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Green Strategic Positioning Analysis for Major Asian Container Seaports

by

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“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.”

— H. James Harrington

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Time flies!

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Abstract

In order to cater social and economic sustainability, port competition has evolved from economic dimension to environmental (green) performance over the past decades. Considering this situation, all worldwide ports have to think about environmental perspective facing competition. Accordingly, most of the Asian seaports have noticed such importance of this change. However, they are in serious lack of related experience, which makes them lag behind the European and American ports in term of green competitiveness. This paper tries to guide the Asian container ports toward a proper way considering a green strategic planning, and support them to find a practical management tool as well.

On the basis of qualitative discussion by lots of literature, this paper offers an empirical analysis firstly. It then focuses on two models of the port portfolio analysis (PPA) in a practical range of Asian container ports and the green portfolio analysis (GPA) in a fictitious range as well. Those models have made copious references to various port traffic throughputs produced in the period of 2001-2015. According to such analyses, we draw conclusions on the way of relating and applying a green strategic positioning analysis to some major Asian container ports. Firstly, we identified that port daily activities have had dramatically negative impacts on environment around both the port area itself (directly) and its surrounding community (indirectly). Whereas, most Asian seaports just take the direct impacts into consideration but lack of awareness and action of the indirect aspects, which can even generate much worse impacts. Secondly, due to data limitations, the GPA can only be applied in the Busan Port rather than the Asian port range. We, therefore, obtained the theoretical results confirming that the remote Busan is a “dirty” port and has worse performance in terms of environment-friendliness. Also, the relationship between economic and environmental performance is inversely proportional unless there is an appropriate green strategy. Thirdly, we recognised that the “green” data is still a big problem for the Asian seaports. Hence, we would like to emphasise a fact that the Asian seaports should give priority to data collections concerning environmental aspect. The decision makers should adopt advanced collection techniques to ensure a successful analysis of a green dimension and link it to the future strategies. Alternatively, in consideration of the indirect port impacts could be incorporated into the existing environmental strategies like the EMS, through the methods of implementation, measurement, and evaluation to achieve further green improvements.

In general, according to some data limitations and the methodologically related issues, the analytical conclusions should, however, be interpreted carefully. Despite all this, this study provides solid contributions and recommendations to assess the seaports and their rivals in the green competition. Moreover, the adopted models could be regarded as a practical tool to analyse the performance of a green port.

Keywords: Strategic positioning, Green portfolio analysis, Asian container seaports, Environmental performance, Green strategy

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List of abbreviations

AAPA	American Association of Port Authorities
A.D.	Anno Domini
ADB	Asian Development Bank
AGVs	Automatic Guided Vehicles
ASEAN	Association of Southeast Asian Nations
AWN	Alphaliner Weekly Newsletter
BCG	Boston Consulting Group
CM	CM Container Management
CO_2	Carbon Dioxide
COSCO	China Ocean Shipping Company
DEA	Data Envelopment Analysis
DG TREN	Directorate-General for Energy and Transport
ECA	Emission Control Areas
EMP	Environment Management Plan
EMS	Environmental Management System
ESPO	European Sea Ports Organisation
EU	European Union
GPA	Green Portfolio Analysis
HC	Hydrocarbon Compounds
HDV	Heavy Duty Vehicle
ICT	Information and Communication Technologies
IMF	International Monetary Fund
ISL	Institute of Shipping Economics and Logistics
ISO	International Standardization Organization
KM	Kilometre
LDV	Light Duty Vehicle
MPA	Maritime and Port Authority of Singapore
OECD	Organization for Economic Co-operation and Development
PM	Particulate Matter
PoA	Port of Antwerp
PoB	Port of Busan
PoTJ	Port of Tianjin
PoR	Port of Rotterdam
PPA	Port Portfolio Analysis
PPRISM	Port Performance Indicators Selection and Measurement
RMB	Renminbi (Chinese currency)
SO_2	Sulphur Dioxide
SPA	Strategic Positioning Analysis
SWOT	Strengths, Weaknesses, Opportunities, Threats
T/S	Transhipment
TEU	Twenty Feet Equivalent Unit
UNCTAD	United Nation Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
VOC	Volatile Organic Compounds
WTO	World Trade Organisation

1 Introduction

Ports are formed because of natural geographic locations. The land or water transportation is so convenient that many commodities and passengers aggregate there (Rodrigue, et al., 2013). With the developments of economy and technological innovation, great changes have taken place in people's lives. People are always living in global villages nowadays so that an interpersonal communication become quite convenient and fast with the help of aeronautic technique. We can reach anywhere whether in large-sized or medium-sized cities within 24 hours worldwide. Besides, as international business contacts are very frequent, cargos can be delivered to any continents across the oceans, which have formed a quite comprehensive seaborne trade network, namely globalisation. Due to flourishing global trade activities, there are more than two-thirds of the total global freights depending on the sea transport (The Maritime Silk Road - 1e, 2016). The maritime transportation and ports play important roles in sustainable developments of world economy.

Nowadays, as international gateways, the ports evolve from conventional break-bulk terminals to containerised distribution centres (Rodrigue, et al., 2013), which are available to the replenishment, berthing and even refuging. As a natural interface linking between the hinterland and waterside, the seaport is also regarded as special international logistics transportation junctions. In addition, the booming containerized transport mode leads to the quite quicker, cheaper and more efficient ocean transportation, which is so-called containerization. Rodrigue and his colleagues (2013) argued that ports are increasingly impacted by processes of globalization and a containerized transportation has substantially changed port dynamics contributing to the emergence of specialised container ports (Rodrigue, et al., 2013). Considering that situation, a port is not an individual or simplex intermediate node any longer. However, it has become the multipurpose gateways and has more impacts and responsibilities according to social economy.

With that comes a question, namely the fierce port competition, which occurs in the port industry not only between ports each other, but also intra-port aspects every day. Many port authorities and stakeholders are therefore busy with a variety of strategies and decision-makings to enhance the self-competitiveness.

In order to ensure a port competitive position within a certain range, a lot of port authorities and stakeholders used to measure competitive figures based on micro-economic views, such as their market shares and annual growth rates among their rivals. However, in past years, it can be seen that an ascending attention on the port's social responsibility, in other words, the environmental impact of port operations and activities has drawn public attention frequently. Port hereby is also facing higher pressure with regard to performances of their social responsibility (Lam & Notteboom, 2014). Such satisfying figures of throughputs or growth rates are not sufficient to measure a competitive position of ports in the current situation. Ports or stakeholders may have to take the extra charges of environmental impacts into consideration, namely emissions, water pollution, noise and so on, in order to achieve sustainable developments of ports.

In brief, a conventional evaluation of the port competitiveness plays an important role in the current port industry, but a portfolio method will be required to have further analyses regarding the social & environmental impacts of ports.

1.1 The impetus of research

Undoubtedly, the shipping and the port industries have close relationships with the world economy, many comments of which can be find in social network media or literature. Ports are the primary cargo carriers and information exchangers with outside regions. Besides, port economies have become an essential force to promote a development of regional economy (Chen, 2015). There is an estimation showing that comparing with the other modes of transport, such maritime transportation is responsible for about 85% of the world trade (Beleya, et al., 2015). Additionally, the global growth rate of container transport has increased to 80.5% in the course of 2005 to 2014 (World Bank, 2015).

Despite of increases in the global containerization and the rapid development of container port economies, environmental issues have become the decisive factors in attracting the business partners and the potential investors. Ports with remarkable environmental performances and high social reputations are likely to be favoured (Lam & Notteboom, 2014). Herewith, it is necessary for ports to take environmental impacts into account (Button, 1993b) (Haezendonck, et al., 2006). All port authorities have to consider their current positioning, advantages, weaknesses and other constraints in order to formulate an effective strategy to improve their performance and competitiveness.

There are various methods to determine their competitiveness especially for the container ports. Stakeholders with diverse perspectives have to be involved (Voorde & Winkelmans, 2002). Generally, lots of literature shows that the key factors influencing port competitiveness like port capacity, productivity, service quality, hinterland accessibility and reputation. However, as the previous section mentioned, there is also a phenomenon showing that the public has increasingly focused on port environmental issues that lead to plenty of much more negative externalities to the society. One of the serious environmental impacts is the exhaust emission (air pollution), which is mainly caused by the means of transportation in the port industry.

INFRAS (2000) has identified the external costs of different transport modes (including road, railway and inland navigation). Based on that data, Haezendonck and her colleagues (2001, 2004, and 2006) analysed the port's green performance (namely, Green Portfolio Analysis) via the hinterland transports (namely, modal split) including the Hamburg-Le Havre seaports. As the result, if the port authorities do not take the environmental impacts into consideration when they make decisions, the port competitive position will decline comparing with the rivals. Thus, environmental performance is still what does really matter and should really be considered according to the port competitiveness (Haezendonck, 2001) (Haezendonck, et al., 2006).

However, such analysis has not been done yet among the Asian container ports. Therefore, the impetus for this research from a challenging question: is it possible to analyse the Asian container ports using the same way? Moreover, before coping with this issue, we have to identify firstly whether a conventional (micro-economic aspects) positioning analysis could be applied to the Asian container ports or not.

1.2 The aim of the study

According to statistics from the World Bank in terms of global container port traffics (World Bank, 2015), there are 9 Asian container ports in the world's top-10 list. Asian container ports, therefore, they have dominant positions in the world. That reflects only in port economic aspects but without considering an environmental aspect. The ports all around the world compete with each other in terms of environmental perspectives. Many seaports in the EU and the US have already introduced environmentally-friendly incentive schemes to promote green ports strategies (Haezendonck, et al., 2006). Asian container ports seem to have more responsibilities to take care of social impacts and negative externalities. Based on our current research, however, among the Asian ports, we cannot observe such a strategic change markedly.

The Asian area relatively lags behind the EU or the US with regards to environmentally friendly aspects. Most of the Asian port strategies and activities remain at a stage of the infrastructure construction, while the environmental strategies mainly stay at the theoretical level. This study aims to provide analyses for major Asian container ports to see whether there are available and possible tools which can help or support them to make proper environmental strategies.

Hence, we decided to conduct a research on the particular Asian container ports. Moreover, this study is supposed to answer the following question:

"How can a green strategic positioning analysis be relevant and be applied to major Asian container ports?"

The principal idea of this main question is that in order to promote the port development of both economic and environmental aspects. A conventional strategy is mainly focused on maximising the total throughputs of cargo rather than reducing the environmental impacts. However, such trend shows that the conventional strategy is too narrow and obsolete for the current situations. Therefore, the Asian container ports need to change the minds and actions in order to achieve sustainable developments. Some ports in the Europe and other parts worldwide have already changed the strategic plan promoting the sustainable growth (Haezendonck, 2016). Thanks to their green strategy applications, the ports are particularly advocated and supported by the public. Thus, this question put forward in this research explores a green strategic positioning of major Asian container ports as well.

In order to answer the main research question sufficiently, there are three sub-questions (as follows) have to be answered during this study accordingly.

"What is the importance of a green strategy for ports in general and Asian container ports in particular?"

"Can we apply a green portfolio analysis to Asian container ports?"

"What are the potential implications of a green portfolio analysis for Asian container ports for their future policy and strategy?"

1.3 Research design and methodology

We will draw the conclusions of our empirical analysis based on both quantitative and qualitative methods in this study. The general green port strategy worldwide will be introduced firstly to demonstrate a developing trend of ports and a concept of the green dimension in worldwide ports. Besides, we will select ten container ports as particular cases in Asia. Therefore, the potential ways to increase their market share will be analysed through the PPA (Port Portfolio Analysis) model. After that, on basis of available data concerning the environmental dimension (modal split), a Green Port Portfolio Analysis (GPA) will be applied to show the port's green position among the rivals. Finally, an implication of green port strategies will be discussed, in particular for the Asian container ports.

PPA model refers to the port portfolio analysis. It is derived from a very famous business model – BCG (Boston Consulting Group), which is able to demonstrate the port performance among rivals and the upside potential of their market growth share. Additionally, due to data limitations, the green dimension analyses (namely, GPA) will conduct in a theoretical port range. That is between the Port of Busan and two typical European container ports, which serve as a qualitative addition to the abovementioned analysis. That comparison will shed light on a conclusion of the last sub-question.

- **Scope of the research**

This study will focus on the maritime container ports in a geographical area of Asia (set of max. ten competing container seaports). We will try to analyse the competitive position of each port with the consideration of both economic and environmental dimensions.

The data focus on total traffic volumes (Tonnes) mainly from each relevant port to their hinterlands. From a perspective of environmental dimensions, according to the availability of data, there are several means of category of traffic from/to the ports and their hinterlands, including road transportation, railways, and inland navigation (so-called modal split). This study will not take into consideration the pipeline transportation, because of that causes negligible harm to the regional environment (Haezendonck, et al., 2006). Such green strategies and analyses of the shipping lines and vessels, and the inland ports are also not discussed in this study.

1.4 Structure of the paper

The followings are main contents of this thesis:

Chapter 2 describes mainly the different kinds of literature in which talk about the previous scientific contributions to the fields of seaport's green strategy applications worldwide.

Also, socio-economic and environmental impacts based on the seaside port activities of their hinterland traffics. Likewise, this section studied also what actions should be taken by Asian ports to solve the relevant question raised in the research. Moreover, some main determining factors of port green competitiveness will be summarised in and associated with several cases. Besides, a discussion concerning some popular methods which can be used to measure the (container) port competitiveness.

Chapter 3 presents the methodological approaches and data applications employed in this paper. Firstly, a tool of port portfolio analysis (PPA) will be adopted for a long time in order to determine the strategic positioning of major Asian container ports. Secondly, after taking the data of “green dimension”, this part compares a representative Asian port with two distinguished seaports in Europe to verify of a green portfolio analysis (GPA), which is a tool that can contribute to the formulation of port green strategies.

Chapter 4 introduces a process of selecting the particular samples of the Asian container seaports, as well as the characteristics of each seaport in term of economic and environmentally friendly aspects.

Chapter 5 contains the results and discussions of the analysis based on PPA and GPA models and the qualitative arguments of entire empirical analysis.

Chapter 6 concludes this study by summarising the highlights of main findings and reviews the research questions with regard to their implications. Moreover, the limitation of this research will be reminded. Besides, it also recommends several future research directions.

2 Literature review

2.1 Evolution of the port industry, competition, competitiveness

In this section, according to the existing literature, we will attempt to highlight the evolution of the port industry as well as competition between the conventional and the modern one. The development of port competition has been a significant topic in maritime economics. Besides, it is the predominant driving force of the port competitiveness over time (Meersman, et al., 2010). Van de Voorde and Winkelmas (2002) argued that because of the complex characteristics and multifaceted nature, the concept of port competition can be interpreted from different perspectives (Voorde & Winkelmans, 2002). Whereas, every movement should be studied on the basis of the development of the port industry.

In general, the port competition keeps changing and depends on the evolution of the port industry. Mei (2013) summarised that the development of port industry could be divided into four stages. The first stage refers to the period before the18th century in which a port was just a place helping load and unload cargos. Moreover, it performed as the key point of the commodity circulation. The second stage is the period from the early 18th century to the middle of the 20th century. Besides, the basic logistics functions, such as storage, transportation and handling, and the port industrial and commercial competencies also began to take shape. Therefore, ports became a cargo value-added service centre in term of the trade and production. The third stage began in the 1950s and 1960s. Thanks to the development of shipping and information technologies, the port has transformed into a multifunctional integrated centre in order to adapt to the requirements of the global trade and logistics. The fourth stage began in the late 20th century. Moreover, many ports seek to the proper path of reform. Ports pay much more attention to the development of the surrounding communities and the economic diversification. The goals aim to be the international gateway, industrial cluster, comprehensive service platform, as well as a shipping centre into the global supply chain (Stopford, 2009) (Mei, 2012).

Along with the port industry's development, the competition between ports is increasingly fierce over time. In a conventional sense of ports, port competition can be divided into three spatial levels that were exemplified by Verhoeff (1977, 1981). He viewed to the geographical and functional factors of port ranges and recognised the first level is the competition between the certain port ranges, which include a number of ports areas. The second competition relates to a level of the certain port areas and serval individual ports exist in those areas. The final competition level is among the ports (Verhoeff, 1977; Verhoeff, 1981). Such the port ranges or areas may have the similar characteristics geographically. Like along with the same coast, calling the relative loops of liner service, or somehow connecting with an overlapping hinterland (Notteboom, 2006).

After that, Slack (1985) proposed a two dimensions concept of the port competition, which includes both of the inter-port and intra-port competitive structures (Slack, 1985). However, Haezendonck (2001) agreed partly of those criteria and considered further that the practical port competition should encompass a four-level scenario. The reformed structures as below (Haezendonck, 2001):

- Level 1: Inter-port competition on a port authority level, which means the competition exists during various ports. The stakeholder likes the government or port authority try to enhance a competitive position in term of meeting the market demands and offer optimal working conditions. Such as the infrastructure or an attract investment project.

- Level 2: Inter-port competition on a commodity level that happens among ports when competing for the similar port undertakings. A port authority focuses on the different port traffic categories to obtain the relatively higher market share or growth rate.

- Level 3: Inter-port competition on an operator level, which states the competition is between the operators from different ports. Also, most of the operators are competing during the certain port traffic structures.

- Level 4: Intra-port cluster competition level, where the competition occurs on the same port but among the similar port undertakings. For example, the terminal, towboat or pilot operations. This level can prevent the monopoly and improve service quality in a port.

As expected, the port competitiveness has also been shifted of attention along with the evolutions as mentioned above. To identify the determinants of competitiveness of port is also an extensive and complex process. Even in the same period, the determinants selection is also very different due to the national or regional situations. So, we are just pointing out the universally recognised evolution of the port competitiveness over here.

We found that in the past, the port competition just focused on cargo volumes between the each other. In another word, the cargo throughputs and the ship callings as the dominant conditions to evaluate the competitive position of a port. Slack (1985), Branch (1986) and Bird & Bland (1988) agreed on that from the perspectives of shippers and forwarders. The numerous ports on that moment tried to formulate diverse strategies to make self as the busiest port among the rivals.

Afterwards, when much public funding has been involved in the port industry, such as a project of additional infrastructure or business merging. Therefore, the public and government became highly aware of the importance of ports in term of social welfare creations. Namely, a port is responsible to provide better working conditions, creates the job opportunities, and so on. Hence, a concept of value added emerged and became the most significant criteria of the port competitiveness. Frankel (1992) and Eklund (1999) indicated such the similar points. Moreover, the accessibility of ports plays also the important role more and more. It not only means the nautical accessibility but also the port hinterland accessibility in particular. In order to response the intensified inter-port competition, many ports and stakeholders try to find solutions regarding the hinterland relationships. Such as a strategy of intermodal transport that is very vital to the containerisation. The related topic has been argued by Muller (1999), De Langen (2007), Chang *et al.* (2008) and Ferrari *et al.* (2011) in different case studies.

Today, the numerous stakeholders catch sight of what ports are doing on the daily basis, which they have the dramatically impacts on our environment.

The impacts could result in a positive and a negative ways. In a positive way such as the dredging projects. Whereas, the adverse impacts like the exhaust emissions, water or light pollution bring even worse of the environmental damages and the negative externalities. Thus, such environmental issues and solutions are currently the first and foremost topic for the port industry worldwide. The public and stakeholders nowadays force ports to not only consider the traffic volumes, social welfare but also the effect of environment. Many kinds of literature affirm that situation, to name but a few, Warwick (1993), Endresen *et al.* (2003), Haezendonck, *et al.* (2001, 2006) and Lam & Notteboom (2014).

To conclude, as the trends of port and shipping industries are moving toward the globalisation and containerization (Stopford, 2009). The more and more stakeholders and governments preferring the reduction of negative externalities in order to strengthen the incentive for organisations to pay more attention to environmental protection. Because of environmental problems do impact on both of the global economic growth and the competitiveness of ports self (Haezendonck, et al., 2006). In the context, that is imperative for port authorities, governments or any related stakeholders to identify their real competitiveness timely.

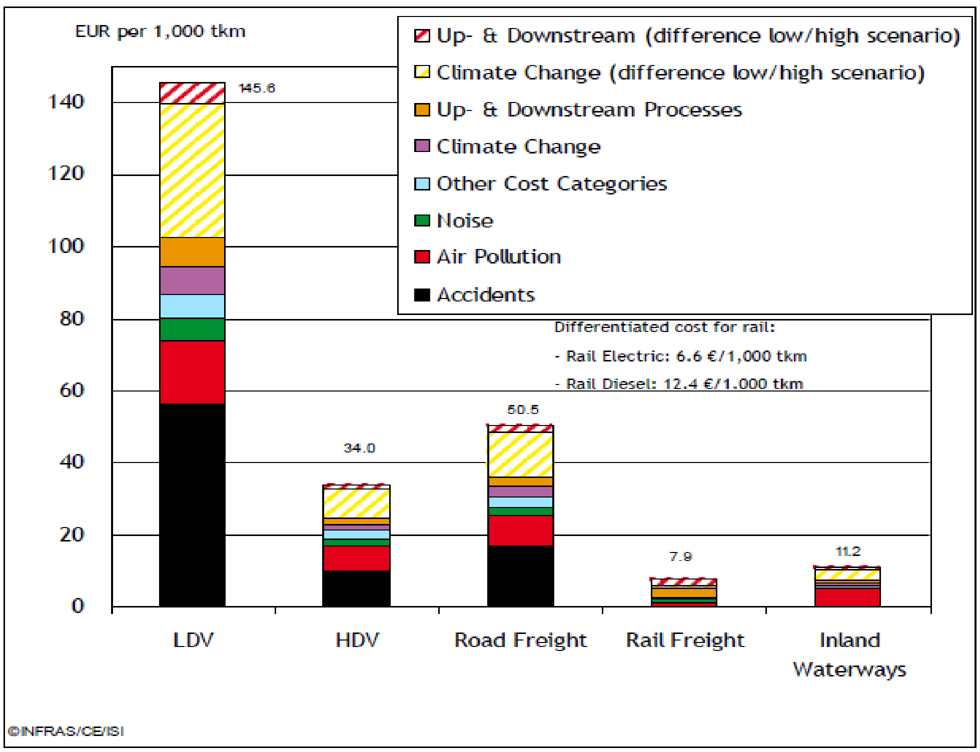
2.2 Environmental concept for port industry

Under the situations of energy crisis and environmental pollution, the green port development is becoming a vital parameter for maintaining the sustainability of society and economy obviously. With the increasing effects of international trade and seaborne activities, as well as maritime industries on enhancing the responsibility of environmental consciousness, ports are ideally positioned to facilitate the industry towards an eco-concept (GreenPort, 2015).

Haezendonck and her colleagues (2006) argued that ports are not only important driving forces of the world economic growth but also energy-intensive and polluting units (Haezendonck, et al., 2006). There are much different pollution being caused by port daily handling activities, including exhaust gas emissions, water pollution, noise and light pollution, congestion and accident, and so forth. Those can be considered as the negative externalities, and play an increasing important role. For example, a decision making of an activity of port authority (or port operator) causes a negative effect on the third party, and this third party pays a price (Haezendonck, et al., 2006). Besides, those costs of negative externalities act as the external costs are based on the economists (Korzhenevych, et al., 2014). In other words, the external costs exist once social costs exceeding private costs, which means that the social costs grow with the pollution levels (Helbling, 2010). That is harmful to our society and economy.

There was a particular study on the external costs in the field of European transportation modes by INFRAS, CE Delft and Fraunhofer ISI in 2008 and 2011. They have concluded that the average external costs in an area of cargo transportation in the EU-27 countries

(Note: Norway and Switzerland instead of Malta and Cyprus). The results showed (as per below Figure 1), the highest average external costs (per 1,000 tonne-km in Euros) is by the road freight (€50.5 per 1,000 tonne-km), which can be interpreted in the weighted average of overall road transport modes (HDV+LDV). However, the lowest one is by the method of railway (only €7.9 per 1,000 tonne-km). Moreover, the inland navigation is in the middle, but only a slightly higher than rail freight to € 11.2 per 1,000 tonne-km (Essen, et al., 2011). Furthermore, it is can be seen clearly that the scale of different cost categories are based on the modal split. There are the primary cost categories such as accidents and exhaust gas emissions (namely, climate change and air pollution) concerning the road transportation (Essen, et al., 2011). Obviously, a road transport plays the worst role in term of environment-friendliness, on both of the transports between the hinterland and foreland. This European study is representative, and can be referred by the global transport modes (except the air transport). However, there is no such similar findings in the Asian areas.



Other cost categories: Costs for nature & landscape, biodiversity losses (due to air pollution), soil and water pollution costs, additional costs in urban areas. Data do not include congestion costs.

* Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Road Freight Total is the weighted average of all road freight transport modes (HDV 85&, LDV 15% of total tkm).

Figure 1: Average external costs for 27 European countries in 2008
Source: CE Delft/ INFRAS/ Fraunhofer ISI (2011)

On one hand, the air pollution is one of the dominating issues of environmental damages by the port industry (Lam & Van De Voorde, 2012). That is not only because of the port ground traffics but also the movements by handling system (like, the straddle carriers or any fuel oil equipment), and vessel callings. In order to clarify that aspect, there is a case study based on the Port of Kaohsiung (2012) showed that the oil tankers reached the top one among the ship groups with regard to emitting pollutants in the Kaohsiung Port, and followed by the container vessels (Berechman & Tseng, 2012).

Additionally, Liao and his colleagues (2010) researched the impact on the CO_2 emissions of container traffics by comparing the ports between Taipei Port and other ports inside the island. According to an activity-based emissions model, they found that a greater decreases in CO_2 level when transhipment routes are changed among those ports to Taipei (Liao, et al., 2010). Besides the CO_2, the other exhaust emissions like CO, PM_{10}, $PM_{2.5}$, SO_2, HC, NO_X and VOC can be produced by ships and port handling activities (Lam & Van De Voorde, 2012). Also, those emitting pollutants do effect negatively to human health, in particular for residents in the surrounding areas, such as "*asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature mortality. In children, there are links with asthma, bronchitis, missed school days, and emergency room visits"* said by Bailey and Solomon (Bailey & Solomon, 2004).

On the other hand, Lam and Van de Voorde (2012) argued that another serious environmental issue is the water pollution that affects a balance of marine ecosystems badly (Lam & Van De Voorde, 2012). They have agreed upon a study result from Ng and Song (2010) regarding an empirical analysis on the Port of Rotterdam. The result assessed environmental costs of the pollutants produced by the routine shipping operations on ports. The findings indicated the main water pollution about the fuel oil residues, ballast water, wash water chemical, domestic waste and dry cargo residue (Ng & Song, 2010) (Lam & Van De Voorde, 2012). Those pollutants from the water side lead to the negative externalities to natural habitats and economic losses to coastal regions.

In summary, a green concept for port industries today is not only pointing to the direct environment impacts, which generated by the daily port operational activities in the port area itself. For example, the energy consumption, dockside water pollution, noise & light pollution, and so on. But also, it relates strongly to the indirect aspects, such as the emissions of incoming and outgoing traffics between a port and its hinterland. Those indirect problems will result in the damage on both of environment and human health significantly. Thus, that is even bigger and worse matter for both of ports themselves and their surrounding communities.

2.3 Green related strategy for seaports

2.3.1 General implication

Environmental strategy, green strategy, environment management plan or sustainability, all of them represent the same meaning and goal in term of environmental preservation. As mentioned above, port related activities do cause harm to environment and bring external costs. Therefore, port authorities or stakeholders have the obligations to determine and control the levels of pollution. Besides, Gupta *et al.* (2005) argued that the actions or strategies can be taken in their daily operations such as identification of pollution sources, disposal of waste and governance, regular monitoring and assessment, and prediction of contamination for future. Thus, that is extremely necessary to have a plan concerning the environmental management for the ports (Gupta, et al., 2005).

