Master's degree thesis

LOG950 Logistics

Port performance: Models and metrics supporting performance evaluation

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Abstract

The overall objective of this research is to measure the productivity of Oslo port and analyze how to improve its performance by performance indicators. To achieve this goal, the author has identified the most crucial traffic category for Oslo port, container traffic, using Growth-share Matrix analysis. Narrowing down the research scope enables the author to focus on the most vital part of Oslo port and identify the bottleneck (event information unavailability of landside service) which hinders performance improvement of this traffic category.

Three indicators of partial productivity measurement selected based on the situation of Oslo port to testify the evolutionary trend of container terminals of Oslo port are labor productivity, area productivity and crane productivity. This research finds that terminals' performances on the first two indicators have increased during the last ten years due to improved information system, cranes and organizational structure, while their performance on crane productivity fluctuates over years because of external environmental factors including ship design and stevedore's break which could not be controlled by terminal operators. In addition, if information sharing between terminal and port users can be improved, the overall performance including crane productivity will be increased.

Based on the primary data derived from interviews with three informants of this project, the author found the availability of event information can improve the container flow in container terminal, thereby increasing area productivity. Because the size of stacking storage area is the constraint of container throughput in Oslo container terminals, increased area efficiency leads to increased container throughput. In addition, information provided by forwarding agents enables terminal operator to prepare containers before trucks come, which can dramatically reduce gate to gate time. Reduced gate to gate time leads to shorter queue in the stacking area which increases the possibility that port chassis coming from ship can go back on time, thereby increasing SSG crane efficiency. Due to the importance of information availability, the author suggests that it should be considered as a new performance indicator by Oslo port authority and also should be adopted by the performance measurement framework published by Woo et al based on its importance shown in the case of Oslo container terminals.

List of Content

List of Figures

List of Tables

List of Abbreviations

3PL	Third-party logistics company
BCG Matrix	Boston Consulting Group Matrix
DEA	Date envelopment analysis
DMU	Decision making unit
EBIT	Earnings before interest and taxes
GE	General Electric
KF	Municipal enterprise
Lo-Lo	Lift-on/Lift-off
OCT	Oslo container terminal
PIMS	Profitability impact of marketing strategy
PPM	Partial productivity measures
PPP	Purchasing Power Parity
Ro-Ro	Roll-on/Roll-off
RTG	Rubber tyred gantry crane
SBU	Strategic business unit
SCT	Sjursøya container terminal
SDR	Special drawing right
SFA	Stochastic Frontier Approach
SITMA	Company name; **S**trategy, **IT** and **Ma**terial Management
SSB	Statistics Norway
SSG	Ship-to-shore gantry crane
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TEU	20 foot equivalent units
WLU	Workload units

1. Introduction

1.1 Background

A seaport is a node in supply chain networks, which enables vessels to transfer cargo and passengers from and to waterways and land. A seaport is also an economic organization which delivers logistics services which distinguishes it from other companies producing physical products in the same supply chain. The subject of my research is ports in Norway. The performance of Oslo port will be studied in this research. There are certain reasons why this research is conducted.

Firstly, port industry is one of the fast expending areas in world economics. Figure 1.1 below tells this fact. The world container trade volumes increased dramatically (from 224.8 million TEU in 2000 to 572.2 million TEU in 2011 (TheWorldBank 2013)) during the last decade with a small drop in 2009 due to economic crisis. Applying logistics knowledge to this expending industry is an exciting experience.

