port competition models based on the game theoretical approaches. Further experimental investigations are needed in order to validate theoretical findings in the scope of container sector, developed operational and structural port systems, and the competition in different platforms.

Looking at the container sector, it is seen a very rapid development and change in the sector. These developments and changes bring with it different demands. For example, although today the handling of mega-ships is quite difficult for the ports, on the other hand, there are quite positive side effects on port efficiency. Some other problems are the environmental factors, the probability that some ports will be flooded due to increasing sea water levels, and perhaps one of the most important problems that threats for the container trade and national security. For this reason, the advantages of offshore harbors should be investigated in detail. The studies should be carried out on the transmission of the offshore port contributions to the container sector in a more efficient manner. The works should also be addressed in the context of environmental, security and social emergencies without taking into account the economic outlook.

This study also attempted to clarify the decision uncertainties of the container port industry stakeholders and developed a four player game theory competition analysis method. The developed game theoretical research approach of this thesis could be improved in several ways. A closer collaboration with industrial counterparties could be developed in order to apply on competition of the other component of the shipping industry.

The method used in this study has a flexible structure. This means that changes in the data or the case do not render the method non-functional. So that if port authorities want to use the developed model in this study they can easily make their own competitive analyses by using their own available data.

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7 APPENDICES

7.1 Appendix A

	Vessel Descriptions		
Vessel Name	Emma Maersk	CMA CGM Marco Polo	Triple-E
Gross Tonnage (GT)	171.542	175.343	194.849
TEU Capacity	15.550	16.020	18.200
	Service Schedule		
Service frequency	Weekly	Weekly	Weekly
Port calls on round voyage	9	9	9
Average operating speed (knots)	19	19	19
Average crane number	7	7	7
Average crane performance (lift/hour)	28	28	28
Average operation time (hour/day)	16	16	16
Outward capacity utilization	90%	90%	90%
Return capacity utilization	60%	60%	60%
Container shipped outward	13.995	14.418	16.380
Container shipped return	9.330	9.612	10.920
Annual transport capacity	1.212.900	1.249.560	1.419.600
	Ship Costs		
Operating costs ($/day)	17.105,00	16.981,20	18.382,00
Capital value ($million)	165	175	200
Depreciation years	30	30	30
Interest rate (% pa)	6	6	6
Capital cost ($/day)	32.841,29	34.831,67	39.807,62
Fuel consumption (tons/day)	144,42	143,14	113,56
Bunker price ($/ton) "average"	320	320	320
Bunker cost ($/day)	46.215,39	45.806,05	36.339,20
Unit cost per TEU ($/day)	6,18	6,09	5,19
	Container Operations		
20' DC containers (% ship capacity)	37	37	37
Number of units loaded	5.754	5.927	6.734
40' DC containers (% ship capacity)	57	57	57
Number of units loaded	4.432	4.566	5.187
20' refrigerated containers (% ship capacity)	6	6	6
Number of units loaded	933	961	1.092

Number of units on full vessel	11.118	11.454	13.013
	Administration Costs		
Administrative productivity (TEU/employee)	2.426	2.499	2.839
Number of employees required	500	500	500
Employee cost ($/year)	40.000	40.000	40.000
Administration cost ($/TEU)	16,49	16,01	14,09

7.2 Appendix B

Assumptions and calculation details			
	Subject	Details	Source
1	Ship type	On the main route, 3 different type of ships; E-class, Explorer class and Triple-E class containerships are taken	Tiedemann (2015)
2	Ship speed	On the main route 19 knots, for barges between OCPS to shore 12 knots	Notteboom and Cariou (2009)
3	Truck speed	For hinterland distribution, 50 km/h	Statista (2017a) and (EU, 2017a)
4	Fuel consumptions	For vessels, according to technical descriptions fuel consumptions are calculated for the assigned speeds; for trucks, 34 l/100km	Todts (2015)
5	Fuel prices	For vessels, $320; for trucks from Hamburg €1,20, from Valencia €1,13, from Rotterdam €1,34 and from Venice €1,55	Ship&Bunker (2017) and Autotraveler (2017)
6	Distance of round trip	17.082 miles for Hamburg, 13.366 miles for Valencia, 16.576 miles for Rotterdam and 12.650 miles for Venice	Sea-distances (2017)
7	Crane number	7 cranes assigned for each vessels in average	Lane and Moret (2014)
8	Crane performance	28 containers/hour	Lane and Moret (2014)
9	Operation time	16 hours per day	Lane and Moret (2014)
10	Operation costs	Includes crew cost, stores, maintenance, insurance and administration	Murray (2016)
11	Capital value	Total construction costs of the designated containerships	MAERSK (2017a) and Bloomberg (2013)
12	Depreciation year	Taken 30 years	Gkonis and Psaraftis (2010) and (AECOM, 2012)
13	Interest rate	Taken %6 per annum	AECOM (2012)
14	Canal fee	Canal fees on main route	Galal (2015)

15	Port cost	Calculated for each containership type and each port but for Venice assumption made	PortofHamburg (2016), PortofRotterdam (2016) and ValenciaPort (2016)
16	Ship capacity share	37% for 20'DC, 57% for 40'DC and 6% for 20' refrigerated containers	Gkonis and Psaraftis (2010)
17	Administration cost	500 employees with $40.000 annual cost are assumed	Gkonis and Psaraftis (2010)