The growth of environmental awareness over the last decades promotes the process of port reforms. Compared with the conventional reform processes (such as improving land utilisation, upgrading infrastructure, strengthening the connectivity with hinterlands and so on.), the new reform processes push port strategies toward the social and environmental aspects intensively (Wang & Notteboom, 2015). A basic aim of green or sustainable strategy can be considered as a driving force to keep balance among economic prosperity, social justice and environmental concerns (Elkington, 1999). That objective has become a vital essence of current port strategy (Wang & Notteboom, 2015) (Lam & Van De Voorde, 2012) (Cheon & Deakin, 2010). AAPA (2007) argued that the port's sustainability can be defined as "*business strategies and activities that meet the current and future needs of the port and its stakeholders, while protecting and sustaining human and natural resources*" (AAPA, 2007) (Sakar & Cetin, 2012). In short, sustainability of ports refer to an equilibrium between economy and environment (Haezendonck, et al., 2006). Herewith, ports as the organisations which have to take the responsibilities and face challenges in term of balancing the economic prosperity, social justice and environmental concerns simultaneously.

As per previous sections mentioned, there is an upward trend towards port environmental impacts due to the negative externalities for the public. Port authorities and stakeholders are indeed facing the challenges for finding the proper green development strategy and improving the competitiveness. They are requested to keep accordance with the environmental demands and green social regulations promptly (Wang & Notteboom, 2015). Moreover, the contemporary competitiveness can be involved in a positive environmental performance of ports, as well as the close relations with local communities (Wiegmans & Geerlings, 2010) (Sakar & Cetin, 2012). Besides, Haezendonck and her colleagues (2006) discussed such port itself and considered its stakeholders as the responsible parties for minimising the ecological impacts, no matter where the impacts come from waterside or landside in ports. Therefore, a green port strategy should settle those ecological impacts as well (Haezendonck, et al., 2006). And, based on other literature, we are also able to conclude that the proper port environmental and sustainable strategy is one of the most important ways to enhance the port competitiveness. Moreover, Wang and Notteboom (2015) believed that a strong port strategy can promote innovations while those innovation techniques could provide an efficient solution to resolve some of the environmental issues faced by ports (Wang & Notteboom, 2015).

There are much kinds of literature focusing on the green management or strategic development tools in order to minimise the negative externalities and measure the green performance of seaports. According to the overview by Haezendonck *et al.* in 2006, there are several different kinds of available methods, including the curative tools like *the Environmental Management System (EMS)*; the preventive instrument such as *the Environmental Impact Assessment (EIA)*; the quality guidelines like *the Eco-Management and Audit Scheme (EMAS)* and *ISO14001*, as well as the special tools developed by ECOPORTS (EU funded project), such as *the Port Environmental Review System (PERS) and Environmental Management Information System (EMIS)* (Haezendonck, et al., 2006).

Such tools or their concepts have been adopted by many governments or port authorities in the practice operations and managements. In the following sections, we will introduce the "green" efforts, which have been implemented already in some experienced countries and areas.

2.3.2 Green initiatives of the Occidental seaports

In this section, we will introduce the specific practices in term of green perspectives by using few seaports in the developed countries as examples.

In Australia, the Sydney Port has advocated a Green Port Guidelines which is a typical green strategy for port developments and operations. It applies to both of the new development projects and the existing activities in port, to encourage sustainable business approaches (Sydney Port, 2016). The Guidelines introduced the typology and evaluation mechanism in ten environmental aspects (See Table 1). Also, there are a series of goals under each aspect, and then those goals will be graded based on the existing criteria. Finally, the mechanism of evaluation could suggest if a project can be approved or rejected.

Table 1: Key environmental issues

1. Resource consumption	2. Environmental quality
1.1 Materials selection	2.1 Indoor environment
1.2 Waste management	2.2 Emissions
1.3 Water consumption	2.3 Water quality
1.4 Energy use	2.4 Land use
1.5 Transportation	2.5 Environmental management

Source: author's elaboration via Sydney Port (2016)

The main benefits of this Guidelines such as ease of use and implementation, a trade-off between environmentally-friendly, commercially viable, and a clear project classification (e.g. Design of a new facility, construction activity, operations or fit out alterations). The guidelines have been managed to improve the environmental issues at the Port (Sydney Port, 2016).

In the USA, there are the extensive environmental programs have to be involved in the Port of New York and New Jersey. For example, in 2009, the Port Authority has cooperated with other parties to promote a Clean Air Strategy officially (Port of NY and NJ, 2014). This strategy mainly focuses on the reduction of port-related maritime emissions based on an Environmental Management System (EMS). Also, such strategy guides certain practical operations that allows the Port and stakeholders take effective actions to reduce emissions in advance of potential regulations. For example, replacement of the oldest and most polluting trucks, installation of shore power system, and retrofit of switcher locomotives and modernization of handling equipment et cetera. (Port of NY and NJ, 2014).

According to Port's measurements (up to 2012), the air contaminant emissions from various aspects have a downward trend (See Table 2), the strategy therefore helps to reduce air pollution effectively.

Table 2: Air pollutant emissions, percent change 2006 to 2012 (tonnes/million TEU)

2006 - 2012	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
Ocean-Going Vessels	-44%	-41%	-41%	-28%	-34%	-56%
Cargo-Handling Equipment	-23%	-30%	-22%	-31%	-25%	-100%
Heavy-Duty Diesel Vehicles	-7%	-47%	-42%	-23%	-14%	-92%
Railroad Locomotives	-21%	-19%	-16%	-16%	-5%	-97%
Harbour Craft	-26%	-25%	-22%	-22%	-4%	-97%

Source: author's elaboration via Port of NY and NJ (2014)

The port industry is a vital sector for Europe, and most of port authorities and operators who measure their performance as an individual level but share the tiny data (Thomas, 2012). Due to the info limitations of port performance and controversies of benchmarking, the European Sea Ports Organization (ESPO) together with the European Commission and other five academic institutions (2010) devolved a Port Performance Indicators Selection and Measurement (PPRISM) project. This project considers the European ports as an entire sector and aims *"to identify a key list of sustainable, relevant and feasible indicators to monitor the overall performance of the EU port system and assess its impact on the society, environment and the economy of the EU"* (Thomas, 2012) (Dooms, 2016).

The main contributions of PPRISM such as increased information transparency, improved environmental awareness and unified the Port Performance Indicators (PPIs) as the EU level. ESPO and their partners analysed total 159 port performance indicators from five different perspectives (Market Trends & Structure, Socio-Economic Impact, Environmental Performance, Logistic Chain & Operational Performance, and Governance) (ESPO, 2012), and based on the Delphi methodology and Pilot survey, they finally gained the top-10 best indicators (See Table 3). The findings of PPRISM form the basis of a future European port observatory and will be a dashboard of performance providing a clear picture of the EU port systems as a whole rather than individual ports (ESPO, 2012).

Table 3: PPRISM Top-10 port performance indicators

1. Maritime Traffic	6. Vessel Traffic
2. Existence of an Environmental Monitoring Programme	7. Levels of Safety
3. Direct Employment	8. Modal Split
4. Existence of an Environmental Policy	9. Existence of an Environmental Management Programme
5. Direct Gross Value Added	10. Degree of Containerization

Source: author's elaboration via Dooms (2016)

In The Netherlands, the Port of Rotterdam has a goal that to become a world class seaport in term of sustainable developments in 2030 (PoR, 2014). The systematic and integrative approach will be requested to keep a long-term sustainable port development (Dooms, 2016). Therefore, since 2012, the Rotterdam Port Authority has been co-operating with the stakeholders to realise all necessary points of actions laid down in the implementation agenda of the Port Vision 2030 (PoR, 2016). The Port Vision as a compass and guides the Port of Rotterdam towards a sustainable development. In order to become the excellent Global Hub and Europe's Industrial Cluster, the ten crucial success factors be identified from the extensive preconditions (See Figure 2).

Success factors	
_Land use	*_Investment climate*
_Accessibility	*_Shipping*
_Environment, safety & quality of life	*_Innovation*
_City & region	*_Laws and regulations*
_Work	*_Europe*

Figure 2: The port vision - Ten success factors
Source: Port of Rotterdam (2011)

In addition, the Port of Rotterdam received for the second time of the Port Environmental Review System (PERS) certification in 2015 (ESPO, 2015). That can be attributed to the environmental strategies based on the Port Version. For instance:

- *offers a discount price to the clean ships with Environmental Ship Index (ESI) to encourage the clean engines;*
- *requests to sustainable innovation in the entire supply chain with modal split and makes modal split agreements with all terminal operators (the cargo be transported by rail and inland navigations should be however increased);*
- *uses the low-sulphur fuel, soot filters, and catalytic converters on the fleets;*
- *Since 2013, the fully Battery-Electric Lift AGV's (Automated Guided Vehicles) have been used at Maasvlakte 2. And compared to the conventional model, the battery-powered AGV's resulting in efficiency increased by 50%, zero CO_2 emission and noise reduction as well* (PoR, 2012) (ESPO, 2015).

2.3.3 Green practices of the major Asian countries and seaports

The financial crisis 2009 has affirmed a position of Asia in global economy. Asia became an engine for the world economic rise and helped the world economy get out of recession gradually (Singh, 2010). According to Mr. Singh's forecast on that moment, the total economy over the next five years will grow 50% more than the current level in Asia-Pacific region, and will be more than 1/3 of the total global economy (Singh, 2010). In the same year, OECD forecasted the Asian middle-class consumption power which will account for 54% of global share in 2020, and 66% in 2030 (Kharas, 2010). Besides, the Wall Street Journal also reported a forecast by the Asian Development Bank (2012), which argued Asia will share about 40% of global GDP in 2030 and reach 52% in 2050 (The Wall Street Journal, 2012). The prospect of Asia is very bullish in point of economic view.

Since 2014, global trade has suffered the feature of turbulence. According to an article from IMF (2016), there was a sharp decline in global trade in the first half year of 2015, and it began a slow climbing in the second half, because of China moves into a new "slowdown growth" developing path. So this path decreases the dependence degree on investment and industrial manufacturing. As a result, the transformation of China's new growth path will lead to an instability of current international trade (Constantinescu, et al., 2016). Although Asian economies have been affected, but the world port statistics (PoR, 2015) indicated that the Asian ports still dominated the global throughputs in both aspects of total traffic volumes (Tonnes), and total container traffics (TEUs).

Today, a large number of the European and American seaports take the lead in the "green port" innovation and toward the remarkable achievements with respect to environment-friendliness. However, most of the Asian ports are still focusing on the economic dimensions rather than the dedication of green or environmental strategies. Therefore, they lag far behind than the Occidental countries. Also, most Asian ports merely remain at a theoretical stage based on our research, or in some cases, there is even a complete lack of related “green” knowledge. For us hereby the Asian container ports are more valuable of this research. Moreover, our sample ports have to be the major players in Asian region in both of the abovementioned two aspects (Tonnes & TEUs), as that the samples will be more representative and persuasive.

Port authorities and stakeholders should be aware that the environmental factors have to be included to ensure a long-term and sustainable port development (Dooms, 2016). However, how the Asian seaport countries are now also focused on the environmental issues? Below we will introduce some relevant policies and environmental awareness in some Asian representatives.

In China, the central government formulates the National Economic and Social Development Plan for every five years. Over the last decades, China put many efforts on the infrastructure and economic development, whereas it hardly considers environmental protection. Since the 12th Five-Year Plan (2011-2015), the environmental concerns has been involved and put in a priority position (The State Council of the PRC, 2011). After that, the 13th Five-Year Plan (2016-2020) has replaced the 12th one at the end of 2015, and this time, the central and branch governments put more efforts on the practical applications rather than a theoretical framework in term of environmental development. In order to pursue an international green standard and resolve the current environmental issues effectively and promptly, China is quite willing to cooperate with some developed centuries. For example, a bilateral cooperation agreement to combat global climate change be signed in 2015 by Chinese and American presidents Xi Jinping and Barack Obama (Knatz & Mollema, 2015).

Maritime shipping’s and port’s emissions are virtually unregulated in China; therefore many major port cities are suffering the poor air quality (Knatz & Mollema, 2015). China as the host to the eight biggest seaports in the world who has already recognised the self’s “green” obligations. According to the 13th Five-Year Plan, the Law of China’s Air Pollution Prevention and Control be amended in several times and finally adopted by The National People’s Congress of the PRC to tackle maritime environment issues (Knatz & Mollema, 2015). Meanwhile, the national Ministry of Transport is planning to designate a strategy about China’s coast Emission Control Areas (ECA), in order to control air pollution and GHG emissions and balance cargo diversion among the seaports (Meng, 2015). China herewith got the applause from outsiders for these important steps. So far we, however, do not see a very detailed and integrated green port strategy and systematic measurement yet, but we believe they are formulating on it, and we will see in near future.

As China's neighbour, South Korea has been at the forefront concerning the initiatives of environmental-friendliness (OECD, 2016). Actually, in 2008, Korea also faced the growing environmental issues about the harbour development, port management and operation, such as the problems of dredging and dredged soil (GreenPort, 2008). In order to improve environment and be Eco-friendly, in 2009, the Five-Year National Plan (2009-2013) for Green Growth and The National Strategy for Green Growth (2009-2050) were enacted, which include the comprehensive policies and strategies for the green growth ambition (OECD, 2016). Meanwhile, the Ministry of Land, Transport, and Maritime Affairs (MLTM) has formulated the National Green Port Project (See Table 4), which as an action plan for the Five-Year National Plan (2009-2013) for Green Growth, particularly to the port industry.

Table 4: National green port project

Aim 1	**Establishing Low-Carbon Hinterland Transportation Systems**
Action 1	Enhancing rail and coastal transportation from/to ports
Aim 2	**Transfer to Low-Carbon Energy-Efficient Ports**
Action 2	Reduction of carbon emissions
Action 3	Transformation of engine-power-systems from fuel oil to electricity
Action 4	Use of renewal resources
Aim 3	**Establishing Resources Recycling Port Systems**
Action 5	Eco-friendly management of marine debris
Action 6	Dredging materials, etc.
Aim 4	**Enhancing Use of Port Space**
Action 7	Securing waterfront
Action 8	Public access, etc.
Aim 5	**Establishing Response System for Climate Change and Ocean Disaster**
Aim 6	**Enhancing R&D for Green Growth and Green Growth Industry**

Source: author's elaboration via Cho (2010)

Furthermore, according to Cho (2010), the "*MLTM indicate that the plan for Alternative Maritime Power and high energy-efficiency will be established in 2010, and as well as the project for a rail transportation system for container to/from Busan Port and Kwangyang Port will be completed in 2011"* (Cho, 2010). Korean governments have the ambition in the environmental perspectives, and they move toward a leading exporter in the field of "green" research and technology (OECD, 2016).

On the other hand, Japan was the first one that proposed the concept of environmental protection in Asia. They were affected by the U.S. in term of the environmental policy-making in 1969. After three decades, the first national green policy - "Environmental Impact Assessment (EIA) Law" has been implemented officially. The main purpose is *"to consider environmental protection properly by establishing a procedure for the EIA of large-scale projects and reflecting the assessment results in the decision-making"* (ENV, 2012). Recently, the Japanese government announces a new long-term strategy (draft) in term of the environmental technology innovations, which is the Energy/Environment

Innovation Strategy. Such the strategic plan is pointing to an ambition of drastically cutting greenhouse gas emissions with the various national undertakings by 2050 (Kaneko, 2016).

In 2014, Kitakyushu joined the Green Award Scheme. It is the first port to join the scheme in Japan, and also as an important milestone to spread the green commitment of the local port industry. According to the Green Award Foundation (2014), the *"Green Award is a quality mark for sea-going and inland navigation vessels that go beyond international conventions and regulations in terms of ship layout and equipment, quality of operations and management"* (Green Award Foundation, 2014). Therefore, the Port of Kitakyushu is trying to attract the quality shipping with certain incentives, such as a 10% discount is available to all the Green Award Certified LNG vessels, to achieve the most safety and best quality practices (Green Award Foundation, 2014).

In Singapore, the Maritime and Port Authority of Singapore (MPA) and stakeholders strongly emphasise on the effective utilisation of resources, environmental protection, safety issues, facilitate port operations, green growth, and innovations (GreenPort, 2014). The first "green initiative" idea was proposed by the Port Authority in 2011 to cut off the negative externalities of maritime related activities and to facilitate the cleaner and greener shipping circumstance in Singapore (MPA, 2016). The Port Authority has invested up to 100 million Singapore dollars since 2011, to support the green initiative that includes three different aspects - Green Ship Programme, Green Port Programme and Green Technology Programme (MPA, 2013), the details as per below Table 5.

Table 5: The maritime Singapore green initiative

The Green Ship Programme	***Encouraging Singapore-flagged ships to reduce carbon dioxide (CO2) and sulphur oxides (SO_X) emissions.***
	- Qualifying vessels that adopt energy efficient ship designs exceeding IMO's Energy Efficiency Design Index (EEDI) will enjoy 50% off of Initial Registration Fees and 20% discount on Annual Tonnage Tax. - Vessels that adopt approved SO_X scrubber technology exceeding IMO's emission requirements will enjoy 25% reduction of Initial Registration Fees and 20% discount on Annual Tonnage Tax. - In a case of vessels meet the above two conditions simultaneously, that will enjoy 75% reduction of Initial Registration Fees and 50% rebate on Annual Tonnage Tax.
The Green Port Programme	***Encouraging ocean-going ships calling at the Singapore Port to reduce the emission of pollutants.***
	Vessels that use type-approved abatement/scrubber technology or burn clean fuel: - During the entire port stay (up to 5 days) within the Port Limits (specified waters) can gain 25% reduction in port dues; - Only while at berth can enjoy 15% reduction.
The Green Technology Programme	***Encouraging the local maritime corporations to develop and adopt green technologies.***

	Corporations are able to apply a grant of up to 50% of total qualifying costs to co-fund the development and adoption of green technological solutions/ systems. Grants have a ceiling at $2 million Singapore dollars per project; however, the extra grants (S$ 2 million) will be awarded once a company can achieve more than 10% reduction in emission levels.

Source: author's elaboration via MPA (2013)

In addition, the Port of Singapore also cooperates with other parties and social networks to pledge their commitment to promoting and support clean and green shipping in Singapore. They launched the Maritime Singapore Green Pledge in 2011, and up to date, there 40 organisations have signed that Pledge (MPA, 2013) (GreenPort, 2014).

Malaysia is trying to abide by the international "green" regulations as a responsible member of the IMO Council (Khalid & Tang, 2010). Furthermore, to strengthen regional cooperation and shipping market, Malaysia with other member states of the ASEAN worked out a new guideline which involves the Maritime Transport and Sustainable Transport affairs in 2015, namely, the ASEAN Transports Strategic Plan 2016-2025 (ASEAN, 2015). The main goals are about enhancing the sustainability of maritime industries, formulating the regional policy frameworks, fostering the marine safety manner within ASEAN, and so forth. (ASEAN, 2015).

Meanwhile, Malaysia government is also enthusiastic about the domestic environmental policies and regulations on the maritime industry (Khalid & Tang, 2010). Such as the Government requests local port authorities and operators to perform the ISO14001 fully, and a staff training project (as OHSAS14001) to improve their environmental initiatives. The green revolution of seaports in Malaysia as the vital point for the national maritime and logistics industries (Beleya, et al., 2015), and we believe that via the various initiatives will help to promote the long-term competitiveness of Malaysia.

Vietnam and Cambodia as the member states have also responded to the "green" call of the ASEAN. Both of countries are forcing their ports to follow green strategies and sustainable developments according to the national green policies. Such as a National Green Growth Roadmap that guides and oversees the economic and social development toward an environmental perspective in Cambodia (GGGI, 2016). Also, in Vietnam, the National Green Growth Strategy that promotes the green growth paradigm (e.g. reducing the energy consumption and exhaust emissions) in term of the national economy (Meessen, et al., 2015).

In particular, the three Vietnamese and two Cambodian ports employed an Environmental Management System (EMS) to resolve local environmental problems in 2006. Le and her colleagues (2014) argued such the EMS tool establishes the port environmental policies and successfully assessed the priorities in environmental protection activities for each of those seaports. Those "green" implementations have received the affirmation by the specialists from the ECOPORT Foundation. And those five (Vietnamese and Cambodian) ports have been awarded the Port Environmental Review System (PERS) certificates as well (Le, et al., 2014).

The government of Indonesia has also its ambition of country's sustainable development. In 2014, the government launched a Green Planning and Budgeting Strategy, and it reflects the concerns about the environmental damage (like climate change or natural resources degradation) that caused by economic growth. The Strategy acts as the roadmap for developing the national economy, meanwhile, reducing the emissions and the climate threats (FISKAL, 2015). That approach covers the period 2015-2020, also will be integrated into other national and regional development politics. Such as the Medium Term National Development Plan, which to support the prioritised green policies into all national undertakings.

That approach impacts on the port industry as well. In order to deal with environmental issues and assure compliance with national policies, a state-owned terminal operator, Pelindo III, developed its Lamong Bay Terminal in a way of environmental-friendly in 2015. Lamong Bay Terminal adopted the automated container handling system, which includes the twenty automated stacking cranes (ACSs) and is associated with the remote operating stations (ROSs) (GreenPort, 2015). Such improvements enhance the productivity and the yard operational performance safely and efficiently. Also, lead the national green transport strategies.

Overviews, we have to say that the Asian container ports are quite important based on our reviews of existing literature, there are 9/10 Asian ports stand in the world top-10 container ports ranking list, and 16/20 Asian ports hold the positions in term of the world top-20 total traffics ports list. There is an inevitable trend of the worldwide green strategy for the port industry, however most of the Asian container ports still lag behind. The U.S. and European countries are much more advanced and experienced already. If Asian container ports or local governments do not take actions, they will be threatened by the European and American countries in term of the sustainable growth competition. That is why so important today to have a closer look at a green strategy of the Asian container ports.

2.4 The determinants of port competitiveness

In this section, on the basis of reviewed literature and the discussed port practical operations, we will summarise the determinants concerning the port competitiveness. The conventional and modern determinants will be illustrated respectively.

Yeo and his collages (2008) demonstrated that *"the analysis of port competitiveness has mainly concentrated on port selection criteria"* (Yeo, et al., 2008). Besides, Pearson was the first one who discussed the port general competitiveness factors in 1979, such as the frequency of call ships, reliability of the port schedules, specific trade routes and port accessibility (Pearson, 1979). Twenty years later, the quite diverse determinants of (sea) port competitiveness are proposed. Based on our research, the popular and primary determinants of conventional port competitiveness are illustrated in Table 6, the sources of which come from (Willingale, 1981) (Slack, 1985) (Murphy, et al., 1989) (UNCTAD, 1992) (Starr, 1994) (Chiu, 1996) (Yeo, et al., 2008).

Table 6: The major determinants of (sea) port competitiveness in the 20th century

Popular and Major Determinants	
Geographical location	Port accessibility
Hinterland connectivity	Port facilities
Shipping and trade routes	Port tariffs
Calling frequency	Port service level
Confidence in port schedules	Port reputation
Cargo safety and Labour issue	Port operation policy
International politics	Port flexibility

Source: author's elaboration via above mentioned literature

In this century, Haezendonck and Notteboom (2002) published a comprehensive appraisal, which argues that a range of competitive advantages gained by the container ports over time determines the competitiveness of the container port (Haezendonck & Notteboom, 2002). Notteboom and Yap (2012) consolidated the different ranges of competitive factors mentioned above (Notteboom & Yap, 2012), which can be seen in the following Table 7. Moreover, Haezendonck and her colleges (2006) argued that the green dimension should be considered as an extra factor of port competitiveness due to the ecological impact of ports in general. That is the incoming and outgoing traffic between a port and its hinterlands (Haezendonck, et al., 2006), videlicet, the modal split.

Besides such conventional determinants (as mentioned in Table 6), Van der Sluijs (2007), Cullinane and Wang (2009) emphasised that the ICT system (as EDI or Port Community System), port social relationships, and environmental responsibilities are also the significant determinants of seaports' competitiveness accordingly (Van Der Sluijs, 2007) (Cullinane & Wang, 2009). We thus summarized the contemporary determinants of the competitiveness of container ports in Table 7 based on the related literature and the list consolidated by Notteboom and Yap in 2012.

Table 7: The modern determinants of container port competitiveness

Popular and Major Determinants Nowadays
Close to the main centres of production and consumption, and major trade lanes;
Excellent maritime and hinterland accessibility and offers superior connectivity to markets;
Port costs flexibility when users through higher productivity;
Enable to persuade and entrench carriers and shippers in relation to their cargo routeings by adding value to the business pursuits of these entities;
Enable to expand capacity in time to meet demand and has sufficient space to cater to future development and capacity extensions;
Competent to challenges posed by the new logistics business environment;
Capability of capitalising on the complementary and reinforcing effects of the port cluster;
Greater involvement from the private sector at the level of terminal operations;
Be perceived to be a key driver of the local economy;
Enjoy a long tradition of support from key stakeholders in the port area and the wider community, and the social networks;

Enables users to compete effectively with other transport modes, and encourage the greener transport modes, namely, modal split;
Apply the ICT system, i.e. EDI, Port Community System and Port Intranet, etc.
Initiative of environmental awareness, green activities and environmental policies and compensations

Source: author's elaboration via literature, Notteboom and Yap (2012)

In other words, the contemporary determinants put more emphasis on the green dimensions. There have been a shift in perceptions from the port infrastructures to superstructures, which means pay more attentions on software applications, services, and green strategies. Apparently, we have also to say there is no such a fixed formwork about port competitiveness factors due to the different port's ranges, backgrounds, objectives of stakeholders, to name but a few. Thus each port has its unique situation respectively.

2.5 Methods used in port competitive and strategic analysis

A variety of methods has been used to measure and analyse the features of container port's competitiveness and competitive position in the relevant market. Normally the analytic methods can be categorised into the quantitative analysis and the qualitative analysis. We will introduce several methods applied in this section accordingly.

The quantitative method focuses on the measurable variables of the port competition and comparable selected samples of container ports (Notteboom & Yap, 2012). For instance, Tongzon and Heng (2005) analysed the quantitative relationship among port ownership structure, efficiency and competitiveness. They first filtered out the nonsignificant port competitiveness factors from the large samples through the Stochastic Frontier Model (SFM) and the Principal Component Analysis (PCA) respectively. After that, the Linear Regression Model (LRM) been employed to identify the real components of port competitiveness and their effects so that the privatised port can improve port efficiency and increase the port competitiveness to some extent (Tongzon & Wu Heng, 2005).

Additionally, the Data Envelopment Analysis (DEA) as an extensive application is usually employed to identify the economic performance. It is a kind of the comparative approach used by the decision makers (or organisations) with the multiple inputs and outputs (Molinero & Woracker, 1996). Besides, it has been applied by Tongzon (2001) to measure the port efficiency of the appointed international ports. Such a tool did analyse the traditional economic efficiency by using the related production functions. What is more, it identified that the Port of Melbourne, Yokohama, Osaka and Rotterdam were not efficient ports among the samples (Tongzon, 2001). Moreover, Barros (2006) recognised that in terms of port operations and financing factors, are the two important parameters of economic performance of the Italian seaports (Barros, 2006) based on the DEA tool.