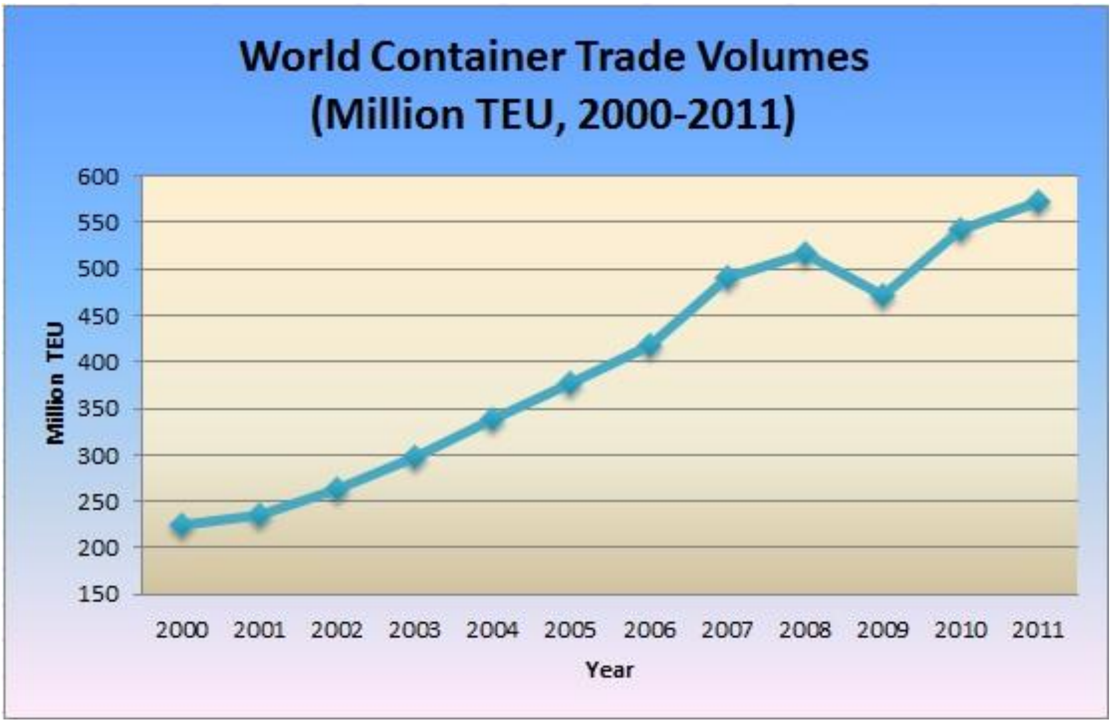

Figure 1.1: World container trade volumes

Secondly, Norway is a long and narrow country. The coastline extends for about 21,930 kilometers (13,620 miles), including all its deeply cut fjords and islands (NationsEncyclopedia 2013). Further, over 80 percent of inhabitants dwell less than ten kilometers from seaside (TransportForum 2006). Therefore, ports and water transport is crucial to Norway's economy. This situation means that measuring port performance in a scientific way is of importance for the whole country and actors involved.

Thirdly, this project is supported by Seamless who has 44 years' experience within port information systems. It is also "a leading actor in the Norwegian market for port information system and has profound experience in maritime business. Seamless provides its Port Administration Tools, Portwin and PortTools, to 95% of Norwegian ports". (Seamless 2012) Therefore, this organization is looking for the technical solutions for port performance and the approach to establish standardized parameters for performance measurement. In terms of this project, a set of PPM indicators will be developed for the focal company, Oslo port, thereby evaluating its performance. Further, a performance indicator will also be proposed based on its current situation.

Fourthly, a great amount of researches focusing on productivity of airport. In contrast, there is much less literatures looking at measuring seaport performance, although port performance is a global concern (Figure 1.1). In addition, Shanghai port has become the busiest container port in the world in terms of TEU turnover since 2010 (WorldShippingCouncil 2013). See Table 1.1 below. This master thesis aims to contribute to the knowledge base of port performance measurement.

Rank	Port	Country	2011	2010	2009
1	Shanghai	China	31,740	29,069	25,002
2	Singapore	Singapore	29,940	28,431	25,866
3	Hong Kong	China	24,380	23,699	20,983
4	Shenzhen	China	22,570	22,510	18,250
5	Busan	South Korea	16,170	14,194	11,954
6	Ningbo-Zhoushan	China	14,720	13,144	10,502
7	Guangzhou	China	14,260	12,550	11,190
8	Qingdao	China	13,020	12,012	10,260
9	Dubai	United Arab Emirates	13,010	11,600	11,124
10	Rotterdam	Netherlands	11,880	11,140	9,743

Table 1.1: The top 10 busiest container port in the world (in thousand TEUs) (WorldShippingCouncil 2013)

1.2 Research questions

The overall objective of present research is to study port performance. More specifically, the author will measure the productivity of Oslo port and analyze how to improve its performance by performance indicators. To achieve this goal, the author needs to identify the most crucial traffic category for Oslo port. By narrowing down the research scope, the author can focus on the most vital part of Oslo port and identify eventual performance bottleneck for container traffic.

- **Research question 1**: Which traffic category is the most important one for Oslo port?