Furthermore, the Simulation as well as the Sensitivity Analysis (SA) is also popular to use when determining the competitiveness criteria of ports. Van Asperen and Dekker (2010) quantified the routeing and rerouting flexibility between a port and its hinterlands. Besides, that Simulation software is based on the Java computer language. After that, they identified the port storage, intermodal transport, postponement issue, and cost structure as the key criteria, which can have effects on the port performance (Van Asperen & Dekker, 2010).

Moreover, there are two methods used for forecasting the growing trend of ports. Firstly, the Logit Models (LM) can explain and forecast an economic tendency of the shipping or port industry. In 2003, Veldman and Bückmann economically evaluated the Maasvlakte II expansion project in the Port of Rotterdam in term of the market share, foreland & hinterland traffic routeings and financial segment. That analysis quantified the route selection and derived a demand function used for forecasting the port traffic. The main variables include the port service performance, transport cost and transit time (Veldman & Bückmann, 2003).

Secondly, the Multinomial Logit Models (MLM) is quite similar to the Logit Models. Moreover, it belongs to the Disaggregate Choice Model (DCM). The aim is to predict the probabilities of the options that could be employed. Generally speaking, this model assumes that every possible scheme will bring the positive and beneficial results to policy makers (Swait & Louviere, 1993). Zondag and his colleagues (2010) introduced a new explicit port forecasting method based on the MLM in term of port competition. Besides, the analysis calculated the policy impacts such as the infrastructure, pricing factor or hinterland accessibility (Zondag, et al., 2010). What is more, the measures are related to the economic scenario.

Despite of quantitative methods, a qualitative way, which quite depends on the observation and interpretation of the potential phenomenon instead of the measurement, is relatively descriptive in nature (Creswell, 2014). For example, on the basis of the existing literature, Notteboom and Rodrigue (2005) argued qualitatively to demonstrate that the port regionalization phase and related hinterland concepts request new management approaches. Furthermore, the function of a port is becoming more important than the conventional port perimeter (Notteboom & Rodrigueb, 2005).

In 2001, Ircha analysed the external and internal competitive circumstances of the major Canadian ports based on the SWOT Analysis (namely Strengths, Weaknesses, Opportunities and Threats). Such purely qualitative method helped her to classify the priorities when competing with other competitors. Moreover, it also indicated the related strategies and development direction in term of port reforms (Ircha, 2001).

Actually, taking the extent and complexity of the container port's competitiveness and competition into consideration, the combination of quantifiable parameters and qualitative methods are also very popular to use (Notteboom & Yap, 2012). Acosta *et al.* (2007) adopted both of the qualitative and quantitative analyses during his study in order to improve the port service, strengthen the competitive position, and make a right decision. Besides, it is important to understand from the perspective of port suppliers. Thus, the model of Porter's Extended Diamond (PED) combined with the questionnaire has been employed to analyse the significant determinants of port competitiveness from the perspectives of agents and companies operating in Port of Algeciras Bay (PAB) (Acostaa, et al., 2007).

Besides that, a method of Principal Component Analysis (PCA) as the basis for benchmarking technique was adopted by Tongzon (1995) to classify the ports in the similar group when comparing systematically. Moreover, he emphasised the critical elements concerning the port classification (Tongzon, 1995).

Moreover, a Benchmarking Analysis (BA) is another comprehensive and flexible analysis method. Both of the qualitative and quantitative variables can be analysed. Therefore, it is suitable to evaluate the complicated situations of ports, such as the determinants of port competitiveness or port operational and financial performance. Many port practitioners or experts prefer to use this approach, because it is easy to use and understand in every port market or port self. What is more, the benchmarking technique is executed by Pardali and Michalopoulos in 2008 in a case study about the Port of Piraeus in the Mediterranean port market. That paper has achieved the main objectives, including identifying the operational weaknesses of the port, estimating the port competitiveness and performance relatively (Pardali & Michalopoulos, 2008).

Additionally, the Grey Relational Analysis (GRA) is used to analyse the relationship between the system factors closely so as to find the primary and secondary determinants that affect the development of the system. Besides, through studying eight East Asian container ports by the GRA model, Teng and his colleagues (2004) presented thirteen significant criteria of the port's competitiveness. After that, a Sensitivity Analysis has assisted the GRA to evaluate the criteria further and confirmed the effectiveness category as the principle, whereas the efficiency type as a minor (Teng, et al., 2004).

Meanwhile, the Analytic Hierarchy Process (AHP) is another popular tool to determine the port competitiveness. Song and Yeo (2004) conducted an empirical analysis based on the framework of AHP to recognise the competitiveness of the major Chinese container ports. That tool weighed and balanced both of the tangible and intangible criteria of competitiveness via the three processes, including 1) establishing the decision hierarchy, 2) reshaping the priority of the considered criteria, and 3) measuring the absolute priorities of the filtered decisions (Song & Yeo, 2004).

Furthermore, Michalopoulos and his colleagues (2007) also studied the port traditional competition circumstance by the Market Share Analysis (MSA). That model analysed the ports' competitive positions on the basis of their market shares purely in a certain port range (Michalopoulos, et al., 2007). As expected, some scholars have questioned this method because of its straightforward nature and not taking some basic competitive factors into consideration.

However, a Port Portfolio Analysis (PPA), which was improved based on the famous BCG-matrix applied to the port sector, has been developed by Haezendonck (2001). The model uses two variables, including the growth rate and market share (namely, growth-share matrix). Moreover, the portfolio analysis model can identify the port competitive positioning vis-à-vis the rivals during a certain period, and detect the growing space of their market share (Day, 1977) (Wind & Mahajan, 1981) (Haezendonck, et al., 2006). Besides, many scholars have also adopted such traditional portfolio analysis. However, the green determinants of port competitiveness have to be requested by the (container) ports while the conventional PPA model herewith faces a limited application only on economic aspects (videlicet, market share and growth rate) of the business activities (Dooms & Haezendonck, 2004).

In order to identify port green competitive positions, Dooms and Haezendonck (2004) extended the function of the PPA model with an extra green dimension – the hinterland transport (namely modal split). In other words, the different transport modes between a port and its hinterlands directly affect the negative externalities (external costs) and environmental issues of ports. According to Dooms and Haezendonck (2004), the new Green PPA (also called GPA) is able to *"assess the relative performance of a port vis-à-vis its competitors in terms of 'environment-friendly' growth and market share by including the environmental dimension in the analysis*" (Dooms & Haezendonck, 2004). Moreover, they have been applied successfully in the analyses of the eight inland ports in the Western Europe in 2004, as well as the seaports in the Hamburg-Le Havre range in 2006.

Haezendonck and her colleagues (2006, 2013) have also introduced a dynamic version of the PPA model combining with the green dimension, which takes the comparisons among various data series and the data in different periods into consideration (Haezendonck, et al., 2006). It will be introduced in the later chapter in detail.

Through the comprehensive literature reviews, we found that there are many systematic and comprehensive methods to measure the port competition and competitiveness. However, there is no such a fixed or more professional model comparing with each other, only based on the objective and research direction that people want to achieve.

Finally, according to the aims of this paper, we want to take not only the economic performance but also the environmental matters into account with respect to the port green strategic positioning. Therefore, we prefer to apply the Port Portfolio Analysis (PPA) model, as well as its extensional function of the green dimension (namely the Green Portfolio Analysis-GPA) to answer the research questions in this thesis. Because the rest of methods are not easy to involve a green dimension, the PPA is possible to deal with that. Besides, we identified that the mechanism of a portfolio analysis is getting closer to our subject and objective. Moreover, in consideration of the data applications, we believe that the PPA + green dimension can help us to find the appropriate results. The detailed story about those models and how we work with them will be introduced in the next chapter accordingly.

3 Methodology

As per discussions in the previous chapter, we should recognize a fact that all worldwide (sea) ports are in the competition and need to consider the environmental factors. We would like to see if there is any possible and available tool that could support the major Asian container ports in environmental strategies.

This chapter will present the methodology and some models to answer the research questions further. Firstly, we will decide on ten major Asian container ports as the samples of this study. What is more, this part intends to describe the detailed information in the next chapter in particular. Secondly, we will interpret two quantitative models (namely the Port Portfolio Analysis and the Green Portfolio Analysis) respectively that were developed by Haezendonck *et al.* (2001, 2006). They are also the key applied methods in this study, but we will also make the certain adjustments to ensure they are suitable to the Asian circumstance.

3.1 Port portfolio analysis

The Port Portfolio Analysis (PPA) is a technique that developed from a conventional "growth-share matrix" to this model applicable to the port industry, particular in the port traffic categories (or traffic structures). The original matrix was discovered by Boston Consulting Group (BCG) in the early 1970's. The BCG-matrix is one of the most popular methods which has been used to analyse company's businesses and their products based on two difference variables (id est, market share and growth rate) among the rivals. The BCG-matrix consists of four unique market positions, each of which represents different interpretation (See Figure 3).

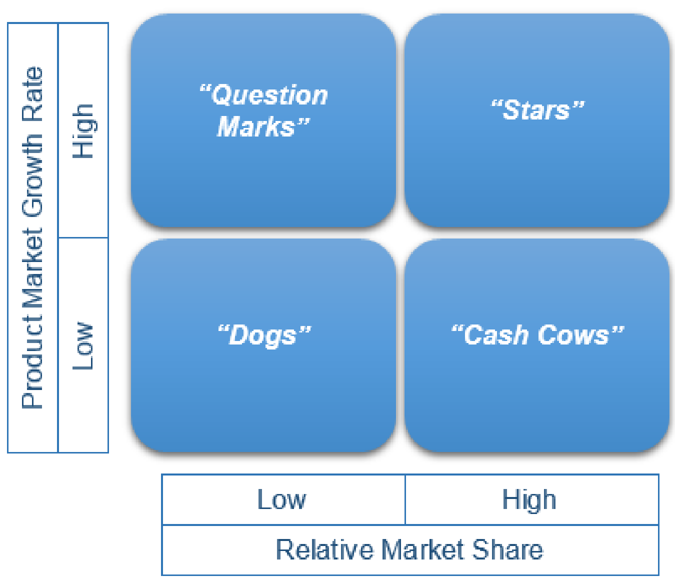


Figure 3: Boston Consulting Group-matrix
Source: author's elaboration via Dibb, *et al.* (1991) and Haezendonck *et al.* (2006)

- *Question Marks:* high growth, low market share. They often appear in company's new business with a great risk. However, due to the high market growth rate, the company has a potential to attract investments to increase their market share. They have variation tendency towards the "Stars".

- *Stars:* high growth, high market share. Business increases promptly in the markets and occupies the dominant market share. They will become the "cash cow" business of the company in the future.

- *Cash Cows:* low growth, high market share. This position may generate the large amounts of cash. Besides, it is the financial resources of an enterprise. However, the future growth prospects are limited.

- *Dogs:* low growth, low market share. In this case, the business always has only a small profit or even a loss. They cannot produce significant amounts of cash but take up many resources. Thus organisation should take advantage of the contraction strategy to tackle them.

On the basis of BCG-matrix, Haezendonck and her colleagues (2001, 2006) emphasised that the original four quadrants do not reflect the context of ports and port traffic categories. However, the fundamental concepts of the BCG-matrix can easily be transplanted into the port sector (Haezendonck, et al., 2006). Therefore, Haezendonck *et al*. (2001, 2006) proposed a new terminology to describe the four quadrants (See Figure 4).

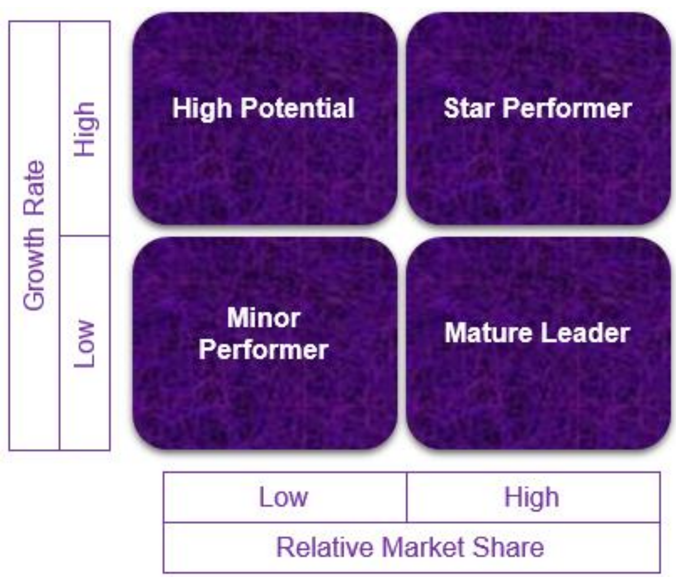


Figure 4: BCG-matrix adapted for Port Portfolio Analysis
Source: author's elaboration via Haezendonck *et al.* (2006)

- The "Star" sector renamed slightly as "Star Performer", which implies that the long-term sustainable development of this favourable position cannot be guaranteed. An internal port performance or a quick environmental change will greatly impact on the current situation of port or its traffic category.

- "Mature leader" replaced "Cash cow" and the original concept of "Cash cow" can be eliminated. The new concept means that *"a high market share and slow growth rate in the port context are entirely unrelated to actual cash flows accruing to either the port authority or the port operators concerned"* (Haezendonck, et al., 2006).

- "Dog" transformed into "Minor performer" and meant that any port or its traffic category in this situation lags behind its rivals.

- "High potential" completely abolished the original concept of "Question mark". The new sense shows that if a traffic category or port itself is possible to keep a growth well above the average over time, it will lead to a higher than the average market share as well.

Hence, the Port Portfolio Analysis has been applied to identify the competitive position of the port itself or port traffic structures among the rivals in the certain periods. Besides, the PPA allows both of the port authorities and the port operators to acquire the insights into the potential growing space of their market share. Haezendonck *et al.* (2006) discussed that *"It allows both a comparative description of past performance and provides a starting point for the strategic planning of future resource allocations that impact upon the traffic portfolio"* (Haezendonck, et al., 2006).

Additionally, such the portfolio analysis has to use the port traffic categories from four different "levels" (Haezendonck, et al., 2006). Since those "levels" together present the various types of analysis individually instead of a hierarchy of priority or significance amongst the different sequences of the data analysis. Those "levels" therefore demonstrate the versatility and the flexibility of the PPA method.

3.1.1 PPA level 1

The first level analyses a general structure of total traffic of our sample container ports (external positioning analysis). Besides, there is also nothing related to the specific traffic categories. The so-called ports range (videlicet, ten major Asian container ports) establishes the conceptualization of the portfolio. In accordance with the original BCG-matrix, the X-axis horizontally shows a market share while the Y-axis vertically represents a growth rate per year. The graph (not only of this level but also of the entire PPA) will be generated by the Excel software. Visually, an extra horizontal line (the average annual growth rate) and another vertical line (average market share) will segment the graph. Then the ports positioning can be easily identified by the PPA matrix.

3.1.2 PPA level 2

The aim of the second level is to investigate the traffic categories of each seaport respectively (internal positioning analysis). The basic concept is consistent with the previous level. But in this section, each seaport is considered as a portfolio in term of traffic categories. Normally a large seaport includes five different traffic categories (namely commodity groups), including liquid bulk, dry bulk cargoes, containers, conventional cargoes and Ro-Ro freighters.

However, in order to achieve the purpose of this research, we will skip this level. Because we are merely focusing on the container seaports, others traffic structures did not add any value to this study.

3.1.3 PPA level 3

At the third level, each traffic category (namely commodity group) will be deemed as a portfolio in the whole range of sample ports. In other words, the Level 1 can be decomposed among these sample ports. The purpose is to classify those ports according to the market share in the range and the growth rate per year in term of the specific traffic structure.

Nevertheless, there is the similar story as the previous level. Therefore, we are not going to discuss the traffic categories like the liquid bulk, dry bulk, conventional cargo and Ro-Ro but focus on the container traffic of interest. Despite of a static analysis of the container traffic category (similar as the Level 1), we will also add a dynamic dimension in this part. A dynamic dimension requests the data comparison in different times. For example, this study undertakes a period of time from 2001 to 2015. Moreover, the dynamic time can be set as three periods accordingly: (2001-2005), (2006-2010), (2011-2015). Visually, the two continuous trajectories will be found from individual sample port in the graph. The additional purpose of the dynamic analysis is to achieve potential developments in the future based on the historical evolution.

3.1.4 PPA level 4

The fourth level shows the structure of a specific traffic category comparing with total port traffic categories, by adding a dimension of the container traffic category in our case. In such a way, the Y-axis remains the same while the X-axis refers to an average proportion of the container within total port traffic categories instead of the market shares. That is, the container traffic category will be examined by the share of the total traffic category in the sample ports.

Due to that extra dimension, every sample ports will be shown as bubbles (in an Excel figure), whose surfaces are proportional to the total traffics (absolute value) in the total port range. Meanwhile, the essence of each bubble illustrates a proportion of container growth rate as well as a market share. According to Haezendonck et al. (2006), the main advantage of this level is that it can measure the three dimensions simultaneously, including a positioning of the total traffic categories in whole sample ports, a size of the container traffic category in comparison to the scale of the same commodity in the other ports, and the growth rate and market share of container traffic in the port range (Haezendonck, et al., 2006).

In general, combining with all the available PPA levels, this method as an instrument offers an eclectic perspective concerning the strategic positioning of each container port

(Haezendonck, et al., 2006). Additionally, in Chapter 5, the outcomes of the three levels (excepted Level 2) will be showed by the separate Excel charts graphically.

3.1.5 Data collection

In this research, we mainly focus on the Asian container seaports. However, due to the time limitation, we are not able to analyse every single container port in Asia. Therefore, the ten major Asian container seaports (come from China, South Korea, Singapore, and Malaysia) will be selected as the samples. Besides, we will introduce the specific details about the selection of samples in the following Chapter 4.

One of the main reasons for us to choose the PPA technique is the requirement of data. All data required in this section are the secondary data, such as the port total traffic volumes (in tonnes per year) and the container throughputs (in TEUs per year), which can be easily obtained through the statistics from each port authority mostly, as well as other public available data sources. There is also a requirement of time span, and the data have to be covered during the last fifteen years (from the year of 2001 to 2015).

We prefer mainly to obtain the necessary data from the professional European institutions with high social reputation, such as the Institute of Shipping Economics and Logistics (ISL), Port of Rotterdam Authority and Port of Antwerp Authority. They have the earlier and advanced technologies in term of the port activities compared with the Asian organisations. What is more, such data have been quoted quite frequently by lots of literature. There are two ways to gather the data, which are the online research (Internet electronic data) and the on-site visit (ISL InfoCenter / Library).

We also have the extra comments on traffic data as below.

- Memo 1: Tonne is not always a tonne

The data of total port traffic volumes are calculated according to the unit of tonnage. However, there are different ways regarding the tonnage measurement (as Metric Tonne, Freight Tonne and Revenue Tonne). China uses the metric tonne, which is the same as most of the European ports. Besides, South Korea prefers to use the revenue tonne while Singapore and Malaysia employ the Freight Tonne. Furthermore, those variant tonnes are not able to convert into a standardised unit. Therefore, we will ignore the differences between the tonnages, then the data of the port total traffic categories will impact on the robustness of this study. It can be considered as a kind of limitation as well in this paper.

- Memo 2: Integer and decimal

In the process of data collection, we found that the numerical expression is inconsistent about the data, such as 12,345,678 Tonnes vs. 12,346,000 Tonnes. We have compared the available data from the institutions mentioned above with that from the port self, World Bank, IMO, and so on. Therefore, we are able to conclude that the round-off is quite common used in the port statistics. According to this fact, we will refer to the later way during this study.

What is more, in a case of the data value as the decimal, we reserves two decimal fractions of the round-off, such as 12.35 instead of 12.345.

- Memo 3: Conversion from TEUs to Tonnes by 11 tonnes

In Level 4 of the PPA analysis, we have to put two parameters (namely, container traffic and total traffic volumes) into comparison. A quite common way is to obtain the container throughputs data in Tonnes directly and then examines the share rate among the total traffic categories. However, most of the samples (especially the Chinese container ports) are lack of the quantitative value in Tonnage on the container category, but available in unit of TEUs only.

In such case, we will attempt to transform the data from TEUs to Tonnes by a coefficient. According to the last issue of ISO 668 (container specifications), the weight of a container box is approximately between 2.5 tonnes (tare/empty) and 30.5 tonnes (max. technical capacity) (EU Taxation and Customs Union, 2002). In consideration of the practical ability of the container handling equipment and technical aspect of container vessels, we are not allowed to use the average value of above-mentioned tonnes. Harries *et al.* (2006) and Verny and Grigentin (2009) mentioned that 14 tonnes per TEU could be regarded as the standard in term of the average weight per box. However, Alphaliner Groups (2013) advocated that "14 Tonnes" is just a theoretical number, which not only reflects the carrying capability but also remain within the requirements for minimum stability of container vessels. Moreover, an average gross weight per box is approximately 10-12 tonnes/TEU (Alphaliner, 2013). Janić (2014) agreed with that theory as well. Thus we will regard 11 tonnes/TEU (Ave. of 10~12) as the coefficient to convert from TEUs to Tonnes. Besides, it will be one of the limitations in this study.

3.2 Green port portfolio analysis

A Green Port Portfolio Analysis, which is also called Green Portfolio Analysis (GPA), is an extensional technique based on the conventional PPA. By adding a "green" dimension (or ecological dimension) of port's hinterland traffic upon the PPA, we can identify the green performance and contribution of ports and their rivals in term of environmentally friendliness. In the early stage, Ilinitch & Schaltegger (1995) and Burke & Lodgson (1996) introduced a "green" concept firstly to the port competitive analysis. After that, Haezendonck (2001) measured port environmental impacts through different transport modes (such as, road, railway, and inland navigation) used for port traffic from/to the related hinterlands. She hereby established the Green Portfolio Analysis technique for the maritime ports in 2001 (Dooms & Haezendonck, 2004).

The GPA focused mainly on environmental harm directly caused by the transport activities between the port and its hinterlands, including road freight, rail transport, and inland navigation. The pipeline transport is not accounted for hinterland transport modes because it primarily reflects a short distance from the port and industrial clusters. Besides, it causes negligible harm to the environment (Haezendonck, et al., 2006). The key advantages of the GPA are a trade-off between the economic benefits (id est, market share and growth rate) and the environmental impacts (e.g. external cost), a comprehensive and dynamic description of ports' (or traffic categories') competitive position and evolution as well as an easy requirement of data (Dooms, et al., 2013). We will replicate the GPA method in this research to recognise whether such the tool can be applied to the major Asian container ports or not.

According to concepts of the Green Portfolio Analysis, the quantitative variables concerning the economic performance are identical with the PPA. Whereas, in order to analyse port environmental impacts, the variables of hinterland port traffics should reflect an extra dimension in the matrix. The higher level of a green dimension presents that the port is relatively cleaner than others among the considered port. In addition, the traditional matrix with the extra terminologies in the four quadrants can be shown as below Figure 5. The terminologies are on the basis of the contributions of Ilinitch and Schaltegger in 1995.

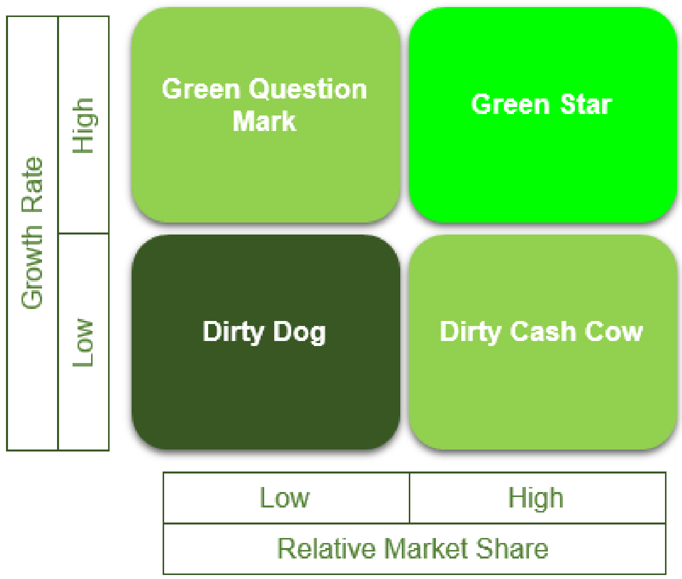


Figure 5: Traditional PPA-matrix with green dimension
Source: author's elaboration via Haezendonck *et al.* (2006)

- "Green Star" has the best position with not only the high economic performance but also the low environmental hazard.
- "Green Question Mark" and "Dirty Cash Cow" constitute the middle position of green dimensions, which reflect that a port or a port traffic category has the high growth rate or market share as well as the pollution and dirty technologies.
- "Dirty Dog" is the least desirable position mirroring that ports or port traffic category produces hardly the satisfactory economic benefits, meanwhile damages to the environment.

Nevertheless, in the practical applications of GPA, a two-dimensional graph was released by Haezendonck (2001). A green bubble will appear on the matrix chart visually, which reflects the environmental impacts of the considered traffic category of each port.

Moreover, the quantitative variables such as road freights, rail transports and inland navigation (videlicet, modal split) between the ports and hinterlands will be applied as the measurements of the environment-friendly degree. That green bubble is comprised of two parameters: one is the size of the bubble, and the other one is the shade of green colour.

On one hand, the size of the bubble can be represented by the external costs (in Euros per tonne- kilometres). In the previous chapter of Literature Review, we have introduced the concept of external costs in term of transportation sector (ton-km, Figure 1) according to the findings of CE Delft/ INFRAS/ Fraunhofer ISI (2008, 2011). For instance:

Road freight: €50.5 per 1,000 tonne-km
Railway: €7.9 per 1,000 tonne-km
Inland navigation: € 11.2 per 1,000 tonne-km

Hence, the total external costs (of each port per year) can be calculated by multiplying the volume tonne-km (generated by each transport mode) with the abovementioned costs. The traffic volume tonne-km per mode is in accordance with the shared volume of each mode divided by an average distance (by each mode of transport). Those can be expressed in below Equation 1.

Equation 1

$$\textbf{Total Average External Costs}_X = \frac{\sum Average\ Shared\ Volumes_X\ (tons)}{\sum Average\ Distance\ per\ year_X\ (km)} * External\ cost_X\ (per\ 1{,}000\ ton\ km)$$

X representatives the specified transport mode (road, railway or inland navigation)

Because of the modal split data limitation, we have no concept of "port range" in this study. Therefore, we will assume an average distance as 1 km per year in order to obtain a numerical value rather than a practical one for all kind of transport modes.

After above calculations, we will get the costs in Euros, which displays the total average external costs generated by the modal split of ports during the years of 2001-2015. In order to compare with each other, the costs will be proportional to the total group's average external costs. The tables of the related calculations will be presented in the appendix sector.

There are two key reasons why we adopt those European criteria of external costs. Firstly, according to our research, we believe that there is no such formulation about external costs calculation in Asia due to quite complex networks and ambiguous situations locally. Secondly, we will take into a comparison between an Asian sample port and two European famous seaports according to the limitations of modal split data.

On the other hand, the green-coloured shade of bubbles indicate the degree of environmentally friendliness, such as a light green colour meaning clean and dark green referring to pollution. CE Delft/ INFRAS/ Fraunhofer ISI (2008, 2011) identified that the railway and inland navigation are the friendliest transport modes, but the road freight is considered as the heavily polluted sector. Haezendonck (2001, 2006) thereby developed a calculative method regarding this green parameter.

We will replicate that calculative method. Through this method, we added the rail traffic and inland navigation for each port in a certain year first. Then, we divided the road traffic for the homologous port and time. Finally, we will reach a ratio. (Equation 2).