To answer this question, growth-share matrix is used to identify this traffic category. Further, the author will evaluate the performance of this specific terminal by partial productivity measures (PPM). The productivity of this specific terminal will be assessed and a comparison will be made between its current and historic performance, thereby exploring whether this terminal of Oslo port improves its performance over a given time period.

- **Research question 2**: Whether Oslo port has improved its productivity for the most important traffic category during the last ten years?

To answer this question, partial productivity measures (PPM) is used and three PPM indicators are selected based on the situation of Oslo port. Thirdly, the author will compare the performance indicators currently used by port authority with the performance measurements framework found in literature and identify the reasons which give rise to the differences between them.

- **Research question 3**: Does the performance indicators used by Oslo Port differ from the ones used by the framework published by Woo et al. in 2011? If so, what are the reasons?

To answer this question, both the framework and performance indicators used by Oslo Port will be studied carefully. Because performance indicators enable the port authority to identify to which extent their terminal operators have achieved their targets. Proper performance indicator(s) will be suggested to port authority based on the major problem found by the author during this project. And possible indicators will also be suggested to the framework.

- **Research question 4**: How can the performance of Oslo port be improved for the most important traffic category?

- **Research question 5**: Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?

- **Research question 6**: Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to this case study?

To answer these three questions, some individuals with in depth knowledge of Oslo port will be interviewed. Suggestions (both to Oslo port authority and performance measurement framework developed by Woo et al.) will be made based on the findings during these interviews. By doing this research, the author aims to enrich the knowledge base of port economics. And hopefully, this project can enable the focal company to achieve a greater success.

2. Theoretical Framework

The purpose of this section is to construct a theoretical framework for the present project. All related theories to this study will be described in details with the descriptions of important previous studies. In addition, the reasons why these theories are adopted will also be provided.

These related theories will be presented in the following order:

Section 2.1: Service users and providers in a port
Section 2.2: Product portfolio analysis
Section 2.3: Weighting rules
Section 2.4: Productivity and efficiency measures
Section 2.5: performance measurements for port industry

2.1. Service users and providers in a port

This section describes service users and service providers of ports. The purpose is to provide readers with a picture of a port: who uses a port? Who operates in a port and how they cooperate? Obviously, actors of a port could be different from an individual port to another. Therefore, actors in Oslo port will be described in detail in Chapter 4. Wayne K. Talley (2009) illustrated all service users and service providers of a port in his book, "Port Economics". This section will follow the information provided by this book.

2.1.1. Service users

"Users may be considered as those which bring passengers or goods to and from port from the seaside, i.e. actors in sea transport. It is those users who pay fees and thereby finance port operations" (Hatteland 2010). In terms of this thesis, forwarding agents and shipping lines are major considered service users of landside service and quayside service respectively.

2.1.2. Service providers

"Service providers of a port are those that provide services to the users of the port, i.e., to carriers, shippers and passengers" (Talley 2009). The port operator is the primary service provider of a port. Besides, because the port operator normally will not operate the whole port on their own and outsource some activities, there are many other service providers operating in a port as discussed in 2.1.2.2.

2.1.2.1. Port operator

Three types of organizations can play as a port operator. They are port authority, private port terminal operator and shipping line. In addition, a port can be divided into common user terminal and dedicated terminal in terms of the right to use. The former one is open to all ships which have made arrangements to call there, while the later one only serves the operator's "own vessels, alliance vessels and customers" (Talley 2009).

1) A port authority "operates its common user terminal".

2) A private port terminal operator "contracts with a port authority or landlord port to operate its common user terminal or to operate a common user terminal that it owns".

3) A shipping line can operate a common user terminal or a dedicated terminal. In the former situation, its "terminal operator division contracts with a landlord port to operate its common user terminal or to operate a common

user terminal that it owns". In the later situation, the shipping line "leases and operates a terminal of a landlord port as a dedicated terminal or operates a dedicated terminal that it owns" (Talley 2009).

Certain shipping lines are willing to expand their port operation business. CMA-CGM and Mediterranean Shipping Company are good examples in this field (Talley 2009). This is because delivering containers to a port which they own can avoid or at least reduce the risk of terminal congestion. Besides, they believe port operation can provide higher profit margin to them than container transportation (Talley 2009). This partially gives rise to the worldwide trend of outsourcing. (Port authority acts as a landlord port.)