Equation 2

$$\text{Annual Green Colour Ratio}_Y = \frac{Shared\ Rail\ traffic_Y + Shared\ Inland\ navigation_Y}{Shared\ Road\ traffic_Y}$$

Y representatives the specified seaport

Under the same reasoning, we can also calculate an average ratio for each port during the observation period. Based on the Excel software, the ratio will be specified a colour in the green colour spectrum. For example, the lowest value of the green performance (the ratio) may equal to shade 30 while the highest one can be set to the green shade of 255 in this study. A higher value of the ratio means cleaner, and vice versa. Therefore, we can distinguish the changes in container traffic of the ports over time.

3.2.1 Busan vs. Antwerp vs. Rotterdam

The GPA model does not require a large number of data resources. On the contrary, it only requests the container throughputs (TEUs) and the modal split figures in our case. Besides, such the container throughputs are the common data and we have got that in the early stage. Hence, the modal split data preparation becomes a critical part of implementing the GPA model.

Unfortunately, based on our deep online research and several email inquiries with the relevant organisations and persons (such as the local statistics bureaus, port authorities, port experts, and so forth), we have noticed that the Asian (sea) ports are quite lack of the observation in term of hinterland traffic (modal split) data. Whereas, there is only an available modal split dataset (in TEUs) existing in the Port of Busan. From this, we may conclude that Asian seaports have lagged behind the European ports concerning environmental perspectives and data monitoring techniques.

On account of this, we can hardly conduct the GPA during the “Asian container port range” concept. Therefore, we will consider the Busan Port as a tentative port, and let it compare with the representative seaports in the Western Europe, like the Port of Rotterdam and Antwerp in a fictitious port range. The only purpose of this is to identify the green performance and evolution of the Asian seaport by contrasting with other two experienced green seaports in term of environment-friendliness. Moreover, in practical cases, that is not comparable among those three seaports, since they are not in competition and not sharing the 100% market with each other physically. Thus, the results obtained from such theoretical port range should be paid great attention to interpret.

3.2.2 Dynamic GPA – container traffic

Due to our study scope and the data limitation, we will examine the container traffics only with the developmental footprints, which is so-called a dynamic structure of container traffics with green dimensions.

Accompanying with the main concepts of PPA and a combination of environmental impact parameters, the visualisation of the GPA will include the following parameters among the Port of Busan, Rotterdam and Antwerp from 2001 to 2015:

- The average market share for each port (X-axis)
- The average annual growth rate for each port (Y-axis)
- The average market share in group (extra horizontal bold line)
- The average annual growth rate in group (extra vertical bold line)
- The external costs of modal split (size of the bubble)
- The extent of modal split (green-coloured shade)
- Dynamic time series (2001-2005), (2006-2010), (2011-2015), and this is similar to PPA level 3.

3.2.3 Data collection

As per discussions above, the Busan port has more remarkable performance than other Asian major container ports in term of the modal split data. Rest of them are lack of such observation. In order to conduct the GPA test, we have to compare the Port of Busan, Rotterdam and Antwerp accordingly.

The data related to the economic performance dimension, such as container throughputs (TEUs), can be obtained from the Institute of Shipping Economics and Logistics (ISL), which mentioned in section 3.1.5. The method is as same as the process of the Port Portfolio Analysis.

Besides that, the quantitative variables of green dimensions (namely modal split) between 2001 and 2015 are required for this analysis. The related data about the Port of Busan, which is obtained from the Port of Busan Container Statistics in the year of 2006, 2010 and 2014 respectively, is the secondary data. However, the datasets of modal split regarding the Port of Rotterdam and Antwerp are the primary data, which we received directly from both of the port authorities by the email communications separately, such as the Strategie & Ontwikkeling Department (Antwerp Port Authority) and the Container Department (Rotterdam Port Authority).

Moreover, the external costs in Euros per tonne-km are based on the study of CE Delft/ INFRAS/ Fraunhofer ISI in 2008 and 2011 (as the hint previously).

We also state the extra notes for this section as follows.

- Note 1: Definition of modal split

In this study, the Modal Split stands for the transport modes between a port and its hinterlands, which includes road, railway and inland navigation, but without the pipeline. All the figures regarding modal split only focus on the container traffics, which means in TEUs. Besides, the figures exclude the amounts of transhipment.

- Note 2: Crucial data limitations

We have encountered the data constraints in this section. Firstly, modal split is one of the significant data limitations. Despite of the Port of Busan, all the rest Asian samples, however, are lack of the modal split data. Moreover, it leads to that the GPA method cannot be applied to the Asian port range directly. As the hint before, a conceptual port range begin to be involved in the analysis of GPA.

Secondly, the INFRAS' data is mainly about the external costs of transport modes. Besides, that is the perfect data to measure the external costs of port's hinterland traffics for the European ports only. We employ such data on Buran as well because there is no similar available data in Asia. Because such data used in Asian port is ordinarily incorrect, it should be checked firstly rather than just applied to Asia directly.

Thirdly, according to the explanation in Equation 1 anteriorly, the dimension of external costs also depends on the average distance of the different transport modes. Whereas, due to a fictitious port range, it is impossible to estimate the precise average distance. Thus, we will use 1 kilometre instead of the all average distances in this study.

- Note 3: Assumption of 2015 modal split in Busan

The 2015 modal split data has not be released by the Port of Busan yet. We have tried to contact the Authority for the clarification. Unfortunately, we only got insufficient feedbacks. Therefore, we will forecast the missing data based on an average value between 2013 and 2014.

- Note 4: Others

The Memo 1, 2 and 3 in the section of 3.1.5 are all applicable to the GPA study.

In the coming chapters (4 and 5), we will conduct the analysis on the basis of the stated methodology from the sample port selections and their characteristics under environmental perspectives (Chapter 4). After that, the analytical results and discussions of the PPA and GPA models will be presented in chapter 5.

4 The major Asian container ports

This chapter is going to present the samples employed in the study. First, we will introduce the process of sample selection. Second, the key characteristics of each port and their current stages concerning the environmental management will be presented. Due to the time and data limitations, we are going to select 10 Asian container ports. Meanwhile, we request that our sample ports should be the influential cluster in Asia and decisive all over the world, such as an approbatory world port ranking.

4.1 Sample selection

The Asian seaports are mainly distributed in the East Asia. According to the overall cargo traffic throughputs worldwide, we gained the information of world's top 20 ports in 2015 by the Rotterdam Port Authority. In the ranking list, Chinese ports accounted for 70%, and the rest of 30% are shared by the United States, The Netherlands, Australia, Malaysia, Singapore and South Korea respectively (See Table 8).Those data are based on cargo volumes calculated by tonnage (PoR, 2015).

Table 8: Top 20 world ports 2015

2015 Rank	Ports	Country
1	Ningbo & Zhoushan	China
2	Shanghai	China
3	Singapore	Singapore
4	Tianjin	China
5	Taicang Port Area	China
6	Tangshan	China
7	Qingdao	China
8	Guangzhou	China
9	Rotterdam	Netherlands
10	Hedland	Australia
11	Dalian	China
12	Rizhao	China
13	Yingkou	China
14	Busan	South Korea
15	South Louisiana	United States
16	Hong Kong	China
17	Qinhuangdao	China
18	Klang	Malaysia
19	Shenzhen	China
20	Xiamen	China

Source: author's elaboration via Port of Rotterdam (2015)

As our research is focusing on major Asian container ports, we have also studied the specialised rankings in the container throughputs released in TEUs. In order to strengthen the reliability, we have compared the statistics among the Port of Rotterdam (2014 and 2015), the CM Container Management (2015) and the Alphaliner Weekly Newsletter (2015) accordingly. Rotterdam Port Authority regarded container throughputs in TEUs as the direct measurements (PoR, 2015), Besides, both of the CM Container Management and Alphaliner Weekly Newsletter attached importance to an integrated measurements under the comparisons of the previous year ranking, the throughputs (TEUs) and the annual growth rate (Cass, 2015) (Alphaliner, 2015). We therefore integrated those sources as per Table 9. The outcomes of different rankings are slightly different because of the discrepant ranking criterions. However, they do not impact on our selection obviously.

Table 9: Top 15 world container ports (comparison)

Ports	Country	2015 Rank (by PoR)	2015 Rank (by CM)	2014 Rank (by PoR)	2014 Rank (by AWN)
Shanghai	China	1	1	1	1
Singapore	Singapore	2	2	2	2
Shenzhen	China	3	3	3	3
Ningbo & Zhoushan	China	4	5	5	5
Hong Kong	China	5	4	4	4
Busan	South Korea	6	6	6	6
Guangzhou	China	7	7	8	8
Qingdao	China	8	8	7	7
Dubai	United Arab Emirates	9	9	9	9
Tianjin	China	10	10	10	11
Rotterdam	Netherlands	11	11	11	12
Klang	Malaysia	12	12	12	13
Kaohsiung	Chinese Taipei	13	14	13	14
Antwerp	Belgium	14	13	16	17
Dalian	China	15	15	14	15

Source: author's elaboration via Port of Rotterdam (2015, 2014) & CM (2015) & AWN (2015)

We should able to select ten major Asian container posts directly according to Table 9 in term of physical geography. However, when we considered the ranking of overall traffic flows (Table 8) as the additional constraint, the Port of Dubai is not eligible to show in our sample list. Hence, in order to achieve the purpose of research, we will select the ten major Asian container ports sequentially (skip the Port of Dubai), including the Port of Shanghai, Singapore, Shenzhen, Ningbo&Zhoushan, Hong Kong, Busan, Guangzhou, Qingdao, Tianjin and Klang.

4.2 Characteristics

In this part we will illustrate key features of each sample port, and what the current policies, actions or contributions they do in term of environmental perspective. Below the figure gives a geographical image about ten major container ports (red underlined) in this study.

Figure 6: Geographic positions of the major Asian container ports
Source: author's elaboration via Port of Rotterdam (2015)

- **<u>Port of Shanghai</u>**

The top one port in term of worldwide container throughputs since 2010. About 36.54 million TEUs handled by the various sub port areas (namely, Baoshan, Waigaoqiao, and Yangshan) in Shanghai Port in 2015. And that was about 3.5% higher than 2014. The direct hinterland of the Port mainly locates in Yangtze River Delta region, which contains 15 different cities with more than 100,000 square kilometres, and nearly 100 million consumer population (Chinaports, 2007).

Two most important container terminals occupied 55% (Waigaoqiao) and 35% (Yangshan) respectively of the total container traffic in last year. As per relatively enhance of environmental perspective and general air quality problems (e.g. PM2.5) in China, the Port has launched a port reform project in 2013 – Yangshan Phase 4. That is a development of a fully automated container terminal and expected to be completed by 2017 (Cass, 2015). The project will effectively improve the Port's capacity and reduce environmental damages, such as noise, emissions, and so forth.

Additionally, there are also several local policies released by the municipality, such as Shanghai Green Port Three Years Action Plan (2015-2017), to control the pollution, use energy effectively, and promote a sea-railway transport mode, et cetera. (MEP, 2016).

- **Port of Singapore**

As the closest rival of Port of Shanghai, Singapore Port handled almost 30.1 million TEUs in 2015, which however decreased 8.7% in comparison with 2014. Port of Singapore is the largest transhipment port in the Asia-Pacific region, and it is located in a shipping lane between the Pacific and the Indian Ocean, which is a very strategic position. It still plays a meaningful role in worldwide seaborne trade.

Singapore Port pays much attention to sustainable developments. Last year, a zero-emission and fully automated yard crane system had to be deployed in the new 3 and 4 phases of Pasir Panjang Terminal (Cass, 2015). In the same year, the Port Authority also signed a Memorandum of Understanding with Rotterdam Port Authority to exchange advanced experiences in term of the sustainable shipping and port optimisation, et cetera. (MPA, 2016). In addition, the Next Generation Port 2030 Vision Plan was released by the Authority and Singaporean government. One of the principal aims is to promote clean energy (e.g. LNG) as the power of vessels (Tan, 2015), and that vision plan emphasizes a requirement of smart and clean technologies in coming future.

- **Port of Shenzhen**

With China's accession to the WTO, Port of Shenzhen has maintained a rapid and stable economic development due to its natural geographical advantage. Its direct hinterlands locate in the Pearl River Delta region, which cover more than nine different cities. The 20 sea miles south far away Hong Kong and 60 sea miles north to Guangzhou, via the Pearl River network, the Port is able to reach all the domestic coastal ports. And the accessibilities of railway are mainly covered by the Beijing-Guangzhou and the Beijing-Kowloon lanes.

The Port contributed 24.2 million TEUs and recorded growth of 0.67% in 2015. The largest terminal is Yantian International Container Terminal (YICT) in the Port, which received the 20 purely electric RTGs (rubber-tyre gantry) in 2015 to support the terminal substantially and to reduce waste gas and noise (Cass, 2015). Moreover, the Da Chan Bay Terminal as the youngest port facility, which is a joint venture sector involving the APM Terminals in order to attract international management techniques.

- **Port of Ningbo&Zhoushan**

The Port can be considered as one of the oldest treaty ports in China, originated from the Sui dynasty (A.D. 581-618). Currently, it is also the busiest seaport in term of total cargo throughputs in the world. Ningbo and Zhoushan were two separate seaports before, after in consideration of the complementary advantages mutually, both ports decided a strategic merging in 2006, namely the Port of Ningbo&Zhoushan.

To meet continually increasing demand from its hinterlands, the Authority is undertaking some expansion projects in different container terminals, videlicet, Chuanshan and Daxie. The new terminals will contribute more capacities and cleaner technologies. The container throughputs reached 20.63 million TEUs and the total cargo volumes represented about 889 million Tonnes in year of 2015. The Port implements further a national green traffic development of "ecological priority" policy to strengthen governances with regard to environmental impacts. In 2016, the National Green & Low Carbon Demonstration Technology Summit was held in Ningbo city, which emphasised some workable plans in near future such as the multimodal transport, Emission Control Zone set up, remote technology of the container terminal and so on (Port.org, 2016).

■ **Port of Hong Kong**

Port of Hong Kong is one of the most efficient international container port, playing a role as a communications hub between China and the neighbouring Asian countries. Based on its relatively cheap port fee in Asia, Hong Kong maintained as the world top one container port for several years. But due to factors such as recessionary global trade and the land limitation, it has been overtaken by few China's mainland seaports. There was a downward trend in container throughputs from 22.2 (2014) to 20.1 (2015) million TEUs. Therefore, the Port Operators Association has requested for government support to provide additional backup land for the large container storage depots so that the issues like congestion and truck emissions can be resolved (Cass, 2015).

Additionally, a regional emissions reduction activity (HK-Macao Cleaner Production Partnerships) is conducted by cooperation between Hong Kong and Macau. The main aim that is to establish a mechanism of reducing pollution during the manufacturing and transportation industry. Meanwhile, the Hong Kong government also very advocates the clean energy application, for example, solar and wind power generation technology, and makes many efforts on R&D and promotion (Li, 2009).

■ **Port of Busan**

Port of Busan has a history of 140 years, and it is the largest seaport in South Korea and current the sixth largest container port worldwide. In 2014, a total of 19.45 million TEU containers were handled in the Port. However, it slightly increased to 19.47 million TEUs in 2015, with an annual growth rate of 0.13%. Compared with that, the Port's average growth rate was about 10.44% positively in period of 2013-2014. That big gap may due to global crude oil prices and the impact of a "slowdown policy" in China's economy.

Busan Port Authority relatively earlier noticed such importance of environment impact in term of sustainable port developments. Until 2010, there were total 94 oil-powered cranes had been converted to electric RTGs to reduce costs and pollution such as emissions and noise (PortStrategy, 2008). Those efforts supported the terminal to reduce CO_2 emissions, save the operational cost and drops the failure rate effectively (Cho, 2010).

The Busan New Container Terminal is the busiest yard in the Port, and its Phase 2 was expanded being as environmentally friendly in 2014, as well as other expansion projects in the Port. The Authority seriously takes it commitment to eco-friendly. For example, besides the continued equipment updates, there are some pilot programs to install solar power on the warehouse roofs, and a mix application of geothermal and solar energy in Port's office areas (GreenPort, 2014).

In 2013, the Port held its first Busan International Port Conference, which emphasised the challenges and perspectives in term of port environmental impacts, and a leading role of Port of Busan in sustainability. Moreover, the Authority also offers an exemption or discount regarding port service fees when a vessel achieves the sufficient Environmental Ship Index rating (GreenPort, 2014). Busan Port is pushing ahead with plans to construct an additional 22 berths and add another advanced facilities by 2020 (Cass, 2015) in order to become an environmentally friendly and cost-efficiently seaport in Asia.

- **<u>Port of Guangzhou</u>**

Guangzhou Port is located in heart of the Pearl River Delta region, since the 3rd century 30's, is has become the significant port of China Maritime Silk Road. The Port also plays as a transportation hub in the south of China, not only in waterways but also in aspects of railways, roads and airways. The direct hinterlands of the Port mainly cover ten provinces in China mainland. And its traffic network can access directly to the areas of Southeast Asia.

Port of Guangzhou comprises four sub-port areas, Huangpu, Xinsha, Nansha and Inner Harbour area. The total cargo volumes reported about 490 million tonnes and the container throughputs reached 17.59 million TEUs respectively in 2015.

In July of 2016, a "Guangzhou Green Port and Shipping Convention" was released by the Port Authority. The primary purposes are to promote the application of clean equipment, utilisation of shore power system rather than the conventional sulphur oil and reduction of vessel particulate matter emissions to improve the air quality during the port surrounding areas. There are 83 organisations have agreed and signed that convention, such as Guangzhou Power Supply Authority, CMA CGM, COSCO, Maersk line, to name but a few (Ma, 2016).

- **<u>Port of Qingdao</u>**

Port of Qingdao founded in 1892, is located in the south coast of Shandong Peninsula. It is an important international treaty port and seaborne hub of the West coast of the Pacific Ocean. The Port is able to welcome all size container vessels, for instance, CSCL Globe and MSC Oscar. Qingdao Port handles primarily the containerized cargo, coal & iron ore and crude oil. The 17.43 million TEUs were handled in previous year, which was around 4.9% above than 2014. That reflects a health economic growth in its hinterlands.

In addition, there are ten new rail lines within the Shandong province and six inter-provincial railways are configured to connect the port facilities and its hinterlands. These developments come from backbones of the intra-Asia and Asia to Europe logistics networks. Those will boost mostly the inland cargo coverage of Port of Qingdao (Cass, 2015).

According to the plan of “One Belt and One Road (OBOR)”, Qingdao Port is looking for cooperation with the European ports in order to promote sustainable developments in term of intermodal transports, environmental protection, smart ports, modern logistics technologies, and so on. For instance, in 2016, the Port of Qingdao has signed a “Deepen Strategic Cooperation Framework Agreement” and a “Strategic Cooperation Memorandum” with the Wilhelmshaven (Germany) and Port of Gdańsk (Poland) respectively (Yu, 2016) (Wen, 2016).

- **Port of Tianjin**

Tianjin Port located in the West of Bohai Bay and the largest comprehensive seaport in the Northern China. It is a world-class artificial deep-water port. The Port covers around 460 square kilometres’ hinterlands those consist of 12 provinces and a country of Mongolia, however, the levels of regional economic development are quite various. The Port got a slow growth from 2014 (14.06 million TUEs) to 2015 (14.11 million TEUs), those efforts were contributed by six container terminals in the Port. The railway network again is much matured, which can connect the port facilities with Mongolia, Russia, and other European countries (namely, the Eurasian Land Bridge).

During 2011-2015, Port Authority reformed much old equipment to achieve an entire shore power system that covered all container terminals, which led to the clean energy utilisation rate increased from 34% to 43%, the production energy consumption reduced by 9.36% (PoTJ, 2016). Hence, that port shore power technique has become an effective method in term of energy savings, emissions and noise reductions in Tianjin Port.

During 2016-2020, Tianjin Port will improve further such as the energy saving plan, data observation, and ecological management, to accelerate the construction of green port and meet the national sustainable development policy (PoTJ, 2016).

- **Port of Klang**

Port Klang was built in 1973, it is the largest seaport in Malaysia and located in the Northeast area of the Straits of Malacca. In about 40 kilometres away from the Kuala Lumpur city, the methods of transport are mainly connected by road and railway. Port of Klang is divided into the Northern and Western sub ports, which is about five kilometres apart each other.

The container throughputs of the Port grew strongly by 8.6% from 10.95 to 11.89 million TUEs between 2014 and 2015. That record allows it retain a seat of the busiest port in Malaysia and the second biggest seaport in the Southeast Asia. In order to enhance their competitiveness, Port Klang is engaged mainly in the infrastructure construction in recent years. For example, the Westports opened the Container Terminal 7 (CT7) by the end of 2014, which is able to increase a handling capacity by 1.5 million TUEs (Cass, 2015). Also, a brand new Container Terminal 8 (CT8) is under construction and will be fully ready by mid-2017, and the CT9 is under a blueprint (PKA, 2016). Additionally, the Northports also reformed its multi-functional wharf (no.6) that covers 1.69 hectares in 2014. The upgrade cost about USD 6.7 million and enhanced the handling capacity to 5.6 million TUEs (Cass, 2015).

Such green revolutions have just started in different industries soon in Malaysia. Port Klang as a leader of the local port industry, also follows actively the national green policy, such as the applications of ISO14001 and OHSAS1400. Those tools have to be mandatory executed during the port operations and managements. But, most of efforts still remain in a theoretical phase.

5 Results and analysis

An aim of this chapter is to illustrate the quantitative and qualitative results based on the models and methodologies used during this study. The quantitative outputs of models, such as PPA and GPA, which will be presented in several graphics visually by a software of Microsoft Excel. Also, all the elaborate findings are based on our data collections with a time span from 2001 to 2015, which have mentioned in Chapter 3. Moreover, all the relevant calculation details/tables like market shares, growth rates or others will be showed in the Appendix section rather than over here.

Firstly, our findings of the Port Portfolio Analysis in ten major Asian container ports will be discussed. After that, we will present the results of the Green Portfolio Analysis between the Port of Busan, Rotterdam and Antwerp. Finally, the implications of the empirical analysis will be proposed. Particularly, some potential implications of the green port portfolio analysis with regards to future policies and strategies of the Asian container ports.

5.1 Findings of port portfolio analysis

According to the discussions in Chapter 3, a conventional PPA has been conducted with four different levels. However, in order to fit this study, we will skip the Level 2 since we are focusing on the container seaport only. Again, the ten sample ports for this analysis which include the Port of Shanghai, Singapore, Shenzhen, Ningbo&Zhoushan, Hong Kong, Busan, Guangzhou, Qingdao, Tianjin and Klang.

5.1.1 PPA level 1

The first level analyses a general structure of total traffic in each of the sample port, during the period 2001-2015. On this level, a range of those ten container seaports is considered as a portfolio of ports. As per below Figure 7 shows that the X-axis represents an average market share of the total traffic during that range, whereas the Y-axis means an average annual growth rate.

There are two bold lines exist also, and the horizontal line shows an average annual growth rate in the whole port range (in our case is 10%), and the vertical one is the average market share of the ten seaports (which is 9.26%). Those two bold lines cross each other on the surface of the graph. Therefore, the four quadrants have appeared on the chart, which allows us to analyse the port competitive positioning in term of total port traffics.

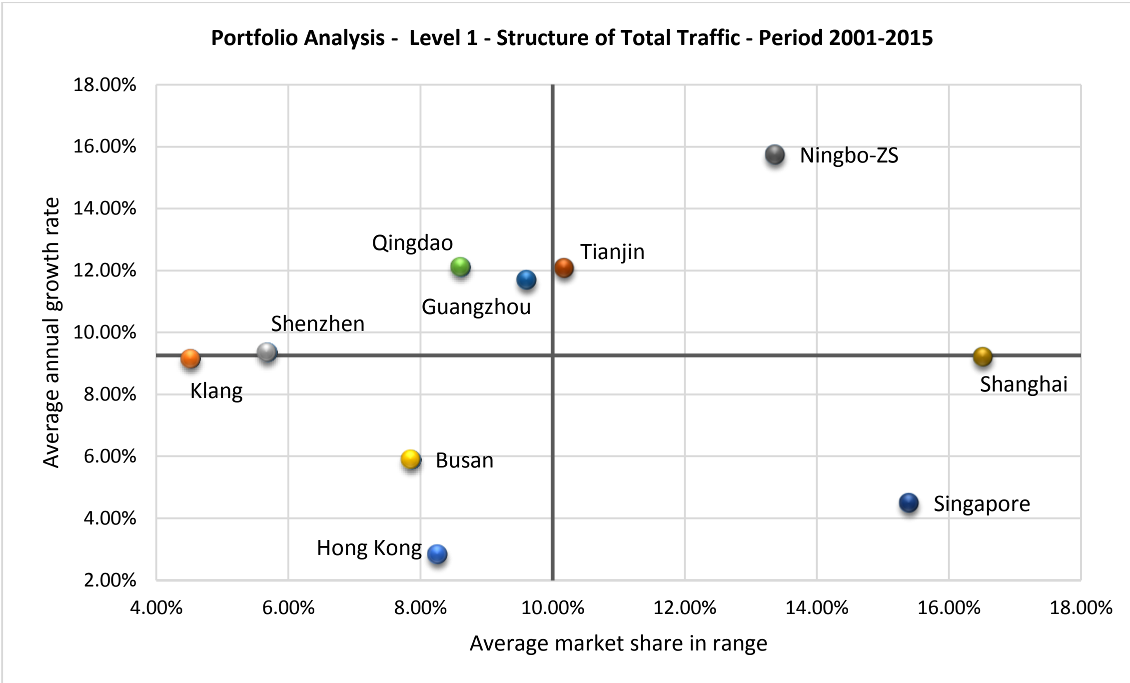


Figure 7: Structure of total traffic - period 2001-2015
Source: author's elaboration

Port of Ningbo&Zhoushan and Tianjin are both positioned as "Star Performer", but Tianjin has a lower position than Ningbo-ZS, which shows the 10.18% of an average market share and 12.08% concerning the average annual growth rate. Ningbo-ZS as the world top one port in term of port total traffics, it has the highest growth rate in that range and plays relatively steady in both of two dimensions (13.37% and 15.75 severally) during the last fifteen years.

Shanghai and Singapore locate in a quadrant of "Mature Leader", which makes the average market share and average annual growth respectively of 16.52%; 9.22% (Shanghai) and 15.40%; 4.5% (Singapore). It is worth mentioning that the Port of Shanghai as one of the biggest seaport that gets the highest point of market shares in the range, and it just slightly lower than an average group growth rate. Based on that phenomenon, Shanghai has a significant potential trend toward to the "Star Performer".

"Minor Performers" consists the Port of Hong Kong, Busan and Klang. During last decade, there was the booming development of China's economy. Hence several seaports in Chinese mainland overtook the Hong Kong's position. Hong Kong is facing a big challenge from the inside of China, and it performs just 8.26% and 2.84% in term of the average market share and the growth rate. Busan represents 7.86% and 5.90% in both of the dimensions separately. Port of Klang gets the lowest average market share (4.52%) in the test range, whereas it has the relatively prompt upward trend to 9.15% in the growth rate.

Shenzhen, Guangzhou and Qingdao stay in a field of "High Potential", they keep an above of group average growth in the past years with 9.36% (Shenzhen), 11.70%

(Guangzhou) and 12.12% (Qingdao). Moreover, in the aspect of the average market share, which they play as 5.68% (Shenzhen), 9.61% (Guangzhou) and 8.61% (Qingdao) respectively. Such the quadrant of “Minor Performers” has the potential ability to lead to a higher market share position, and we will expect them to provide better performance in coming years.

5.1.2 PPA level 3

We jump to the Level 3 since we have skipped the Level 2. In this level, we will analyse those ten Asian ports, in particular, the category of container traffic. Therefore, we consider the container traffic of those ports as a portfolio analysis to recognise the relative positioning of competition. We will provide both of a static and a dynamic structures of container traffic in the port range. Especially, the main aim of that dynamic analysis is to show port container traffic’s evolutions over time, and to assess the possible opportunities of future trends.

For both of the static and dynamic graphs consist the X-axis and Y-axis, which represent the identical meanings as per the Level 1. Additionally, one bold vertical line shows an average market share of the total samples, which equals to 10%. The bold horizontal line represents the average group annual growth of container traffic in the range, which is 12.16%. Below Figure 8 shows the static analysis of container traffics.

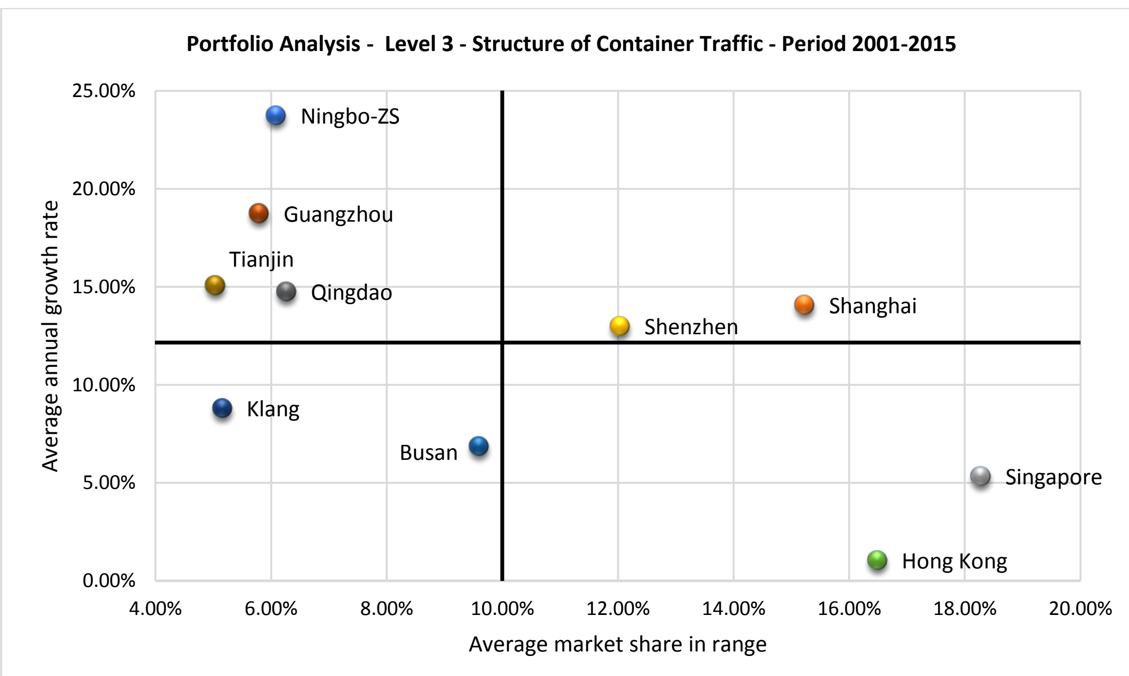


Figure 8: Structure of container traffic - period 2001-2015
Source: author’s elaboration

Shenzhen and Shanghai perform apparently as the “Star Performer”. There is 12.04% of an average market share and 13.01% of annual growth rate in the Port of Shenzhen. Meanwhile, Shanghai has results of 15.23% and 14.09% on both of the X-axis and Y-axis accordingly. This step shows an entirely appropriate outcome, which confirms the strengths of the Port of Shanghai and Shenzhen in term of the container traffic category. Shanghai holds the No.1 place and Shenzhen as the 3rd winner for the last three consecutive years in the world container port rankings.

Singapore and Hong Kong as the seasoned seaports in the port industry. They have the relatively higher average market share. However, because of changes of an international trade market in recent years, their annual growth rates are hence not noticeable. In this step, they stay at “Mature Leader” sector, and with the 12.04% and 13.01% (Shenzhen), and 15.23% and 14.09% (Singapore) in term of the average market share and annual growth rate aspects.

Port of Busan and Klang are situated as “Minor Performers” in the container traffic structure. They make 9.60%; 6.88% (Busan) and 5.16%; 8.81% (Klang) of the average market share and average annual growth separately. The outcomes correspond with their relatively lower positions in the world ranking list, in particular for the Klang Port.

All the rest of seaports aggregate in the quadrant of “High Potential”, among others, the Port of Ningbo&Zhoushan has the highest annual growth rate as 23.76% not only in this quadrant but also in the whole group. Conversely, the Port of Tianjin stays at the lowest point as 5.04% on the average market share in the range. Obviously, those four seaports are all from China, and we, therefore, believe that such positioning of them can be attributed to the direct impacts of the “slowdown growth” economic policy of China.

A dynamic PPA of the container traffic structure is shown graphically in below Figure 9. Also, the fifteen years be divided into three time periods, such as 2001-2005, 2006-2010, and 2011-2015.

On a dynamic observation, the Port of Singapore and Hong Kong have succeeded in maintaining their positions in “Mature Leader” over the last 15 years. However, there is a clear trend shows that their move toward to a lower market share direction, which from 23.30% to 11.19% (Hong Kong) and from 21.53% to 15.80% (Singapore). Whereas, the Busan Port is considered as the “Mature Leader” in the first five-year period. But after that, Busan is not able to keep its position and glides to “Minor Performers”. The Port of Klang still struggles in the “Minor Performers” during periods. Based on its current performance, we hardly see future opportunities that the Klang can jump out of this quadrant shortly.

Additionality, all the Chinses sample container ports stayed above a group average annual growth rate line (12.16%) in the first period. But they have lost their growth rates eventually. It can be seen that has been vertical shifts from the “High Potential”, “Star Performer” to the “Minor Performers”, “Mature Leader” accordingly. According to the dynamic trends, we believe that they will stay in the latter two quadrants for couple of years. Again, it is worth reminding here such this situation is related to the new economic policy of China.

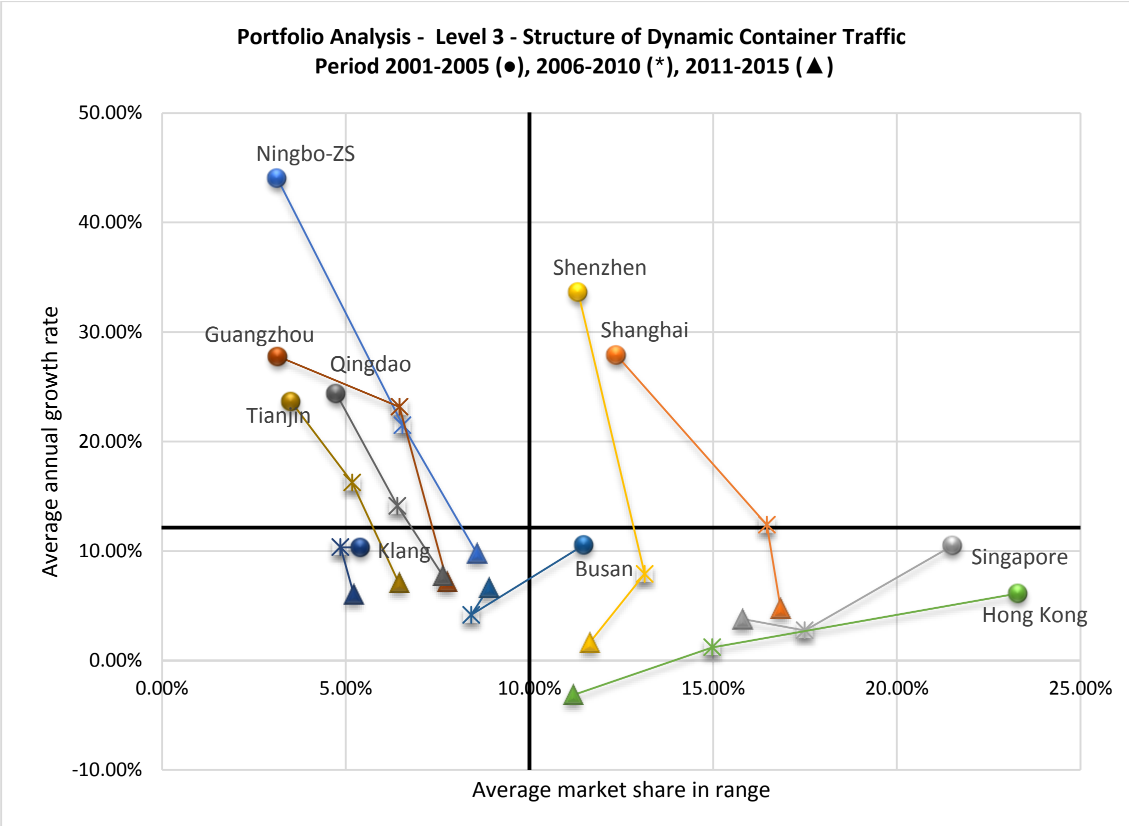


Figure 9: Dynamic of container traffic - period (2001-2005) (2006-2010) (2011-2015)
Source: author's elaboration

5.1.3 PPA level 4

The last level of PPA analyses the proportion of container traffic of ports within their total traffic category in the sample range. Compared with the previous levels, the Level 4 completes the process by adding an extra dimension, which is the total traffic category of considered seaports in the same range and time span.

Since the comparison conducts between the volume of the container traffic and the total traffic, we first have to transform the TEU to Tonne, which multiplied by 11 tonnes. The main reason is the lack of statistical container traffic in Tonnage in the Chinese sample ports (as per discussions in Chapter 3).

After that, we are able to run the Level 4, and Figure 10 represents the visualisation outcomes. The X-axis is not as same as before, which displays an average market share of container traffics within the total port traffic category, for each of the ten samples. The Y-axis remains the same, and shows the average annual growth rate of containerised commodity during the port range. So again, the two intersecting bold lines describe the group's average annual growth rate (12.16%) and the average share rate of the container in total port traffic for each port (56.35%) respectively.

Due to an extra dimension is added, the surface size of each bubble is proportional to the total traffic volume of each considered sample port in the range. However, the percentages within the bubbles display ratios of the container vs. total traffic, rather than the size of the bubbles.

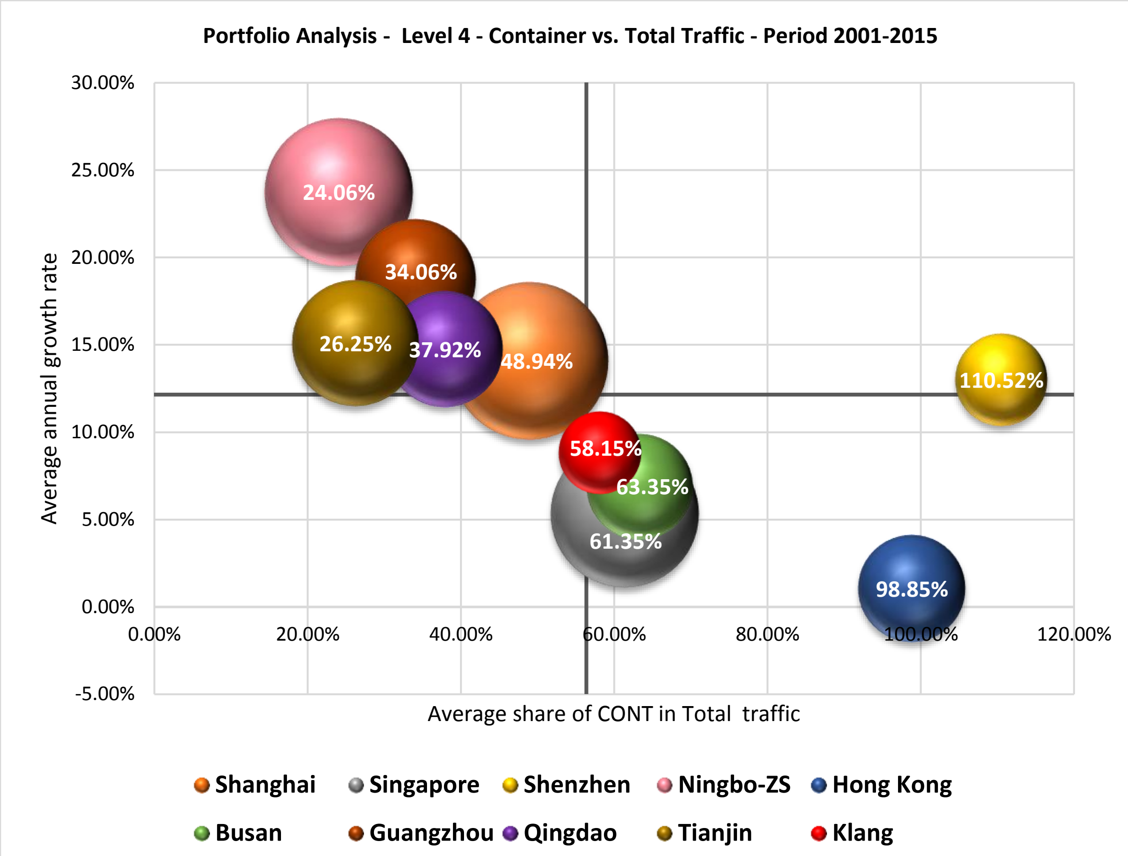


Figure 10: Structure of container vs. total traffic - period 2001-2015
Source: author's elaboration

First of all, we have to clarify that there is a very unusual phenomenon showing on our result, which a ratio of the container vs. total traffic overs 100% and reaches at 110.52% in the Port of Shenzhen. That is not a realistic story we believe, and there are two key reasons could lead to such the unusual situation, for example, 1) An inaccurate conversion from the TEU to Tonnage by the coefficient 11 Tonnes; 2) An error port statistics of the original data in the beginning. After the consideration, we will take the Port of Shenzhen out of the discussion of this level. Therefore, there is no "Star Performer" in this step.

It can be seen clearly that the sample seaports divide two quadrants of "Mature Leader" and "High Potential" in the past years. The "Mature Leader" includes the Port of Singapore, Hong Kong, Busan and Klang. Among others, Singapore has the biggest size of a bubble not only in that quadrant but also in the whole group. That means it shares the relatively greater total traffic during the range. Besides, Hong Kong gets the highest average container share as 98.85%, which indicates it is more suitable for container business maybe due to its geographical location and the land limitation, but such a single business will restrict their future developments. The Port of Busan and Klang display of 63.35% and 58.15% respectively in term of the average share of container traffic in total traffic aspect, but both of them have much lower growth rate in the entire group.

The Port of Shanghai, Ningbo&Zhoushan, Guangzhou, Qingdao and Tianjin are positioned as “High Potential”. That is a no surprise outcome, because of those Chinese seaports were growing quite rapidly in recent years. That is attributable to the booming economic development of China, in particular, the ports are from the Southeast area, id est, Ningbo&Zhoushan (23.76%), Guangzhou (18.76%) and Shanghai (14.09%). According to this analysis, the Port of Ningbo&Zhoushan can be considered as the most potential performer in term of the container traffic category.

5.2 Findings of green portfolio analysis

We will provide outcomes of the Green Portfolio Analysis (GPA) particularly for the container traffic category (TEUs) in this section. As per discussions in Chapter 3, the critical data of modal split will be requested to run the GPA model. However, such the data is only available from the Port of Busan rather than other Asian seaports. Due to that data limitation, the GPA now performs for a particular seaport group including the Port of Busan, Rotterdam and Antwerp as a fictitious port range. That assumes all the three ports in such range share a same market. All the necessary data and methods used to obtain findings are already explain in Chapter 3.

The GPA just adds an environmental dimension based on the Port Portfolio Analysis, and it as an extensional function of the PPA, which suggested by Haezendonck (2001, 2006). The GPA remains the concept and terminologies (four quadrants) of the PPA in term of economic aspects (id est, “Star Performers”, “Mature Leaders”, “Minor Performers” and “High Potentials”). The main aim of GPA model to proof such a “green” technique is also possible to be applied to the Asian container ports whereas on the premise of the data availability. The visualisation model of GPA conducts in both of a static and a dynamic ways as well.

5.2.1 Static GPA

Figure 11 shows the visualisation outputs of the GPA statically for the Port of Busan, Rotterdam and Antwerp between 2001 and 2015. The X-axis displays a theoretical average market share of container traffic during the group, whereas the Y-axis shows an average annual growth rate conceptually.

Besides, the bold horizontal line expresses the group average growth of container traffic among each other that is 5.81%, which can make the distinction between relatively growing speeds of the three ports. The bold vertical line represents the conceptual average market share of the three samples that equals to 33.34%, because of we are assuming those three seaports in one competitive port range and share a same market.

An environmental perspective is expressed by the green colour shade (on the surface of bubbles), to visualise the results of such “clean” or “dirty” port. Again, the lighter of the green colour means a port is more environment-friendly.

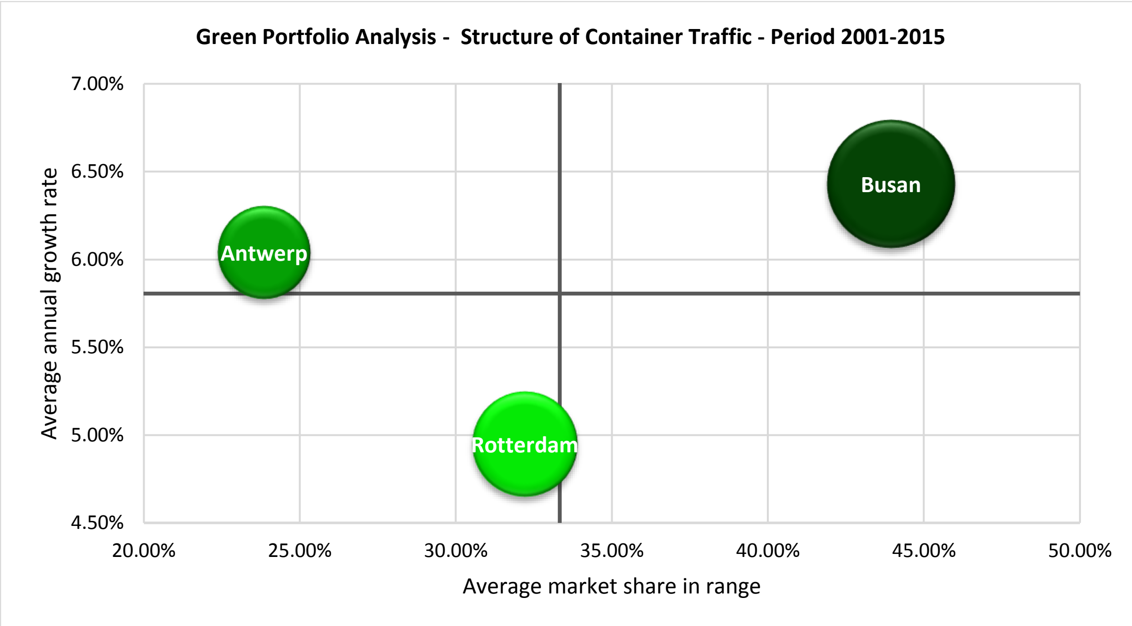


Figure 11: GPA structure of container traffic - period 2001-2015
Source: author’s elaboration

During this conceptual range, the Port of Busan is belong to “Star Performers” in economic aspects. However, it performs poorly in term of an environment-friendly sector. The average external costs rate generates at 45.53%, and the average environment-friendly ratio of its hinterland traffic is 0.12, which are the poorest figures during the fictitious range.

The Port of Rotterdam is situated as “Minor Performer” concerning the conceptual average market share (32.21%) and the growth rate (4.95%) in same periods, but it is the “greenest” performer in that range. Rotterdam noted 0.75, which is the highest average environment-friendly ratio of its hinterland traffic, and along with the average external costs rate at 30.73% in the range. Therefore, the Port of Rotterdam can be considered as the cleanest seaport.

The Port of Antwerp, however, has the lowest average market share (23.86%) in the group, but depends on a relatively high annual growth rate (6.04%), it becomes as “High Potential” in economic aspects. Also, Antwerp has the smallest external costs rate as 23.74%, which could because of the lower container throughputs handled than the rivals over the periods. However, an average environment-friendly ratio of its hinterland traffic is 0.66, which is close to the Port of Rotterdam and we hereby conclude that the performance of Antwerp is satisfactory in an environmental term as well.

According to the same clusters in seaports and a theoretical concept of port range, it will be interesting to conduct the GPA model from a dynamic perspective.

5.2.2 Dynamic GPA

A dynamic GPA of the container traffic category is exhibited graphically in below Figure 12. So again, the time span can be divided into three different periods, e.g. 2001-2005, 2006-2010, and 2011-2015. Furthermore, all the X- axis, Y-axis and the crossed bold lines have the identical meanings as the static figure.

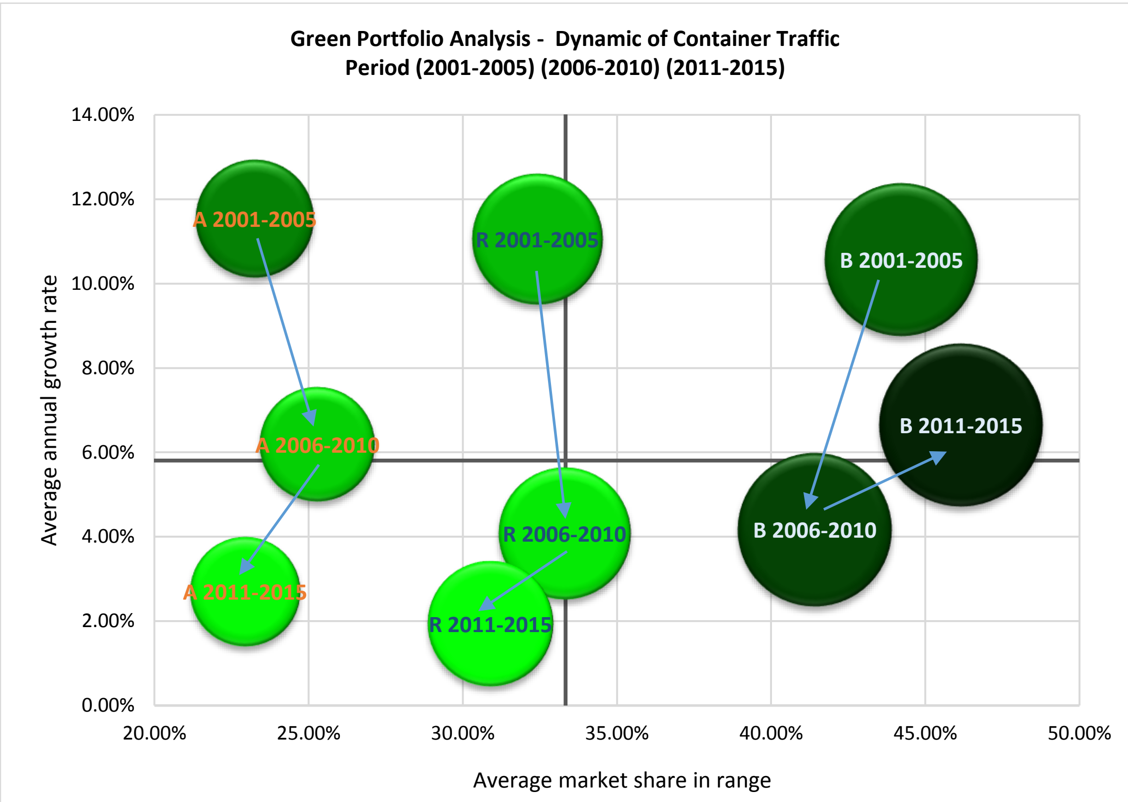


Figure 12: GPA dynamic of container traffic - period (2001-2005) (2006-2010) (2011-2015)
Source: author's elaboration

According to above outcome, we observe that there are the similar paths between the Port of Rotterdam **(R)** and Antwerp **(A)** in considered periods. Both of them move from the quadrant of "High Potential" in the first period to an unfavourable "Minor Performer" positioning in the last period in term of the theoretical economic performance. However, it can be seen clearly that Rotterdam and Antwerp are getting cleaner gradually over time. The average environment-friendly ratio of the hinterland traffic shift from 0.67 to 0.85 (Rotterdam), and 0.55 to 0.76 (Antwerp) respectively. They have the obvious contributions with regard to environmental friendliness over those periods.

Due to relatively higher container throughputs in the Port of Busan **(B)**, it produces much more the average external cost rate compared with the Port of Rotterdam and Antwerp accordingly. For instance, as the 49.00% (Busan), 28.86% (Rotterdam) and 22.14% (Antwerp) until the third period.

Additionally, the Port of Busan shifts from the “Star Performer” to “Mature Leader” between the first period (2001-2005) and the second term (2006-2010) in the theoretical performance of economy. We believe that feature can be considered by the impact of the global financial crisis in 2009. That does not only impact on Busan but also on Rotterdam and Antwerp, even the port traffics worldwide. After that, Busan returns to the quadrant of “Star Performer”, whereas Busan is the “dirtiest” port than the other two ports in such theoretical port range, and even getting worse based on self-development over time. The average environment-friendly ratio of its hinterland traffic shows a downward trend from 0.13 to 0.11 over the periods. We can see that a “green gap” is colossal compared to the European ports, and such the laggard environmental perspective does impact on sustainable developments of ports.

Overall, the compelling results are illustrated in above two GPA graphs, due to we put the Port of Busan, Rotterdam and Antwerp in the same economic framework theoretically, in the other words that we assume they are in the same (conceptual) port range and share one local market jointly. Whereas, in practice they are not in the competition, since they do not share the same market accordingly. The more detailed implications of this situation will be discussed in the subsequent section.

5.3 Implications and discussions

In this study, we apply the port portfolio analysis as an advance measure for the major Asian container ports to achieve our final goal, which is to adopt the green portfolio analysis to identify the ecological performance and the comprehensive competitiveness of particular seaports.

The port portfolio analysis (PPA) executed in this research confirms that there is an important revolution in the economic performance and the development of major Asian container seaports in the last fifteen years. It further describes the competitive positioning of each sample port in terms of the total traffic category of ports (Level 1), the container traffic (Level 3), and the contrastive structures between the container and total traffic (Level 4) based on the four qualitative quadrants.

The results of the PPA indicate that the Port of Ningbo&Zhoushan with a favourable position as the “Star Performer” in terms of the total port traffic structure (Level 1). However, if considering the container traffic (Level 3) only, it evolves into the “High Potential”. That is entirely consistent with the ranking of world top-rated ports according to the total traffic volume and the practical situation. Due to a strategic merger in 2006 (discussed in Chapter 4), Ningbo&Zhoushan has been in place with the traditional advantage and push into first place of the total traffic since 2012. Besides, Ningbo&Zhoushan boasts the highest annual growth rate of the container traffic among the Asian range (Level 3 and 4). Also, that is the relatively small ratio between the container and the total traffic in the Level 4, which implies that the Port here enjoys a huge potential and rare opportunity for development and is a great threat to the Port of Shanghai, Singapore and Shenzhen.

The Port of Shanghai ranks as the “Mature Leader” in a structure of total port traffics (Level 1) over the last fifteen years. Whereas, it has enormous advantages concerning the container business and keep competing with Singapore and Shenzhen for a long time. It performs as the “Star Performer” together with Shenzhen in the Level 3 and has the appropriate ratio (48.94%) in the Level 4. We believe that Shanghai still has significant potential to perform better in terms of port economic development. Moreover, it should be achieved on the premise of the energetically regional economy and policy.