Rank	Operator	TEUs handled (millions)	Percent share of world TEU port throughput
1	Hutchison Port Holdings	60.9	13.8
2	APM Terminals	52.0	11.8
3	PSA International	47.4	10.7
4	DP World	41.6	9.4
5	Cosco Pacific	22.0	5.0
6	Eurogate	12.5	2.8
7	SSA Marine	11.9	2.7
Total		248.3	56.2
World TEU port throughput		441	100

Table 2.1.1: The world top 7 largest private container port terminal operators in 2006 (Talley 2009)

An increasing number of port authorities no longer operate their own terminals nowadays. And they act as landlord ports and hire private port terminal operators to manage their ports. The table 2.1.1 below lists the world top 7 largest private container port terminal operators in 2006. They handled 248.3 million TEUs which accounts for 56.2 percent of container throughput in the world. Further, the top four largest port operators occupied 45.7 percent market share of the world TEU port throughput. The largest one is a Hong Kong based operator, Hutchison Port Holdings. It handled 13.8 percent of worldwide containers, followed by APM Terminals which composes 11.8 percent market share (Talley 2009).

2.1.2.2. Other service providers

In addition to port operator, there are normally at least ten port service providers working for each port and providing services to carriers, shippers and passengers. They are: (Talley 2009)

1) A **stevedore** is a company who is in charge of loading stowing and unloading vessels. “In many port it is an independent contractor hired by shipping lines to work their ships while in port, i.e., load and unload cargo.” It will be a major service provider considered in this project.
2) A **ship’s agent** “is a company that looks after the interest of a ship and her master and crew while in port on behalf of ship owner.” For example, ship’s agent will make necessary arrangements with other service providers for a ship, including port operators (for a berth), stevedores, pilots and towage companies. It helps shipping lines to “handle relations with shippers, consignees and government officials.”
3) A **pilot** is a licensed and experienced mariner familiar with a specific port who provides ship’s masters assistance in navigating their vessels when entering and leaving a port.
4) A **towage company** tows and pushes ships in a port.
5) A **ship repair and maintenance company** provides repair and maintenance services for ships.
6) A **surveyor** of a ship classification society “may also be at ports to undertake periodical surveys of ships to ensure that they meet the minimum standards for maintaining their classification society certificates, which are required by ships for obtaining of insurance.”
7) A **customer broker** “is a company that clears cargo through customs at a port on behalf of the consignee of imported cargo.”
8) A **freight forwarder** “is a company that arranges for the carriage of cargo on behalf of a shipper. The arrangements include booking space on a carrier’s ship or vehicle (e.g., a railroad car or truck) and providing the necessary accompanying documentation.”
9) A **third-party logistics company (3PL)** “integrates logistics activities, e.g., inventory management and warehousing, in the carriage of cargo.”
10) **Government** can also be a service provider in a port. In some countries, governments are “responsible for constructing (deepening and widening) and maintaining harbor channels, disposal of dredged materials and building harbor jetties and breakwaters”.

2.2. Product portfolio analysis

Two crucial problems are faced by companies who have multiple product lines or business units when they manage to improve overall corporate performance: (Wheelen and Hunger 2009)

1) “How much of our time and money should we spend on our best products and business units to ensure that they continue to be successful?
2) How much of our time and money should we spend developing new costly products, most of which will never be successful?”

Product portfolio analysis is designed to tackle these two problems and develop organization's strategy in the context of multiple product lines. There are a number of tools available to conduct product portfolio analysis, including experience curve, SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, GE (General Electric) business screen, PIMS (profitability impact of marketing strategy) model, and the BCG (Boston consulting group) growth-share matrix. They enable practitioners and researchers to compare business units and determine their competitive position. In terms of this study, BCG matrix is selected to analyze traffic structure of port of Oslo.

2.2.1. BCG growth-share matrix

BCG growth-share matrix was developed for strategic business planning by Boston Consulting Group (BCG) in 1968 (BostonConsultingGroup 2012), which enables top managers to interpret the performance of their business units by two variables, namely, market share and growth rate. Although the number of companies using portfolio analysis dropped dramatically after 1980s, there are still approximately 27 percent of Fortune 500 corporations using it during corporate strategy determination (Wheelen and Hunger 2009).