Moreover, according to discussions in Section 5.1.3 (Level 4), there is an unusual phenomenon existing in the Port of Shenzhen in terms of the container share rate of the total traffic based on results of our analysis. Therefore, we skip a detailed interpretation about Shenzhen in this part. Meanwhile, we will refer to this situation later when we talk of limitations of the study.

The Port of Singapore, as the seasoned one in the port industry, enjoys stable development in the past. It acts as the “Mature Leader” in all levels of the given analyses. However, it is implied that Singapore choke on its own growth, including the limitation of land size, the restriction of its hinterlands and the strong competitors. Therefore, the Port Authority is facing some challenges. It should consider new development strategies in order to maintain a relatively stable status and the port sustainability.

The Port of Hong Kong seems to get into a similar situation or even worse as Singapore according to the graphs. In the past few years, the China's economic policy, combining with Hong Kong’s own resource constraints, is more favourable to promote development of the mainland’s ports. Hence, such position of the Hong Kong Port is gradually replaced. Moreover, the Level 4 shows that the container share rate is 98.85%, which implies a unicity of commodity and the saturated risks of container traffics locally. Therefore, the Port authority is better to seek the extensive cooperation with other ports to expand scopes of the hinterlands, and promote multimodal transports, such as the railway and inland navigation.

The other ports, namely Guangzhou, Qingdao and Tianjin, are regarded as the moderate forces in terms of the overall assessment. Because of their relatively high growth rate in the port range of Asia, as well as the related economic policies over the past decades, they perform as the “High Potential” in the process of evolution. Besides, an impact of the Five-Year Plan of China has been played an important role in ports’ evolution, which argued in Section 2.3.3. Moreover, the common advantage of those ports is widely believed as a comprehensive commodity structure. Despite of container traffics, they also receive liquid cargoes, bulk commodities, RO-RO freighters, and so forth. They have the strong potential competitiveness to achieve the “Star Performer”.

The Ports of Klang and Busan are situated at an unfavourable position as the “Minor Performers” in both of the Level 1 and 3. The outcomes are consistent with their relatively lower stations in the world rankings respectively. Although developing as the “Mature

Leader” in the Level 4, they are still facing lower growth rates in the entire range over time. The direct reasons can be considered as 1) the limitation of local resource; 2) the financial crisis in Asia 2009; 3) the current China’s economic policy. In order to solve such dilemma, those port authorities can improve the productivity through many methods, such as the infrastructure reforming.

Furthermore, among all levels of all Asian sample ports in the dynamic PPA (Figure 9), all the considered seaports show a significant decline in the overall trend in terms of container traffics, which verifies the impacts of the local economic policy and the relevant crisis worldwide on developmental trends of the ports. Moreover, port authorities, stakeholders and decision makers must be able to observe such trend and competitive situation of the ports among the existing rivals, and make predictions of the short-term development plan based on the port portfolio analysis.

However, only focusing on the port economic development is insufficient to remain a sustainable growth today. As what has discussed above, all the seaports around the world are facing to the competition concerning environmental perspectives. Therefore, we must take a green dimension into consideration while evaluating the current port competition.

The green portfolio analysis (GPA) conducted in this paper is an advanced step based on the PPA model to meet the requirements of measuring ecological or social dimensions, including the green port performance or environmental-friendly aspects. Besides, the GPA was introduced by Haezendonck (2001) and empirically tested on both of the seaports and inland ports in the Hamburg-Le Havre range. As what Haezendonck *et al*. (2006) said, the essential difference between the PPA and the GPA is that a shift occurred in the process of transforming from maximising the total volume of cargo in the port to minimising the external costs generated by the same port (Haezendonck, et al., 2006). In general, GPA can reach a balance between economic benefits and environmental impacts according to ports and their hinterland traffics.

We are quite interested in replicating such the tools on the Asian container ports. Whereas, on the basis of our observation, there is devoid of the modal split variables to help us conduct the GPA model during the selected Asian ports. Fortunately, we found that the modal split data exist in the Port of Busan only, which allowed us to test Busan as a tentative seaport in the area of Asia. We can prove that the GPA can be applied on the Asian port as well on the premise of the data availability.

On the basis of hints in the previous sections, we at this moment restrict a theoretical port range among the Port of Busan, Rotterdam and Antwerp. It can be seen from the Figure 11 (and the Figure12), the X and Y axes refer to the growth and market shares in the same scenario of the market respectively. However, in the practical situation, those three ports apparently do not belong to a same market. It is well known that the rates of economic development are inconsistent in different areas. Moreover, the development of Western Port industry is relatively slower in recent years while the Asian ports are growing rapidly. For instance, a growth rate of 5% today can be regarded as a tremendous advance in Europe but a low figure obviously in Asia (already proved in the PPA Level 3). In Addition, they are not competing with each other or shared equally in same market.

Therefore, it is not really comparable between those three seaports. The only reason why we analyse them together here is to show how “dark” of the Port of Busan is with comparing with the other Western European seaports in terms of environment-friendly aspects. Therefore, we put them in the same graphs, and assume that they belong to the same competitive port range conceptually. Moreover, we have to be quite careful with interpretations of the results. Meanwhile, that will become one of the limitations of this study, which we will summarise in the final chapter of this paper.

On the basis of main implications of green portfolio analysis in this paper, they are confirmed that the Western European seaports (the Port of Rotterdam and Antwerp) have made great progress in the environmental performance in the past years. It shows notably in the visualisation of the dynamic GPA, which demonstrates that they have become the lighter green over the periods. On the contrary, the Busan Port becomes even darker during the same period. One of the main reasons causing the difference is that the European ports introduced green strategies in a very earlier stage, whereas most ports in Asia just follow their paths gradually in recent years. Also, based on the dynamic GPA graph, Busan performs dynamically even worse than itself ten years ago, whereas other two European seaports with the green strategy are evolving. That is due to the lack of a systematic strategic planning and an effective green management tool with respect to port’s indirect impacts. However, according to our observation, a solution to resolve direct port impacts (such as the additional infrastructure) is still the theme for its future green development. Hence, the relevant green strategy to address the indirect port effect is inadequate. Also, it is worth mentioning that such the situations do not only exist in the Port of Busan but also as common phenomena stay in the Asian port range. Therefore, the days without the proper green strategies noting have gone for ever.

Secondly, we have compared volumes of the container traffic among those three seaports in a fictitious port range yet, and we identify that the Port of Busan is much larger than two others in terms of the container traffic category. That is because of the global economy shifted the centre of gravity to Asia. Also, the Asian economy replaced the European and American positions and became an important engine of the global economic growth. Therefore, such the Busan Port gained direct benefits from that and had the relatively strong growth in that fictitious range. However, the Port of Busan as a tentative port is just a “medium-size” seaport among the container port in Asia (ranking at the sixth). Hence, we are actually talking about the largest port group in the world whereas they (Asian container ports) are not doing well with respect to the environmental-friendly aspect.

Thus, the Asian port authorities or stakeholders should think over carefully the question, which is “how can we do something impressively in terms of the local ecological impact”. Such the industrial or metropolitan complex of seaports in Asia act as a great driving force for the global economy regardless of the proper green strategies, which will lead to the inevitable result of environmental damages, not only for local area but also for the whole world at large. It is well done that the Western European ports such as the Port of Rotterdam and Antwerp are doing a lot for the local environment. However, we also need the other ports, in particular, the Asian container ports to make such a contribution as well.

Thirdly, according to the existing literature, we found that there is a quite obvious development in Asia in the research and application of port environmental strategies. Whereas, most of the stakeholders nowadays pay only more attention to the direct issues in ports, such as the pollution direct for the waterside, yard or landside of the port areas. It is worth reminding the Asian port authorities, stakeholders and policy makers of understanding that despite the direct impacts on port areas, the indirect factors, such as the traffics between the port and its hinterland, are even bigger and worse issues for the harbour and its surrounding area.

Moreover, a hinterland connectivity is one of the major determinants of port competitiveness (as per discussion in Chapter 2). Therefore, the transport modes that used to connect ports with their hinterlands play the significant roles not only in regional economies but also in the local environment, such as the load capacity, time issue, internal and external costs and so on. According to the research by INFRAS, CE Delft and Fraunhofer ISI (2008), in Europe, the most popular way of transportation is still by roads. Whereas, that is quite harmful to environment and will produce huge extra costs to the public. Due to a pressure from the public, many ports are choosing to replace the mode of transportation from roads to waterways, which are much more environmental-friendly. Because of the main European continent is mainly connected by the Rhine, Seine, Scheldt or Main, et cetera. Therefore, the most environmental-friendly way is by rail transports. However, there are some inconsonant rules and domestic laws on railway systems in the different European countries. Hence, the rail freight is relatively rare in Europe. However, In Asia, the geographical situation is much more complex and vast comparing with Europe. Thus the local railway networks are quite extensive, as well as the inland waterways. The local port authorities or stakeholders should take into account environment issues deeply, such as an indirect factor (hinterland traffic), and utilise the local strengths of developed transport systems of railways and waterways to reduce such external costs. That is an essential method to improve the environment pollution for both of ports themselves and their surrounding communities.

Nevertheless, based on our observation, most of the Asian seaports are still bound up in the infrastructure upgrade, such as applications of the shore power system, electric cranes or even AGVs. Despite of this, we believe that a port is also responsible for the hinterland traffic now. Otherwise, the port is still facing difficulty in resolving the “dirty” situation and lag behind the European ports in terms of the green competition nowadays. Maybe, those Asian port authorities, decision makers or stakeholders are better to start with the data collection, in order to analyse the green portfolio analysis and link that to a strategy application systematically. Such as an example in Europe, many ports are busying with the Portopia project, which is a methodical way of collecting data, including the environmental data as well. Therefore, the Asian port projects should employ such a system as well to cover the shortages in the techniques of data collection. Alternatively, in a way of combining the indirect port impacts with existing environmental strategies. For instance, with integration of the EMS strategy. Taking into account the segment of hinterland transports when making the future commitments and policies. Developing an appropriate scheme and implementation plan, then through the approaches of measurement and evaluation to achieve the further green improvements ultimately.

Finally, it is worth mentioning that the external costs in the GPA model refer to the costs of environmental impacts, which generated by the different transport modes from/to a port and its hinterland. Normally, this analysis should calculate an average distance of the each transport mode respectively. For instance, in Europe, the average distance of the inland navigations and the railway transports are much longer, whereas the road transports are quite shorter. However, in this study, it is not possible to calculate such average distance of the different transport modes among those three seaports during the fictitious market range (Busan, Rotterdam and Antwerp). We hereby use 1 kilometre instead of all the average distances in this study. Moreover, that will become one of the limitations of this research as well.

Additionally, the size of a bubble is based on a value of port's external costs, which can be impacted by various factors, such as the size of traffic throughputs, or the possibility of the local neutralisation. In this study, the external costs do not influence the green portfolio analysis. We regard this relevant parameter as the size of the bubble to create visible bubbles in the colour of green. Besides that, the value of the external costs in our GPA model does not demonstrate any other information. Moreover, the fictitious range in the course of the green portfolio analysis just recognised how large the "green" problem and the time lag are between the Asian and European seaports in terms of the green dimension and the container throughputs. However, that is certainly not an actual competitive range. The results thus have to be interpreted carefully.

6 Conclusions

This paper is guided by the main research question of how can a green strategic positioning analysis be relevant and be applied to major Asian container ports. With development of port industry, port economy not only merely focuses on financial gains but also on environmental (green) performance nowadays. In fact, all international ports have to take the environmental influence into account when facing competition. Many of seaports in Europe and America took the lead in perceiving and conducting green strategies to achieve the sustainable development. While Asia relatively lag behind, most Asian seaports still remain at the phase of infrastructure mainly, and seek theoretical frameworks with regard to environmental strategies. Up till now, a prominent strategic change in Asian ports is still absent. In this paper, the author tried to find proper tools that can help Asian ports develop future environmental strategies.

The main contribution of this study is explaining reasons why such a green analysis is critical and essential for the Asian seaports today through the scientific approaches. Additionally, this research is also the first to execute (static & dynamic) methods of the port portfolio analysis (PPA) and the green portfolio analysis (GPA) for major Asian container seaports. Therefore, both of tools were applied in a 15-year-long (2001-2015) traffic dataset. In particular, the GPA technique has been implemented in a conceptual port range, including one Asian (Busan), and two Western European (Rotterdam, Antwerp) seaports, to draw the theoretical positioning of the environmental competition.

We first identified the importance of the environmental (green) dimension in the general competitiveness of ports by existing literature. Then, we selected ten major Asian seaports as samples in this study. After that, we tried to analyse strategically by applying the port portfolio analysis (PPA) technique with the green dimension (namely, GPA). Last but not least, we concluded implications for their (samples) future policy and strategies based on the research results. In order to perform such the entire empirical analysis clearly, the main research question was subdivided into three sub-research questions. Moreover, some findings are based on conceptual discussions. We thus have to be quite careful with an interpretation of the results.

- **Empirical findings**

This section is about empirical findings of the sub-research questions. We primarily focused on the container traffic of each sample seaport, which is a reason why we collect ten container seaports as samples. Moreover, when the GPA measured a green port performance, it is based on port's incoming and outgoing transports between its hinterlands, namely the modal split. So we analysed GPA during a theoretical port range due to the data limitation.

Sub-Q1: What is the importance of a green strategy for ports in general and Asian container ports in particular?

This question was answered based on comprehensive literature in a way of qualitative matter. There are lots of literature on port that is needed to explain green strategies in order to reinforce competitiveness and achieve sustainable developments. We found that in the past, port competition merely focused on cargo volumes. Later on, when a lot of governments' funding was involved in port industry, the industry focused more on social welfare as requested by governments, such as more job opportunities in ports. So the concept of value added is increased and gained more attention. Today, numerous stakeholders pay more attention on what ports do on a daily basis, including their dramatically positive impact on environment. Environmental impacts could be positive in a way such as a dredging project. However, there are also some negative impacts like creating emissions. Numerous stakeholders nowadays develop ports not only consider in the volumes, social welfare but also in its effect on our environment.

As a result, the Asian ports started to focus on environment issues. They applied some tools such as EMS, ISO14001 to resolve its negative influences in the port area itself (i.e. energy consumption, water or noise pollution and so on.). Whereas, most of the European seaports have already put into effect and implemented the relatively mature green strategies in terms of indirect impacts like emissions amongst the traffics of ports and hinterlands. Consequently, such indirect problems grow bigger and worse for not only the port itself but also its surrounding community. Therefore, the Asian ports, as leaders of global port industry, should shoulder more responsibilities and also contribute more to the current genuine green strategies.

Sub-Q2: Can we apply a green portfolio analysis to Asian container ports?

To answer this question, we first selected ten busiest Asian container ports as the sample ports range. Then, we investigated whether we can apply a port portfolio analysis without the green dimension via a quantitative way. We found that the PPA was workable for the whole range. We also successfully recognised the strategic positioning of each port in term of economic performance over time. To name but a few, Singapore Port held the highest average market shares (18.28%) in range and is positioned as the "Mature Leader" in a static container traffic category over time. Whereas, the Port of Ningbo&Zhoushan gained the biggest average annual growth rate in both of the port total traffic structure (15.75%) as the "Star Performer" and the container traffic (23.76%) as the "High Potential" respectively.

However, a green portfolio analysis cannot be applied in the whole Asia due to lack of the necessary data (modal split) in most samples. However, we have had the data of the Busan Port already. Therefore, we applied the GPA in a conceptual market range to Busan and compared it with the Port of Rotterdam and Antwerp, because they have more available data. The only reason why we analysed them together in such theoretical range is to show how "dark" of the Port of Busan is comparing with the other two experienced seaports in term of environment-friendly aspects. The experiment proved that the Rotterdam and Antwerp have showed the relatively weak economic performance. But they have made great progress and were getting much greener in past years. On the contrary, the Busan Port has got a fast growth and high market share but become even darker and worse than it was ten years ago.

We believe that there are three reasons could lead to such the position of the Busan Port. 1) Global economy shifted the centre of gravity to Asia, and the Asian economy replaced the position of the Occident, and became an important engine of global economic growth. Therefore, the Busan Port gained direct benefits from that and had relatively strong growth in the fictitious range. 2) An environmental damage is inevitable in a process of economic development, the large-scale economic activities thus harm to local environment correspondingly. 3) The lack of a systematic strategic planning and an effective green management tool with regard to the port's external (indirect) impact. To resolve the direct port impact (as mentioned earlier) is still a theme for future green developments. Such relevant strategies to address the indirect port effect is very inadequate. Overviews, the above situations do not only exist in the Port of Busan but also as the widespread phenomenon stay in the Asian port range. The theoretical results of our experiment, therefore, have confirmed further that the Asian seaports lag badly behind in term of port environment-friendliness.

Sub-Q3: What are the potential implications of a green portfolio analysis for Asian container ports for their future policy and strategy?

On one hand, concerning a theoretical implication, we are the first one applying the GPA technique in a conceptual port range comparing with the contemporaneous large Asian and European seaports. Notwithstanding the GPA cannot be applied to the entire Asian port range, an elaborate theory has been provided for the green evolution of an Asian tentative seaport and the direction of green developments for the Asian container ports. Moreover, we are consistent with the previous studies by Haezendonck *et al*. (2001, 2006) and Dooms *et al*. (2013) but contradict some other theories. Hence, we should take into account port's green strategies in the port surrounding area and the local community instead of the port itself only.

On the other hand, in terms of an implication of the related policy (or managerial), we identified that data is still a big problem faced by the Asian container ports currently. We would like to add a recommendation to the importance of data collections while planning the future of the Asian seaports. Just as an aphorism saying, *"Measurement is the first step that leads to control and eventually to improvement - H. James Harrington".* Therefore, if there is no necessary data, we can impossibly make proper strategies. The Asian port authorities or stakeholders are better to start with data collections so that to be able to analyse a green portfolio analysis and link it systematically to the strategy application. Taking the ports in Europe for instance, many seaports are busying with the Portopia project, which is a methodical way of collecting data, including environmental data. Hence, maybe the Asian port project should adopt such system while collecting the related data. Alternatively, by combining with existing environmental strategies. For example, a dimension of the indirect port impact could blend into a current EMS strategy. Taking into account the aspect of hinterland traffic when making a commitment and a policy. By developing the appropriate scheme and implementation plan, then through the approaches of measurement and evaluation to achieve further improvements eventually.

- **Research limitations**

According to the empirical analysis provided in this research, a number of limitations were encountered in this study as follows:

- A tonne is not a tonne: in accordance with the hints in Chapter 3, there are various meanings of tonnage in different countries. They always use Metric Tonne, Freight Tonne or Revenue Tonne respectively. The quantitative outcomes of the PPA and GPA will be more valuable, when this study is likely to adopt the uniform unit of the weight. However, such weighting rule would need much more efforts and times, which is a main reason preventing us from conducting it in this study.

- In terms of throughputs (TEUs or Tonnes): we found an interesting phenomenon during the process of data mining: throughput data is not consistent with each other (but not big deviation). Each port authority or institution uses the different digit system in the report or statistics, such as 1,234,567 TEUs vs. 1,234,000 TEUs. We used the latter way for calculations in this study.

- Conversion from TEUs to Tonnes: the level 4 of the PPA model requests a contrast between the container traffic and the total port traffic. Nevertheless, most samples use the TEUs rather than the Tonnage when they measure container throughputs in Asia. Through literature review and deliberate considerations, we decided to multiply by a coefficient – 11 tonnes when converting from TEUs to Tonnes. This method will not only have a significant influence on the accuracy of the data calculation, but also reveal the weakness in the data observation in Asia.

- An unusual figure of Port of Shenzhen: the outcome of the PPA level 4 showed that a ratio between the container and the total traffic reached 110.52% in the Port of Shenzhen. That is apparently not a regular figure. In general, the container traffic is part of the total traffic, and the percentage of container category should not exceed 100%. We clarified few probable reasons in Section 5.1.3; meanwhile, there was no discussion about Shenzhen in that section. So the entire analysis will not be affected.

- Modal split data: it is an essential data to run the GPA model. Despite of the Port of Busan, all the rest Asian samples are lack of such observation. Moreover, such situations have been confirmed by the local port authorities, statistical bureaus and even academies through emails respectively. Therefore, that is the only reason why the GPA cannot be applied in the range of Asia. Additionally, only the Busan Port has available modal split data until 2014. The data of 2015 is not available yet. Hence, we used the average value in the course of 2013 and 2014 as an assumed figure for that of 2015.

- A theoretical port range: it has been highlighted several times. Due to limitations of modal split data, we have to conduct the GPA in a fictitious range in order to evaluate green port performance. Whereas, the relevant economic dimension cannot be interpreted directly according to such ranges. More discussions can be found in Section 5.3 about this fictitious port range.

- External costs: we should be well aware of it while calculating the external costs of hinterland port traffic. Because of we used the data from INFRAS for Busan Port as well. However, INFRAS's data is used to the European ports only. And there is no similar external costs data exist in Asian range. Therefore, it should be carefully checked rather than just applied directly. Due to laggard data used in Asia and a limitation of time, we are not able to conduct the relevant test. Moreover, the average distances of different transport modes are required to calculate the size of external costs. Whereas, it is impossible to compute an average distance during the fictitious port range. We thus used 1 kilometre instead of all average distances in this study. The more interpretations are demonstrated in Section 5.3 as well.

- **Recommendation for future research**

Based on the methodology and data limitation in these issues, this study lays some solid foundations of further researches. In particular, it can be improved as follows:

- The time span could be extended to 20 or 25 years of the PPA and GPA. The longer time horizon will lead to more accurate analysis.
- Besides the container traffic, other commodities and traffic categories are also worth drawing our attentions.
- We will possibly have more sufficient modal split data in Asia in the future. Therefore, a practical port competing range is much more significant than the theoretical one.
- Such INFRAS' data concerning the external costs of the transport modes should be approved scientifically to link to the Asian port range.
- A strategic value of the current study could be increased when the analysis integrates an intensive SWOT or benchmarking technique.
- Such techniques are applied to the Asian inland ports as well, for example, the industrial vs. metropolitan inland ports. That will also be a meaningful learning and interpretation.

In conclusion, the port portfolio analysis added an environmental dimension (namely, GPA) can be considered as a strategic positioning tool to assess the port vis-à-vis its competitors concerning the relative environment-friendly growth and economic performance in certain periods. Due to data limitations and methodological issues put forward in this study, the Asian port authorities, stakeholders or policy makers should, however, be quite careful with an interpretation of the analytical conclusions. Nonetheless, the reliable and valid contributions have been provided and served as a facilitator to guide the Asian container seaports to make environmental strategy in future.

Bibliography

AAPA, 2007. *Embracing the concept of sustainability as a standard business practice for ports and the association,* s.l.: American Association of Port Authorities.

Acostaa, M., Coronado, D. & Cerbana, M. M., 2007. Port competitiveness in container traffic from an internal point of view: the experience of the Port of Algeciras Bay. *Maritime Policy & Management: The flagship journal of international shipping and port research,* 34(5), pp. 501-520.

Alphaliner, 2013. *Ship Glossary,* London: Alphaliner.

Alphaliner, 2015. Top 30 Container Ports : 2014 Throughput and Annual Growth %. *Alphaliner Weekly Newsletter,* 2015(19).

ASEAN, 2015. *Kuala Lumpur Transport Strategic Plan (ASEAN Transports Strategic Plan) 2016-2025,* Jakarta: ASEAN Secretariat.

ATENCO, 1999. *Analysis of the cost structures of the main ten ports - Final Report,* Antwerp: Technum Flanders Engineering NV.

Bailey, D. & Solomon, G., 2004. Pollution prevention at ports: clearing the air. *Environmental Impact Assessment Review,* 24(7-8), pp. 749-774.

Barros, C. P., 2006. A Benchmark Analysis of Italian Seaports Using Data Envelopment Analysis. *Maritime Economics & Logistics,* 8(4), pp. 346-365.

Beleya, P., Raman, G., Chelliah, M. K. & Nodeson, S., 2015. Sustainability and green practices at Malaysian seaports: Contributors to the core. *Journal Of Business Management And Economics,* 3(3.45), pp. 23-27.

Berechman, J. & Tseng, . P. H., 2012. Estimating the environmental costs of port related emissions: The case of Kaohsiung. *Transportation Research Part D: Transport and Environment,* 17(1), pp. 35-38.

Bichou, K. & Gray, R., 2005. A critical review of conventional terminology for classifying seaports. *Transportation Research Part A 39(1)*, pp. 75- 92.

Bird, J. & Blad, G., 1988. Freight forwarders speak: the Perception of Route Competition via Seaports in the European Communities Research Project.Part 1. *Maritime Policy & Management ,* 15(1), pp. 35-55.

Branch, A., 1986. *Elements of Port Operation and Management.* London: Chapman and Hall Ltd.

Burke, L. & Logsdon, J. M., 1996. How corporate social responsibility pays off. *Long Range Planning,* 29(4), pp. 495-502.

Button, K., 1993b. *Transport, the environment and economic policy.* Cheltenham,UK: Edward Elgar.

Caris, A., Macharis, C., Pekin, E. & Jourquin, B., 2010. The intermodal transport market in Belgium. In: *A Decision Support System for Intermodal Transport Policy.* Belgium: VUB University Press, pp. 18-21.

Cass, S., 2015. World Top Container Ports 2015. *CM Container Management*, 24 8, pp. 12-35.

Chang, Y. T., Lee, S. Y. & Tongzon, J. L., 2008. Port selection factors by shipping lines: Different perspectives between trunk liners and feeder service providers. *Marine Policy,* 32(6), p. 877–885.

Chen, J., 2013. Shipping gambling of Big Ship Era. *China Water Transport Newspaper,* p. 06.

Chen, Z., 2015. Research on the Interaction between Innovation and Port-City Economic System: A Case from China. *Discrete Dynamics in Nature and Society,* 2015(692476), pp. 1-9.

Cheon, S. H. & Deakin, E., 2010. Supply Chain Coordination for Port Sustainability - Lessons for New Institutional Designs. *Transportation Research Record: Journal of the Transportation Research Board ,* 2166(2), pp. 10-19.

Chinaports, 2007. *上海港.* [Online]
Available at: http://www.port.org.cn/info/200708/100234.htm
[Accessed 31 7 2016].

Chiu, R. H., 1996. *Logistics performance of liner shipping in Taiwan,* Cardiff: University of Wales.

Cho, D. O., 2010. *ENVIRONMENTAL IMPACTS OF INTERNATIONAL SHIPPING: A CASE STUDY OF THE PORT OF BUSAN,* Paris: OECD.

Constantinescu, C., Mattoo, A. & Ruta, M., 2016. Trade Turbulence. *Finance & Development,* 53(1), pp. 47-49.

Creswell, W. J., 2014. *Research design: Qualitative, quantitative, and mixed methods approaches.* 4th ed. Los Angeles: Sage publications.

Cullinane, K. & Wang, Y., 2009. A Capacity-Based Measure of Container Port Accessibility. *International Journal of Logistics: Research and Application,* 12(2), pp. 103-117.

Day, G. S., 1977. Diagnosing the Product Portfolio. *Journal of Marketing,* 41(2), pp. 29-38.

De Langen, P., 2007. Port Competition and Selection in Contestable Hinterlands: the case of Austria. *European Journal of Transport and Infrastructure Research,* 7(1), pp. 1-14.

De Langen, P., 2016. *Ecosystem Case - Appendix 1 - The Port Of Rotterdam In A Nutshell,* Delft: CE Delft.

De Lombaerde, P. & Verbeke, A., 1989. Assessing international seaport competition: A tool for. *International Journal of Transport Economics,* p. 16(2) 175–192.

Dooms, M., 2016. *Port Performance Management,* Rotterdam: Vrije Universiteit Brussel.

Dooms, M., 2016. *Strategic Port Planning,* Rotterdam: Vrije Universiteit Brussel.

Dooms, M. & Haezendonck, E., 2004. *An extension of 'green port portfolio analysis' to inland ports: an analysis of a range of eight inland ports in Western Europe..* s.l., Proceedings of the annual Conference of the International Association of Maritime Economists (IAME).

Dooms, M., Haezendonck, E. & Valaert, T., 2013. Dynamic green portfolio analysis for inland ports: An empirical analysis on Western Europe. *Research in Transportation Business & Management,* Volume 8, pp. 171-185.

Eklund, E., 1999. 'Intelligently Directed Welfare Work'?: Labour Management Strategies in Local Context: Port Pirie, 1915-29. *Labour History,* Volume 76, pp. 125-148.

Elkington, J., 1999. *Cannibals with forks – The triple bottom line of 21st century business.* Oxford: Capstone Publishing Ltd .

Endresen, Ø. et al., 2003. Emission from international sea transportation and environmental impact. *Journal of Geophysical Research: Atmospheres,* 108(D17).

ENV, 2012. *Environmental impact assessment in Japan,* Tokyo: Ministry of the Environment.

ESPO, 2012. *Port Performance I Port Performance Indicators - Selection and Measurement indicators,* s.l.: European Sea Ports Organization.

ESPO, 2015. *PORT OF THE MONTH - Port of Rotterdam (The Netherlands).* [Online] Available at: http://www.espo.be/news/port-of-the-month-port-of-rotterdam-the-netherland
[Accessed 22 7 2016].

Essen, H. v. et al., 2011. *External Costs of Transport in Europe (Update Study for 2008),* Delft: CE Delft, Infras, Fraunhofer ISI.

EU Taxation and Customs Union, 2002. *Good Practice Guide - Chapter 3 Container Specifications,* s.l.: European Commission.

Ferraria, C., Parolab, F. & Gattornaa, E., 2011. Measuring the quality of port hinterland accessibility: The Ligurian case. *Transport Policy,* 18(2), pp. 382-391.

FISKAL, 2015. *Green Planning and Budgeting Strategy for Indonesia's Sustainable Development, 2015-2020.* Jakarta: Centre for Climate Change Financing and Multilateral Policy - Fiscal Policy Agency, Ministry of Finance, Republic of Indonesia.

Frankel, E. G., 1992. Hierarchical logic in shipping policy and decision-making. *Maritime Policy & Management ,* 19(3), pp. 211-221.

GGGI, 2016. *Cambodia Green Growth Planning.* [Online]
Available at: https://mitigationpartnership.net/cambodia-green-growth-planning
[Accessed 15 08 2016].

Green Award Foundation, 2014. *Kitakyushu is the first Japanese port to join the Green Award scheme.* [Online]
Available at: http://www.greenaward.org/greenaward/606-2014-02-b.html
[Accessed 15 08 2016].

GreenPort, 2008. *Korea focuses on ports and the environment.* [Online]
Available at: http://www.greenport.com/news101/asia/korea-focuses-on-ports-and-the-environment
[Accessed 7 23 2016].

GreenPort, 2014. *Environmental stewardship at Busan.* [Online]
Available at: http://www.greenport.com/news101/asia/environmental-stewardship-at-busan
[Accessed 2 8 2016].

GreenPort, 2014. *Singapore Green Initiative.* [Online]
Available at: http://www.greenport.com/news101/asia/singapore-green-initiative
[Accessed 24 7 2016].

GreenPort, 2015. *Incentivising cleaner shipping.* [Online]
Available at: http://www.greenport.com/news101/opinion/incentivising-cleaner-shipping
[Accessed 20 5 2016].

GreenPort, 2015. *Indonesia launches green container terminal.* [Online]
Available at: http://www.greenport.com/news101/asia/indonesia-launches-green-container-terminal
[Accessed 10 08 2016].

Gupta, A. K., Gupta, S. K. & Patil, R. S., 2005. Environmental management plan for port and harbour projects. *Clean Technologies and Environmental Policy,* 7(2), pp. 133-141.

Haezendonck, E., 2001. *Essays on Strategy Analysis for Seaports.* Leuven/Apeldoorn: Garant.

Haezendonck, E., Dooms, M. & Coeck, C., 2006. Environmental strategy for ports: green portfolio analysis as a strategic tool for seaports and inland ports. In: T. Notteboom, ed. *Ports are more than piers: Liber Amicorum Presented to Prof. Dr. Willy Winkelmans.* Antwerpen: De Lloyd, pp. 147-172.

Haezendonck, E. & Notteboom, T., 2002. The competitive advantage of seaports. In: M. Huybrechts, et al. eds. *Port Competitiveness: An Economic and Legal Analysis of the Factors Determining the Competitiveness of Seaports.* Antwerp: De Boeck Ltd., pp. 67-87.

Haezendonck, E., Verbeke, A. & Coeck, C., 2006. Strategic positioning analysis for seaports. *Research in Transportation Economics,* Volume 16, pp. 141-169.

Han, C. H., 2002. Strategic Positioning Analysis on the Asian Container Ports. *Maritime Logistics Research,* Volume 34, pp. 99-115.

Harries, S., Abt, C., Heimann, J. & Hochkirch, K., 2006. *Advanced hydrodynamic design of container carriers for improved transport efficiency,* London: Design & Operation of Container Ships.

Heaver, T., 2006. The Evolution and Challenges of Port Economics. *Research in Transportation Economics,* Volume 16, pp. 11-41.

Helbling, T., 2010. What Are Externalities?. *FINANCE & DEVELOPMENT,* 47(4).

Hofstra University, 2016. *THE GEOGRAPHY OF TRANSPORT SYSTEMS.* [Online] Available at: https://people.hofstra.edu/geotrans/eng/ch3en/conc3en/largestcontainerships.html
[Accessed 19 07 2016].

Ilinitch, A. Y. & Schaltegger, S. C., 1995. Developing a green business portfolio. *Long Range Planning,* 28(2), pp. 29-38.

Ircha, M. C., 2001. Port strategic planning: Canadian port reform. *Maritime Policy & Management: The flagship journal of international shipping and port research,* 28(2), pp. 125-140.

ISL, 2003. World Port Traffic. In: M. Zachcial & C. Heideloff, eds. *Shipping Statistics Yearbook 2003.* Bremen: Institute of Shipping Economics and Logistics (ISL), p. 358.

ISL, 2006. World Port Traffic. In: C. Heideloff & M. Zachcial, eds. *Shipping Statistics Yearbook 2006.* Bremen: Institute of Shipping Economics and Logistics (ISL), p. 327.

ISL, 2008. World Port Traffic. In: P. D. M. Zachcial, ed. *Shipping Statistics Yearbook 2008.* Bremen: Institute of Shipping Economics and Logistics (ISL), pp. 320-323.

ISL, 2010. World Port Traffic. In: M. Zachcial, ed. *Shipping Statistics Yearbook 2010.* Bremen: Institute of Shipping Economics and Logistics (ISL), p. 319.

ISL, 2014. World Port Traffic. In: P. D. B. Lemper, ed. *Shipping Statistics Yearbook 2014.* Bremen: Institute of Shipping Economics and Logistics (ISL), pp. 320-323.

Janić, M., 2014. *Advanced Transport Systems: Analysis, Modeling, and Evaluation of Performances.* London: Springer.

Kaneko, K., 2016. *Japan Announces Long-term Strategy for Green Technology Innovations.* [Online]
Available at:
http://techon.nikkeibp.co.jp/atclen/news_en/15mk/041200505/?ST=msbe
[Accessed 17 08 2016].

Khalid, N. & Tang, J., 2010. *Greening the Malaysian Maritime Sector: Issues, Challenges and Opportunities,* Kuala Lumpur: Maritime Institute of Malaysia.

Kharas, H., 2010. *The Emerging Middle Class in Developing Countries,* Paris: OECD Development Centre.

Knatz, G. & Mollema, P., 2015. *China's green port push has parallels abroad.* [Online]
Available at: http://www.joc.com/port-news/chinas-green-port-push-has-parallels-abroad_20151015.html
[Accessed 23 7 2016].

Korzhenevych, A. et al., 2014. *Update of the Handbook on External Costs of Transport,* London: Ricardo-AEA.

Lam, J. S. L. & Notteboom, T., 2014. The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe. *Transport Reviews,* 34(2), pp. 169-189.

Lam, J. S. L. & Van De Voorde, E., 2012. *Green Port Strategy for Sustainable Growth and Development,* Singapore: Nanyang Technological University.

Langen, P. W. d., 2007. Port competition and selection in contestable hinterlands; the case of Austria. *European Journal of Transport and Infrastructure Research,* 7(1), pp. 1-14.

Le, X. Q., Vub, V. H., Hensc, L. & Heura, B. V., 2014. Stakeholder perceptions and involvement in the implementation of EMS in ports in Vietnam and Cambodia. *Journal of Cleaner Production,* 64(1), pp. 173-193.

Liao, C. H., Tseng, P. H., Cullinane, K. & ShanLu, C., 2010. The impact of an emerging port on the carbon dioxide emissions of inland container transport: An empirical study of Taipei port. *Energy Policy,* Volume 38, p. 5251–5257.

Li, J., 2009. *環保趨勢下香港的綠色發展戰略,* 香港: 信報財經新闻.

Lloyd's List, 2007. Compensation call over boxship pollution in Europe. *Lloyd's List.*

Ma, H., 2016. *广州绿色港口行动计划启动.* [Online]
Available at: http://news.21cn.com/caiji/roll1/a/2016/0720/21/31316540.shtml
[Accessed 1 8 2016].

Malkiel, B. G., 1973. *A Random Walk Down Wall Street.* New York: W. W. Norton & Company, Inc..

Meersman, H., Voorde, E. V. d. & Vanelslander, T., 2010. Port Competition Revisited. *Review of Business and Economics,* Volume 2, pp. 210-232.

Meessen, J., Croizer, C. & Verlé, P., 2015. *The Vietnam Green Growth Strategy: A review of specificities, indicators and research perspectives,* Bruxelles : Cooperation Technique Belge (BTC) .

Mei, G., 2012. 世界港口发展模式, 演进方向与经验借鉴. *中国流通经济,* 26(12), pp. 69-75.

Meng, Q., 2015. *Share green development experience, Search for port low-carbon path,* Beijing: Ministry of Transport the PRC.

MEP, 2016. *上海市人民政府办公厅关于转发市交通委制订的《上海绿色港口三年行动计划（2015-2017 年）》的通知.* [Online]
Available at:
http://www.mep.gov.cn/gzfw_13107/zcfg/hjjzc/gjfbdjjzc/qtjjzc/201606/t20160623_355913.shtml
[Accessed 31 7 2016].

Michalopoulos, V., Pardalis, A. & Stathopoulou, C., 2007. *Estimating Port Competition: the Case of the Mediterranean Sea,* Athens: Proceedings of the International Association of Maritime Economists.

Molinero, C. M. & Woracker, D., 1996. Data Envelopment Analysis: a non-mathematical introduction. *OR Insight,* 9(4), p. 22–28.

MPA, 2013. *Maritime Singapore Green Initiative Brochure,* Singapore: Maritime and Port Authority of Singapore.

MPA, 2016. *Maritime Singapore Green Initiative.* [Online]
Available at: http://www.mpa.gov.sg/web/portal/home/maritime-singapore/green-efforts/maritime-singapore-green-initiative
[Accessed 24 7 2016].

MPA, 2016. *Singapore and the Port of Rotterdam Strengthen Partnership through a Series of Collaborative Projects on Port Solutions.* [Online]
Available at: http://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/66d1c7bd-0a46-4f22-bcfd-83a989818e8f
[Accessed 1 8 2016].

Muller, G., 1999. *Intermodal Freight Transportation.* Washington, D.C: Enotrans—IANA.

Murphy, P., Dalenberg, D. & Daley, J., 1989. Assessing international port operations. *International Journal of Physical Distribution and,* 19(9), pp. 3-10.

Notteboom, T., 2009. The relationship between seaports and the intermodal hinterland in light of global supply chains: European challenges. In: *Port Competition and Hinterland Connections.* Belgium: OECD, pp. 25-70.

Notteboom, T. E., 2006. Traffic inequality in seaport systems revisited. *Journal of Transport Geography,* 14(2), pp. 95-108.

Notteboom, T. E. & Rodrigueb, J. P., 2005. Port regionalization: towards a new phase in port development. *Maritime Policy & Management: The flagship journal of international shipping and port research,* 32(3), pp. 297-313.

Notteboom, T. & Yap, W. Y., 2012. Port Competition and Competitiveness. In: W. K. Talley, ed. *The Blackwell Companion to Maritime Economics.* West Sussex: Blackwell Publishing Ltd, pp. 549-570.

Ng, A. . K. & Song, S., 2010. The environmental impacts of pollutants generated by routine shipping operations on ports. *Ocean & Coastal Management,* 53(5-6), pp. 301-311.

OECD, 2016. *Green growth in action: Korea.* [Online] Available at: http://www.oecd.org/korea/greengrowthinactionkorea.htm [Accessed 23 7 2016].

OPM, 2014. *A roadmap for green growth: Indonesia's draft strategy points the way for national sustainable development.* Oxford: Oxford Policy Management.

Pardali, A. & Michalopoulos, V., 2008. Determining the position of container handling ports, using the benchmarking analysis: the case of the Port of Piraeus. *Maritime Policy & Management ,* 35(3), pp. 271-284.

Pearson, R., 1979. *Containerline performance and service quality,* Liverpool: Marine Transport Centre,University of Liverpool.

PKA, 2016. *About us - Port Klang Authourity (PKA).* [Online] Available at: http://www.pka.gov.my/index.php/en/about-us-/gms-message.html [Accessed 2 8 2016].

PoA, 2015. *2015 Facts & Figures,* Antwerp: Port of Antwerp.

PoA, 2015. *Maritime cargo turnover,* Antwerp: Antwerp Port Authority.

PoA, 2015. *Yearbook of statistics 2015,* Antwerp: Antwerp Port Authority.

PoB, 2006. *Port of Busan Container Statistics,* Busan: Port of Busan Authority.

PoB, 2010. *Port of Busan Container Statistics,* Busan: Port of Busan Authority.

PoB, 2014. *Port of Busan Container Statistics,* Busan: Port of Busan Authority.

PoR, 2008. *Annual Report 2008,* Rotterdam: Port of Rotterdam.

PoR, 2009. *Annual Report 2009,* Rotterdam: Port of Rotterdam.

PoR, 2012. *Celebration of 20 years AGV's.* [Online] Available at: https://www.portofrotterdam.com/en/news-and-press-releases/celebration-of-20-years-agv%E2%80%99s [Accessed 22 7 2016].

PoR, 2014. *Port Vision 2030,* Rotterdam: Rotterdam Port Authority.

PoR, 2015. *Containers and TEU time series,* Rotterdam: Port of Rotterdam.

PoR, 2015. *Modal split maritime containers 2015,* Rotterdam: Port of Rotterdam.

PoR, 2015. *Port Statistics 2015,* Rotterdam: Port of Rotterdam.

PoR, 2015. *TOP 20 World Container Ports,* Rotterdam: Rotterdam Port Authority.

PoR, 2015. *TOP 20 World Ports,* Rotterdam: Rotterdam Port Authority.

PoR, 2016. *Port Vision 2030.* [Online] Available at: https://www.portofrotterdam.com/en/the-port/port-vision-2030 [Accessed 22 7 2016].

Port of NY and NJ, 2014. *A Clean Air Strategy for the Port of NY and NJ - 2014 update,* New York: Port Authority of NY&NJ.

Port.org, 2016. *全国绿色港口示范现场会在宁波召开.* [Online] Available at: http://www.portcontainer.com/newsAction.do?command=viewData&rootCategoryId=8a9289fb300b172d01300b1cfddf0001&categoryId=8a9287fa300b0b0001300b4189670002&dataId=2c90c0875483be45015523809e7e0bb8 [Accessed 1 8 2016].

PortStrategy, 2008. *Busan puts environment first.* [Online] Available at: http://www.portstrategy.com/news101/products-and-services/busan_puts_environment_first [Accessed 2 8 2016].

PoTJ, 2016. *节能领跑 绿色发展 低碳创新 我港"绿色港口"建设成果丰.* [Online] Available at: http://www.tianjin-port.com/port/Show.asp?m=1&d=5517 [Accessed 1 8 2016].

Rodrigue, J.-P., Slack , B. & Notteboom, T., 2013. Chapter 4 - Transportation Terminals. In: *The Geography of Transport Systems - 3rd Edition.* Abingdon: Routledge, pp. 127-149.

Sakar, G. D. & Cetin, C. K., 2012. Port Sustainability and Stakeholder Management in Supply Chains: A Framework on Resource Dependence Theory. *The Asian Journal of Shipping and Logistics,* 28(3), pp. 301-319.

Schreyer, C. et al., 2004. External costs of transport: update study. *INFRAS*, Otc., pp. 1-16.

Shaheen, A. & Abd El-All, H. M., 2014. The Competitive Advantage Of Seaports And Applied To The East Port Said - Port Said. *International Journal of Research in Applied, Natural and Social Sciences*, 11 11, pp. 111-120.

Singh, A., 2010. Asia leads global economic growth. *Finance & Development,* 6.pp. 5-7.

Slack, B., 1985. Containerization inter-port competition and port selection. *Maritime Policy and Management,* 12(4), pp. 292-303.

Song, D. W. & Yeo, K. T., 2004. A Competitive Analysis of Chinese Container Ports Using the Analytic Hierarchy Process. *Maritime Economics & Logistics,* 6(1), pp. 34-52.

Starr, J., 1994. The mid-Atlantic load centre: Baltimore or Hampton Road?. *Maritime Policy and Management,* 21(3), pp. 219-227.

Stopford, M., 2009. *Maritime Economics.* 3rd ed. London and New York: Taylor & Francis Ltd.

Swait, J. & Louviere, J., 1993. The role of the scale parameter in the estimation and comparison of multinomial logit models. *Journal of marketing research,* 30(3), pp. 305-314.

Sydney Port, 2016. *Green Port Guidelines.* [Online]
Available at:
http://www.sydneyports.com.au/__data/assets/pdf_file/0012/1254/gpg_guidelines.pdf
[Accessed 21 7 2016].

Tan, A., 2015. *Maritime and port authority of Singapore on the "next generation port 2030,* Singapore : Maritime and Port Authority of Singapore .

Teng, J. Y., Huang, W. C. & Huang, M. J., 2004. Multicriteria Evaluation for Port Competitiveness of Eight East Asian Container Ports. *Marine Science and Technology,* 12(4), pp. 256-264.

The Maritime Silk Road - 1e. 2016. [Film] Directed by Guangxin Lv. Beijing: China Central Television - Culture Official Channel.

The State Council of the PRC, 2011. *The 12th five-year plan for national economic and social development,* Beijing: The State Council of the PRC.

The Wall Street Journal, 2012. *ADB: The 2050 Asian economy may accounting for half of global GDP,* s.l.: cn.WSJ.com.

Thomas, V., 2012. *Port Performance Indicators:Selection and Measurement - PPRISM,* Le Havre: University of the Aegean .

Tongzon, J., 2001. Efficiency measurement of selected Australian and other international ports using data envelopment analysis. *Transportation Research Part A: Policy and Practice,* 35(2), pp. 107-122.

Tongzon, J. L., 1995. Systematizing international benchmarking for ports. *Maritime Policy & Management ,* 22(2), pp. 171-177.

Tongzon, J. & Wu Heng, 2005. Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals). *Transportation Research Part A: Policy and Practice,* 39(5), pp. 405-424.

UNCTAD, 1992. *Port Marketing and the Challenge of the Third Generation Port,* Geneva: United Nations Conference on Trade and Development-UNCTAD.

Van Asperen, E. & Dekker, R., 2010. Flexibility in Port Selection: A Quantitative Approach Using Floating Stocks. *Report / Econometric Institute, Erasmus University Rotterdam,* Volume 44, pp. 1-21.

Van Der Sluijs, C., 2007. *Determinants of the Competitive Position of Dutch Seaports,* Amsterdam: Transport Research Centre (AVV), Dutch Ministry of Transport, Public Works and Water Management.

Veldman, S. J. & Bückmann, E. H., 2003. A Model on Container Port Competition: An Application for the West European Container Hub-Ports. *Maritime Economics & Logistics,* 5(1), pp. 3-22.

Verhoeff, J. M, 1977. Seaport competition: an analysis of its nature. *International Journal of Transport Economics ,* 4(3), pp. 271-284.

Verhoeff, J. M., 1981. Seaport competition: some fundamental and political aspects. *Maritime Policy & Management ,* 8(1), pp. 49-60.

Vernya, J. & Grigentin, C., 2009. Container shipping on the Northern Sea Route. *International Journal of Production Economics,* 122(1), pp. 107-117.

Vitsounis, T., 2004. *An economic and legal analysis of the factors determining the competitiveness of ports.* Aegean: Port Economics.

Voorde, E. V. d. & Winkelmans, W., 2002. A general introduction to port competition and management. In: M. Huybrechts, et al. eds. *Port Competitiveness: An Economic and Legal Analysis of the Factors Determining the Competitiveness of Seaports.* Antwerp: De Boeck Ltd, pp. 1-16.

Wang, L., Guo, W., Song, W. & Xie, Z., 2015. The Worth and the Significance of Port in Economic Integration Development Model: A Case Study on Yangtze River Economic Belt China. *Open Journal of Social Sciences,* pp. 3, 44-55.

Wang, S. & Notteboom, T., 2015. The role of port authorities in the development of LNG bunkering facilities in North European ports. *WMU Journal of Maritime Affairs,* 14(1), pp. 61-92.

Warwick, R., 1993. Environmental impact studies on marine communities: Pragmatical considerations. *Austral Ecology,* 18(1), pp. 63-80.

Wei, D., 2010. *Application Integration Technology Research and Implementation of Large Freight Shipping Platform,* Shanghai: Fudan University.

Wen, J., 2016. *青岛港与波兰格但斯克港签署战略合作备忘录.* [Online] Available at: http://ql1d.com/news/show/id/178150.html [Accessed 1 8 2016].

Wiegmans, B. W. & Geerlings, H., 2010. Sustainable port innovations: barriers and enablers for successful implementation. *World Review of Intermodal Transportation Research,* 3(3), pp. 230-250.

Willingale, M., 1981. The Port routing behaviour of short sea ship operator theory and practices. *Maritime Policy and Management,* 40(1), pp. 35-51.

Wind, Y. & Mahajan, V., 1981. Designing product and business portfolios. *Harvard Business Review,* 59(1), pp. 155-165.

Winkelmans, W. & Coeck, C., 1993. Strategic positioning analysis as an evaluation instrument for effective port policy. *Planologisch Nieuws,* 13(3), pp. 263-270.

World Bank, 2015. *Container port traffic (TEU: 20 foot equivalent units).* [Online] Available at: http://data.worldbank.org/indicator/IS.SHP.GOOD.TU [Accessed 15 07 2016].

Yap, W. Y. & Lam, J. S., 2006. Competition dynamics between container ports in East Asia. *Transportation Research Part A*, pp. 35-51.

Yeo, G. T., Roe, M. & Dinwoodie, J., 2008. Evaluating the competitiveness of container ports in Korea and China. *Transportation Research Part A,* 42(6), pp. 910-921.

Yu, N., 2016. *青岛港与德国威廉港签署深化战略合作备忘录.* [Online] Available at: http://finance.sina.com.cn/roll/2016-07-19/doc-ifxuaiwa7205689.shtml [Accessed 1 8 2016].

Zeebrugge Port Authority, 2016. *Port economy.* [Online] Available at: http://www.portofzeebrugge.be/en/node/452 [Accessed 13 7 2016].

Zondag, B., Bucci, P., Gutzkow, P. & Jong, G. d., 2010. Port competition modeling including maritime, port, and hinterland characteristics. *Maritime Policy & Management ,* 37(3), pp. 179-194.

Appendices

■ Data for Port Portfolio Analysis

Table 10: Data for PPA - Port of Shanghai

Port of Shanghai - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	23,633	259,964	531,220
Share Traffic Category %	/	48.94%	100.00%
Average Annual Growth	**14.09%**		**9.22%**
Growth 2001-2002	35.96%		19.37%
Growth 2002-2003	30.71%		19.86%
Growth 2003-2004	24.42%		19.86%
Growth 2004-2005	20.41%		16.94%
Growth Dynamic 2001-2005		27.88%	/
Growth 2005-2006	16.30%		6.14%
Growth 2006-2007	33.21%		4.66%
Growth 2007-2008	7.00%		3.88%
Growth 2008-2009	-10.97%		-1.11%
Growth 2009-2010	16.42%		29.13%
Growth Dynamic 2006-2010		12.39%	/
Growth 2010-2011	9.36%		11.42%
Growth 2011-2012	2.55%		1.15%
Growth 2012-2013	3.34%		5.43%
Growth 2013-2014	4.98%		-2.67%
Growth 2014-2015	3.54%		-5.02%
Growth Dynamic 2011-2015		4.75%	/
Average Market Share 2001-2015	**15.23%**		**16.52%**
Market Share 2001	9.88%		15.00%
Market Share 2002	11.32%		15.65%
Market Share 2003	12.71%		16.47%
Market Share 2004	13.49%		16.79%
Market Share 2005	14.45%		17.58%
Market Share Dynamic 2001-2005		12.37%	/
Market Share 2006	14.90%		17.16%
Market Share 2007	16.89%		16.26%
Market Share 2008	17.03%		15.95%
Market Share 2009	16.64%		15.62%
Market Share 2010	16.89%		17.68%
Market Share Dynamic 2006-2010		16.47%	/
Market Share 2011	17.03%		17.97%
Market Share 2012	16.69%		17.62%
Market Share 2013	16.73%		17.07%
Market Share 2014	16.61%		15.80%
Market Share 2015	17.16%		15.17%
Market Share Dynamic 2011-2015		16.84%	/

Table 11: Data for PPA - Port of Singapore

Port of Singapore - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	25,929	285,219	464,893
Share Traffic Category %	/	61.35%	100.00%
Average Annual Growth	**5.34%**		**4.50%**
Growth 2001-2002	8.80%		6.92%
Growth 2002-2003	8.68%		3.73%
Growth 2003-2004	15.85%		13.14%
Growth 2004-2005	8.73%		7.60%
Growth Dynamic 2001-2005	10.51%		/
Growth 2005-2006	6.90%		-0.02%
Growth 2006-2007	12.68%		5.98%
Growth 2007-2008	7.09%		7.83%
Growth 2008-2009	-13.54%		6.60%
Growth 2009-2010	0.60%		-2.37%
Growth Dynamic 2006-2010	2.75%		/
Growth 2010-2011	15.05%		5.54%
Growth 2011-2012	5.72%		1.28%
Growth 2012-2013	2.94%		4.24%
Growth 2013-2014	3.96%		3.66%
Growth 2014-2015	-8.70%		-1.10%
Growth Dynamic 2011-2015	3.79%		/
Average Market Share 2001-2015	**18.28%**		**15.40%**
Market Share 2001	24.26%		21.28%
Market Share 2002	22.26%		19.89%
Market Share 2003	20.76%		18.11%
Market Share 2004	20.53%		17.43%
Market Share 2005	19.85%		16.79%
Market Share Dynamic 2001-2005	21.53%		/
Market Share 2006	18.82%		15.43%
Market Share 2007	18.04%		14.82%
Market Share 2008	18.21%		15.08%
Market Share 2009	17.28%		15.92%
Market Share 2010	15.15%		13.63%
Market Share Dynamic 2006-2010	17.50%		/
Market Share 2011	16.07%		13.12%
Market Share 2012	16.24%		12.88%
Market Share 2013	16.21%		12.34%
Market Share 2014	15.94%		12.16%
Market Share 2015	14.53%		12.16%
Market Share Dynamic 2011-2015	16.08%		/

Table 12: Data for PPA - Port of Shenzhen

Port of Shenzhen - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	18,085	198,936	180,007
Share Traffic Category %	/	110.52%	100.00%
Average Annual Growth	**13.01%**		**9.36%**
Growth 2001-2002	50.00%		32.08%
Growth 2002-2003	39.87%		28.16%
Growth 2003-2004	28.22%		20.28%
Growth 2004-2005	16.43%		13.83%
Growth Dynamic 2001-2005	33.63%		/
Growth 2005-2006	14.81%		14.36%
Growth 2006-2007	15.59%		13.07%
Growth 2007-2008	1.50%		2.51%
Growth 2008-2009	-14.78%		7.35%
Growth 2009-2010	22.42%		0.91%
Growth Dynamic 2006-2010	7.91%		/
Growth 2010-2011	1.00%		0.90%
Growth 2011-2012	1.67%		2.29%
Growth 2012-2013	1.47%		2.59%
Growth 2013-2014	3.27%		-4.57%
Growth 2014-2015	0.67%		-2.78%
Growth Dynamic 2011-2015	1.62%		/
Average Market Share 2001-2015	**12.04%**		**5.68%**
Market Share 2001	7.91%		4.51%
Market Share 2002	10.00%		5.20%
Market Share 2003	12.01%		5.85%
Market Share 2004	13.14%		5.99%
Market Share 2005	13.61%		6.10%
Market Share Dynamic 2001-2005	11.33%		/
Market Share 2006	13.86%		6.42%
Market Share 2007	13.63%		6.57%
Market Share 2008	13.04%		6.36%
Market Share 2009	12.19%		6.76%
Market Share 2010	13.01%		5.98%
Market Share Dynamic 2005-2010	13.14%		/
Market Share 2011	12.11%		5.51%
Market Share 2012	11.77%		5.46%
Market Share 2013	11.58%		5.15%
Market Share 2014	11.31%		4.67%
Market Share 2015	11.37%		4.59%
Market Share Dynamic 2011-2015	11.63%		/

Table 13: Data for PPA - Port of Ningbo&Zhoushan

Port of Ningbo&Zhoushan - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	10,193	112,119	466,000
Share Traffic Category %	/	24.06%	100.00%
Average Annual Growth	**23.76%**		**15.75%**
Growth 2001-2002	53.34%		19.84%
Growth 2002-2003	47.85%		20.39%
Growth 2003-2004	45.67%		21.84%
Growth 2004-2005	29.33%		20.58%
Growth Dynamic 2001-2005		44.05%	/
Growth 2005-2006	35.82%		13.69%
Growth 2006-2007	34.01%		11.46%
Growth 2007-2008	18.98%		5.33%
Growth 2008-2009	-8.02%		2.17%
Growth 2009-2010	26.66%		68.78%
Growth Dynamic 2006-2010		21.49%	/
Growth 2010-2011	1.14%		10.21%
Growth 2011-2012	22.35%		7.67%
Growth 2012-2013	7.12%		8.84%
Growth 2013-2014	12.25%		7.80%
Growth 2014-2015	6.07%		1.83%
Growth Dynamic 2011-2015		9.79%	/
Average Market Share 2001-2015	**6.09%**		**13.37%**
Market Share 2001	1.89%		8.72%
Market Share 2002	2.44%		9.14%
Market Share 2003	3.10%		9.66%
Market Share 2004	3.86%		10.01%
Market Share 2005	4.43%		10.81%
Market Share Dynamic 2001-2005		3.14%	/
Market Share 2006	5.34%		11.29%
Market Share 2007	6.09%		11.40%
Market Share 2008	6.83%		11.34%
Market Share 2009	6.89%		11.47%
Market Share 2010	7.61%		16.98%
Market Share Dynamic 2005-2010		6.55%	/
Market Share 2011	7.10%		17.07%
Market Share 2012	8.30%		17.81%
Market Share 2013	8.62%		17.81%
Market Share 2014	9.15%		18.26%
Market Share 2015	9.69%		18.80%
Market Share Dynamic 2011-2015		8.57%	/

Table 14: Data for PPA - Port of Hong Kong

Port of Hong Kong - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	21,929	241,215	244,013
Share Traffic Category %	/	98.85%	100.00%
Average Annual Growth	**1.06%**		**2.84%**
Growth 2001-2002	7.39%		8.02%
Growth 2002-2003	6.82%		7.84%
Growth 2003-2004	7.51%		6.41%
Growth 2004-2005	2.81%		4.16%
Growth Dynamic 2001-2005	6.13%		/
Growth 2005-2006	4.15%		3.52%
Growth 2006-2007	1.95%		3.02%
Growth 2007-2008	-6.27%		5.70%
Growth 2008-2009	-6.46%		-6.32%
Growth 2009-2010	12.64%		10.21%
Growth Dynamic 2006-2010	1.20%		/
Growth 2010-2011	2.89%		3.58%
Growth 2011-2012	-5.19%		-2.92%
Growth 2012-2013	-3.31%		2.53%
Growth 2013-2014	-0.68%		7.82%
Growth 2014-2015	-9.46%		-13.81%
Growth Dynamic 2011-2015	-3.15%		/
Average Market Share 2001-2015	**16.49%**		**8.26%**
Market Share 2001	27.78%		12.10%
Market Share 2002	25.15%		11.42%
Market Share 2003	23.06%		10.81%
Market Share 2004	21.16%		9.79%
Market Share 2005	19.34%		9.13%
Market Share Dynamic 2001-2005	23.30%		/
Market Share 2006	17.87%		8.69%
Market Share 2007	15.50%		8.11%
Market Share 2008	13.69%		8.09%
Market Share 2009	14.06%		7.50%
Market Share 2010	13.80%		7.25%
Market Share Dynamic 2005-2010	14.98%		/
Market Share 2011	13.09%		6.85%
Market Share 2012	11.86%		6.45%
Market Share 2013	11.12%		6.07%
Market Share 2014	10.45%		6.23%
Market Share 2015	9.44%		5.43%
Market Share Dynamic 2011-2015	11.19%		/

Table 15: Data for PPA - Port of Busan

Port of Busan - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	13,699	150,687	237,873
Share Traffic Category %	/	63.35%	100.00%
Average Annual Growth	**6.88%**		**5.90%**
Growth 2001-2002	18.29%		10.69%
Growth 2002-2003	9.32%		12.98%
Growth 2003-2004	10.98%		17.41%
Growth 2004-2005	3.70%		-1.18%
Growth Dynamic 2001-2005	10.57%		/
Growth 2005-2006	1.71%		0.32%
Growth 2006-2007	10.10%		11.79%
Growth 2007-2008	1.44%		-0.78%
Growth 2008-2009	-11.20%		-6.41%
Growth 2009-2010	18.80%		6.59%
Growth Dynamic 2006-2010	4.17%		/
Growth 2010-2011	13.95%		11.95%
Growth 2011-2012	5.31%		-3.67%
Growth 2012-2013	3.46%		12.46%
Growth 2013-2014	10.44%		6.70%
Growth 2014-2015	0.09%		3.75%
Growth Dynamic 2011-2015	6.65%		/
Average Market Share 2001-2015	**9.60%**		**7.86%**
Market Share 2001	12.39%		10.16%
Market Share 2002	12.36%		9.83%
Market Share 2003	11.60%		9.75%
Market Share 2004	10.99%		9.74%
Market Share 2005	10.13%		8.62%
Market Share Dynamic 2001-2005	11.49%		/
Market Share 2006	9.14%		7.95%
Market Share 2007	8.56%		8.05%
Market Share 2008	8.19%		7.54%
Market Share 2009	7.98%		6.99%
Market Share 2010	8.26%		6.53%
Market Share Dynamic 2005-2010	8.42%		/
Market Share 2011	8.68%		6.67%
Market Share 2012	8.74%		6.23%
Market Share 2013	8.76%		6.43%
Market Share 2014	9.15%		6.53%
Market Share 2015	9.14%		6.84%
Market Share Dynamic 2011-2015	8.90%		/

Table 16: Data for PPA - Port of Guangzhou

Port of Guangzhou - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	9,552	105,069	308,500
Share Traffic Category %	/	34.06%	100.00%
Average Annual Growth	**18.76%**		**11.17%**
Growth 2001-2002	25.43%		19.50%
Growth 2002-2003	27.06%		12.21%
Growth 2003-2004	19.42%		25.19%
Growth 2004-2005	39.15%		12.31%
Growth Dynamic 2001-2005	27.77%		/
Growth 2005-2006	40.71%		25.28%
Growth 2006-2007	42.97%		13.38%
Growth 2007-2008	18.79%		1.08%
Growth 2008-2009	1.82%		4.90%
Growth 2009-2010	11.49%		-31.15%
Growth Dynamic 2006-2010	23.16%		/
Growth 2010-2011	14.20%		22.91%
Growth 2011-2012	1.78%		18.38%
Growth 2012-2013	5.48%		22.38%
Growth 2013-2014	8.30%		12.24%
Growth 2014-2015	6.09%		-2.16%
Growth Dynamic 2011-2015	7.17%		/
Average Market Share 2001-2015	**5.80%**		**9.61%**
Market Share 2001	2.71%		8.70%
Market Share 2002	2.86%		9.09%
Market Share 2003	3.12%		8.95%
Market Share 2004	3.18%		9.53%
Market Share 2005	3.94%		9.59%
Market Share Dynamic 2001-2005	3.16%		/
Market Share 2006	4.92%		11.04%
Market Share 2007	5.98%		11.34%
Market Share 2008	6.70%		10.82%
Market Share 2009	7.48%		11.24%
Market Share 2010	7.27%		6.79%
Market Share Dynamic 2005-2010	6.47%		/
Market Share 2011	7.65%		7.61%
Market Share 2012	7.45%		8.73%
Market Share 2013	7.62%		9.82%
Market Share 2014	7.80%		10.48%
Market Share 2015	8.26%		10.36%
Market Share Dynamic 2011-2015	7.76%		/

Table 17: Data for PPA - Port of Qingdao

Port of Qingdao - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	9,910	109,010	287,460
Share Traffic Category %	/	37.92%	100.00%
Average Annual Growth	**14.77%**		**12.12%**
Growth 2001-2002	29.22%		17.40%
Growth 2002-2003	24.34%		15.40%
Growth 2003-2004	21.20%		14.76%
Growth 2004-2005	22.73%		13.98%
Growth Dynamic 2001-2005		22.45%	/
Growth 2005-2006	21.85%		21.65%
Growth 2006-2007	23.12%		18.20%
Growth 2007-2008	9.07%		5.02%
Growth 2008-2009	-0.68%		-1.44%
Growth 2009-2010	17.17%		27.63%
Growth Dynamic 2006-2010		14.11%	/
Growth 2010-2011	8.41%		7.11%
Growth 2011-2012	12.20%		7.20%
Growth 2012-2013	6.24%		11.94%
Growth 2013-2014	7.02%		6.67%
Growth 2014-2015	4.94%		4.17%
Growth Dynamic 2011-2015		7.76%	/
Average Market Share 2001-2015	**6.27%**		**8.61%**
Market Share 2001	4.11%		7.06%
Market Share 2002	4.48%		7.24%
Market Share 2003	4.78%		7.34%
Market Share 2004	4.95%		7.16%
Market Share 2005	5.40%		7.31%
Market Share Dynamic 2001-2005		4.74%	
Market Share 2006	5.83%		8.18%
Market Share 2007	6.11%		8.75%
Market Share 2008	6.28%		8.68%
Market Share 2009	6.85%		8.47%
Market Share 2010	6.99%		9.48%
Market Share Dynamic 2005-2010		6.41%	/
Market Share 2011	6.99%		9.26%
Market Share 2012	7.50%		9.63%
Market Share 2013	7.72%		9.90%
Market Share 2014	7.82%		10.04%
Market Share 2015	8.19%		10.57%
Market Share Dynamic 2011-2015		7.64%	/

Table 18: Data for PPA - Port of Tianjin

Port of Tianjin - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	8,091	89,001	339,060
Share Traffic Category %	/	26.25%	100.00%
Average Annual Growth	**15.09%**		**12.08%**
Growth 2001-2002	16.95%		13.54%
Growth 2002-2003	24.58%		25.33%
Growth 2003-2004	27.17%		27.44%
Growth 2004-2005	25.87%		18.87%
Growth Dynamic 2001-2005		23.64%	/
Growth 2005-2006	23.89%		5.10%
Growth 2006-2007	19.40%		20.15%
Growth 2007-2008	19.67%		18.00%
Growth 2008-2009	1.18%		4.35%
Growth 2009-2010	17.16%		7.06%
Growth Dynamic 2006-2010		16.26%	/
Growth 2010-2011	15.01%		10.54%
Growth 2011-2012	6.13%		5.54%
Growth 2012-2013	5.68%		5.17%
Growth 2013-2014	8.18%		7.87%
Growth 2014-2015	0.36%		0.19%
Growth Dynamic 2011-2015		7.07%	/
Average Market Share 2001-2015	**4.73%**		**10.18%**
Market Share 2001	3.21%		7.72%
Market Share 2002	3.16%		7.66%
Market Share 2003	3.38%		8.43%
Market Share 2004	3.67%		9.14%
Market Share 2005	4.11%		9.72%
Market Share Dynamic 2001-2005		3.51%	/
Market Share 2006	4.52%		9.39%
Market Share 2007	4.59%		10.22%
Market Share 2008	5.17%		11.39%
Market Share 2009	5.75%		11.77%
Market Share 2010	5.87%		11.05%
Market Share Dynamic 2005-2010		5.18%	/
Market Share 2011	6.22%		11.14%
Market Share 2012	6.31%		11.40%
Market Share 2013	6.47%		11.01%
Market Share 2014	6.62%		11.30%
Market Share 2015	6.63%		11.44%
Market Share Dynamic 2011-2015		6.45%	/

Table 19: Data for PPA - Port of Klang

Port of Klang - Traffic Categories (x1,000 TEUs or Tonnes)			
2001-2015	**CONT (TEUs)**	**CONT (Tonnes)**	**TOT (Tonnes)**
Average Traffic	7,609	83,702	143,933
Share Traffic Category %	/	58.15%	100.00%
Average Annual Growth	**8.81%**		**9.15%**
Growth 2001-2002	20.48%		17.40%
Growth 2002-2003	6.87%		8.02%
Growth 2003-2004	8.32%		12.37%
Growth 2004-2005	5.72%		9.81%
Growth Dynamic 2001-2005	10.35%		/
Growth 2005-2006	14.11%		11.21%
Growth 2006-2007	12.54%		11.07%
Growth 2007-2008	12.01%		12.40%
Growth 2008-2009	-8.33%		-9.65%
Growth 2009-2010	21.37%		24.27%
Growth Dynamic 2006-2010	10.34%		/
Growth 2010-2011	6.35%		13.57%
Growth 2011-2012	6.00%		-18.49%
Growth 2012-2013	3.49%		26.47%
Growth 2013-2014	5.76%		8.49%
Growth 2014-2015	8.60%		1.20%
Growth Dynamic 2011-2015	6.04%		/
Average Market Share 2001-2015	**4.84%**		**4.52%**
Market Share 2001	5.86%		4.76%
Market Share 2002	5.95%		4.88%
Market Share 2003	5.46%		4.63%
Market Share 2004	5.05%		4.43%
Market Share 2005	4.74%		4.35%
Market Share Dynamic 2001-2005	5.41%		/
Market Share 2006	4.80%		4.45%
Market Share 2007	4.60%		4.48%
Market Share 2008	4.85%		4.75%
Market Share 2009	4.88%		4.25%
Market Share 2010	5.17%		4.63%
Market Share Dynamic 2005-2010	4.86%		/
Market Share 2011	5.06%		4.80%
Market Share 2012	5.13%		3.79%
Market Share 2013	5.15%		4.40%
Market Share 2014	5.15%		4.54%
Market Share 2015	5.58%		4.65%
Market Share Dynamic 2011-2015	5.22%		/

■ Data for Green Portfolio Analysis

Table 20: Data for GPA - Port container traffic

Port Container Traffic (x1,000 TEUs)			
2001-2015	**Rotterdam**	**Antwerp**	**Busan**
Average Traffic	9,960	7,405	13,699
Share in Group %	32.06%	23.84%	44.10%
Average Annual Growth	**4.95%**	**6.04%**	**6.43%**
Growth 2001-2002	6.76%	13.74%	18.29%
Growth 2002-2003	9.34%	14.09%	9.32%
Growth 2003-2004	16.07%	11.17%	10.98%
Growth 2004-2005	12.01%	7.16%	3.70%
Growth Dynamic 2001-2005	11.05%	11.54%	10.57%
Growth 2005-2006	3.93%	8.28%	1.71%
Growth 2006-2007	11.79%	16.48%	10.10%
Growth 2007-2008	-0.06%	5.91%	1.44%
Growth 2008-2009	-9.65%	-15.58%	-11.20%
Growth 2009-2010	14.42%	15.84%	18.80%
Growth Dynamic 2006-2010	4.08%	6.19%	4.17%
Growth 2010-2011	6.54%	2.31%	13.95%
Growth 2011-2012	-0.09%	-0.33%	5.31%
Growth 2012-2013	-2.06%	-0.66%	3.46%
Growth 2013-2014	5.83%	4.66%	10.44%
Growth 2014-2015	-0.51%	7.53%	0.09%
Growth Dynamic 2011-2015	1.94%	2.70%	6.65%
Average Market Share 2001-2015	**32.21%**	**23.86%**	**43.94%**
Market Share 2001	33.50%	22.95%	43.54%
Market Share 2002	31.55%	23.03%	45.43%
Market Share 2003	31.24%	23.79%	44.97%
Market Share 2004	32.19%	23.49%	44.32%
Market Share 2005	33.64%	23.48%	42.88%
Market Share Dynamic 2001-2005	32.42%	23.35%	44.23%
Market Share 2006	33.62%	24.45%	41.93%
Market Share 2007	33.49%	25.37%	41.14%
Market Share 2008	32.79%	26.33%	40.88%
Market Share 2009	33.60%	25.21%	41.18%
Market Share 2010	32.98%	25.05%	41.97%
Market Share Dynamic 2005-2010	33.30%	25.28%	41.42%
Market Share 2011	32.36%	23.60%	44.04%
Market Share 2012	31.62%	23.01%	45.37%
Market Share 2013	30.73%	22.69%	46.58%
Market Share 2014	30.20%	22.04%	47.76%
Market Share 2015	29.58%	23.34%	47.07%
Market Share Dynamic 2011-2015	30.90%	22.94%	46.16%

Table 21: Port of Rotterdam - external costs

Port of Rotterdam - External Costs (x1,000 TEUs or Tonnes)			
Modal Split	**Road**	**Railway**	**Inland Navigation**
Split Share 2001	3,020	405	1,467
Split Share 2002	3,165	510	1,774
Split Share 2003	3,387	550	1,771
Split Share 2004	3,814	591	1,928
Split Share 2005	4,090	640	2,035
Split Share Dynamic 2001-2005	***3,495***	***539***	***1,795***
Split Share 2006	4,368	815	2,232
Split Share 2007	4,749	905	2,445
Split Share 2008	4,476	1,010	2,337
Split Share 2009	3,653	744	2,218
Split Share 2010	4,030	759	2,361
Split Share Dynamic 2005-2010	***4,255***	***847***	***2,319***
Split Share 2011	3,951	818	2,393
Split Share 2012	3,998	794	2,613
Split Share 2013	4,039	790	2,572
Split Share 2014	4,262	870	2,846
Split Share 2015	4,481	884	3,042
Split Share Dynamic 2011-2015	***4,146***	***831***	***2,693***
Average Split Share 2001-2015 (TEUs)	**3,966**	**739**	**2,269**
Conversion to Tonnage, x11 (Tonnes)	**43,621**	**8,129**	**24,959**
External cost (Per 1,000 ton-km)	€ 50.50	€ 7.90	€ 11.20
Average External Costs	**€ 2,202,872.28**	**€ 64,221.42**	**€ 279,535.46**
Total Average External Costs	**€ 2,546,629.16**		
% of Total Average External Costs in Group	**30.73%**		
Dynamic 2001-2005 - Volume in Tonnes	38447.2	5931.2	19745
External cost	€ 1,941,583.60	€ 46,856.48	€ 221,144.00
Total External costs	**€ 2,209,584.08**		
2001-2005 Share in the fictitious range	**31.48%**		
Dynamic 2006-2010 - Volume in Tonnes	46807.2	9312.6	25504.6
External cost	€ 2,363,763.60	€ 73,569.54	€ 285,651.52
Total External costs	**€ 2,722,984.66**		
2000-2010 Share in the fictitious range	**32.18%**		
Dynamic 2011-2015 - Volume in Tonnes	45609.3	9144.08	29625.97
External cost	€ 2,303,269.65	€ 72,238.23	€ 331,810.86
Total External costs	**€ 2,707,318.75**		
2011-2015 Share in the fictitious range	**28.86%**		

Table 22: Port of Antwerp - external costs

Port of Antwerp - External Costs (x1,000 TEUs or Tonnes)			
Modal Split	**Road**	**Railway**	**Inland Navigation**
Split Share 2001	2,663	245	1,034
Split Share 2002	2,359	250	1,135
Split Share 2003	2,948	275	1,259
Split Share 2004	3,193	337	1,481
Split Share 2005	3,221	332	1,603
Split Share Dynamic 2001-2005	***2,877***	***288***	***1,302***
Split Share 2006	3,416	360	1,669
Split Share 2007	3,448	420	1,924
Split Share 2008	3,452	474	1,849
Split Share 2009	2,674	367	1,601
Split Share 2010	3,113	434	1,796
Split Share Dynamic 2005-2010	***3,221***	***411***	***1,768***
Split Share 2011	3,200	490	1,889
Split Share 2012	3,159	486	1,918
Split Share 2013	3,051	394	2,016
Split Share 2014	3,114	379	2,152
Split Share 2015	3,593	416	2,113
Split Share Dynamic 2011-2015	***3,223***	***433***	***2,018***
Average Split Share 2001-2015 (TEUs)	**3,107**	**377**	**1,696**
Conversion to Tonnage, x11 (Tonnes)	**34,176**	**4,150**	**18,655**
External cost (Per 1,000 ton-km)	€ 50.50	€ 7.90	€ 11.20
Average External Costs	**€ 1,725,901.47**	**€ 32,784.47**	**€ 208,938.99**
Total Average External Costs	**€ 1,967,624.93**		
% of Total Average External Costs in Group	**23.74%**		
Dynamic 2001-2005 - Volume in Tonnes	31644.8	3165.8	14326.4
External cost	€ 1,598,062.40	€ 25,009.82	€ 160,455.68
Total External costs	**€ 1,783,527.90**		
2001-2005 Share in the fictitious range	**25.41%**		
Dynamic 2006-2010 - Volume in Tonnes	35426.6	4521	19445.8
External cost	€ 1,789,043.30	€ 35,715.90	€ 217,792.96
Total External costs	**€ 2,042,552.16**		
2000-2010 Share in the fictitious range	**24.14%**		
Dynamic 2011-2015 - Volume in Tonnes	35457.4	4763	22193.6
External cost	€ 1,790,598.70	€ 37,627.70	€ 248,568.32
Total External costs	**€ 2,076,794.72**		
2011-2015 Share in the fictitious range	**22.14%**		

Table 23: Port of Busan - external costs

Port of Busan - External Costs (x1,000 TEUs or Tonnes)			
Modal Split	**Road**	**Railway**	**Inland Navigation**
Split Share 2001	4,460	551	119
Split Share 2002	4,942	580	44
Split Share 2003	5,399	636	122
Split Share 2004	5,964	631	105
Split Share 2005	5,893	686	85
Split Share Dynamic 2001-2005	***5,332***	***617***	***95***
Split Share 2006	6,053	750	28
Split Share 2007	6,624	820	7
Split Share 2008	6,782	856	7
Split Share 2009	6,019	550	39
Split Share 2010	7,193	643	82
Split Share Dynamic 2005-2010	***6,534***	***724***	***33***
Split Share 2011	7,895	813	124
Split Share 2012	7,946	863	90
Split Share 2013	8,087	847	4
Split Share 2014	8,466	788	0
Split Share 2015	8,277	818	2
Split Share Dynamic 2011-2015	***8,134***	***826***	***44***
Average Split Share 2001-2015 (TEUs)	**6,667**	**722**	**57**
Conversion to Tonnage, x11 (Tonnes)	**73,333**	**7,943**	**629**
External cost (Per 1,000 ton-km)	€ 50.50	€ 7.90	€ 11.20
Average External Costs	**€ 3,703,314.82**	**€ 62,750.49**	**€ 7,047.04**
Total Average External Costs	**€ 3,773,112.35**		
% of Total Average External Costs in Group	**45.53%**		
Dynamic 2001-2005 - Volume in Tonnes	58647.6	6784.8	1045
External cost	€ 2,961,703.80	€ 53,599.92	€ 11,704.00
Total External costs	**€ 3,027,007.72**		
2001-2005 Share in the fictitious range	**43.12%**		
Dynamic 2006-2010 - Volume in Tonnes	71876.2	7961.8	358.6
External cost	€ 3,629,748.10	€ 62,898.22	€ 4,016.32
Total External costs	**€ 3,696,662.64**		
2000-2010 Share in the fictitious range	**43.68%**		
Dynamic 2011-2015 - Volume in Tonnes	89475.1	9082.7	484
External cost	€ 4,518,492.55	€ 71,753.33	€ 5,420.80
Total External costs	**€ 4,595,666.68**		
2011-2015 Share in the fictitious range	**49.00%**		

Table 24: Green colour shade of ports

Ratio of Port Green Colour Shade			
2001-2015	**Rotterdam**	**Antwerp**	**Busan**
Average Ratio Value	**0.75**	**0.66**	**0.12**
Ratio 2001	0.62	0.48	0.15
Ratio 2002	0.72	0.59	0.13
Ratio 2003	0.69	0.52	0.14
Ratio 2004	0.66	0.57	0.12
Ratio 2005	0.65	0.60	0.13
Dynamic Ratio 2001-2005	0.67	0.55	0.13
Ratio 2006	0.70	0.59	0.13
Ratio 2007	0.71	0.68	0.12
Ratio 2008	0.75	0.67	0.13
Ratio 2009	0.81	0.74	0.10
Ratio 2010	0.77	0.72	0.10
Dynamic Ratio 2005-2010	0.75	0.68	0.12
Ratio 2011	0.81	0.74	0.12
Ratio 2012	0.85	0.76	0.12
Ratio 2013	0.83	0.79	0.11
Ratio 2014	0.87	0.81	0.09
Ratio 2015	0.88	0.70	0.10
Dynamic Ratio 2011-2015	0.85	0.76	0.11
Green Colour Spectrum	0.11 =	30	
	0.12 =	60	
	0.13 =	90	
	0.55 =	120	
	0.66 =	150	
	0.67 =	175	
	0.68 =	195	
	0.75 =	220	
	0.76 =	235	
	0.85 =	255	