Boston Consulting Group (BCG) growth-share matrix (shown in Figure 2.2.1) depicts the performance of organizations. Each strategic business unit (SBU) of a corporation can be plotted in a four-cell matrix according to two variables, market growth rate and relative market share. They are question mark, star cash cow and dog. Market growth rate, sometimes called business growth rate or industry growth rate, is the percentage of market growth of a SBU during a given period. In addition, relative market share, sometimes also called relative competitive position, can be calculated by the ratio of market share of a SBU in a range to that of the largest other competitor. To interpret the result, a SBU with a relative market share above 1.0 can be regarded as market leader (Wheelen and Hunger 2009).

In addition, each SBU is presented by a circle. The sizes of these circles represent the relative significance of each SBU to this focal company. That is to say, the size indicates the actual sales or volume of each SBU. This dimension is crucial because certain SBUs may create a great amount of revenue based on its absolute volume. However, they might look very unattractive to the decision maker in terms of their market growth rate and relative market share. More specifically, a SBU plotted as a dog may generate more revenue than cash cow because the former plays in a big market and it make profits based on its huge absolute volume. However, although the later has a big relative market share, the total market is small.

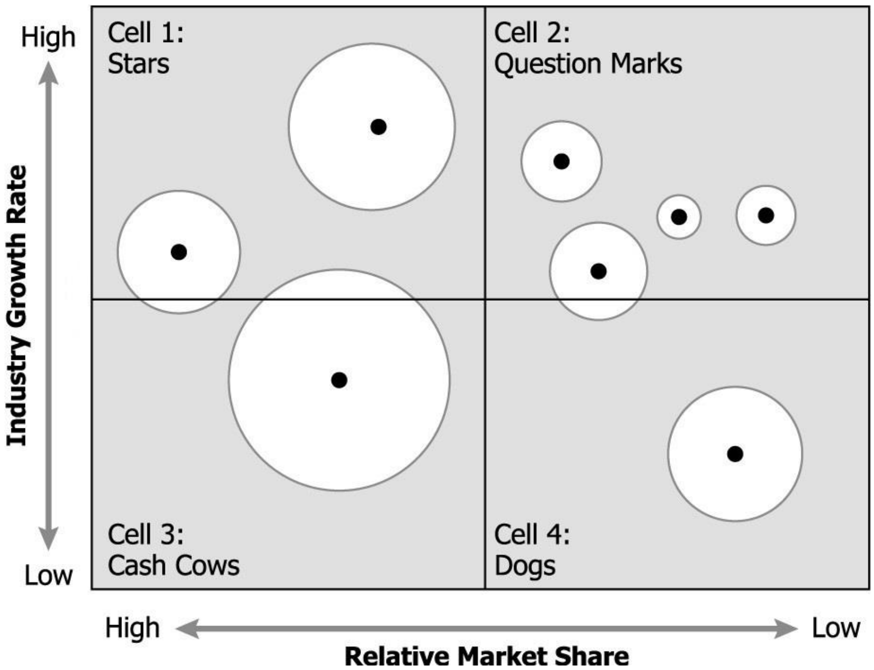

Figure 2.2.1: BCG growth-share matrix (Hill and Jones 1998)

As can be seen from Figure 2.2.1, this matrix is divided into four quadrants by a horizontal line and a vertical line. The horizontal line represents the average growth rate of different type of products (i.e., container, Ro-Ro, parcel, wet bulk, dry bulk) in port of Oslo. And there are different ways to identify the vertical line, which distinguishes the relatively high market share products from relatively low market share products. David Mercer believes that the market share of “Star” should be “as twice as that of the second best in the same market and as triple as that of the third”. This is the rule of 123 (Mercer 1996). He believes that this type of brand leaders should be in a very stable position, otherwise, their leadership is easily changed by their followers. However, this situation is quite rare in the market. So, Wheelen and Hunger (2009) suggested this line should be set at 1.5 times that of the second best. Considering the situation of port of Oslo, 1.5 times is used in this research to separate areas of high and low relative competitive position.

The four quadrants represent four principal categories named as dogs, question marks, stars and cash cows. A successful SBU should move from question mark through star to cash cow and become dog in the end of its life cycle. However, an unsuccessful one will go directly from question mark to dog because it fails to gain adequate market share. Figure 2.2.2 illustrates four stages of a SBU and the corresponding main strategic options for each stage.

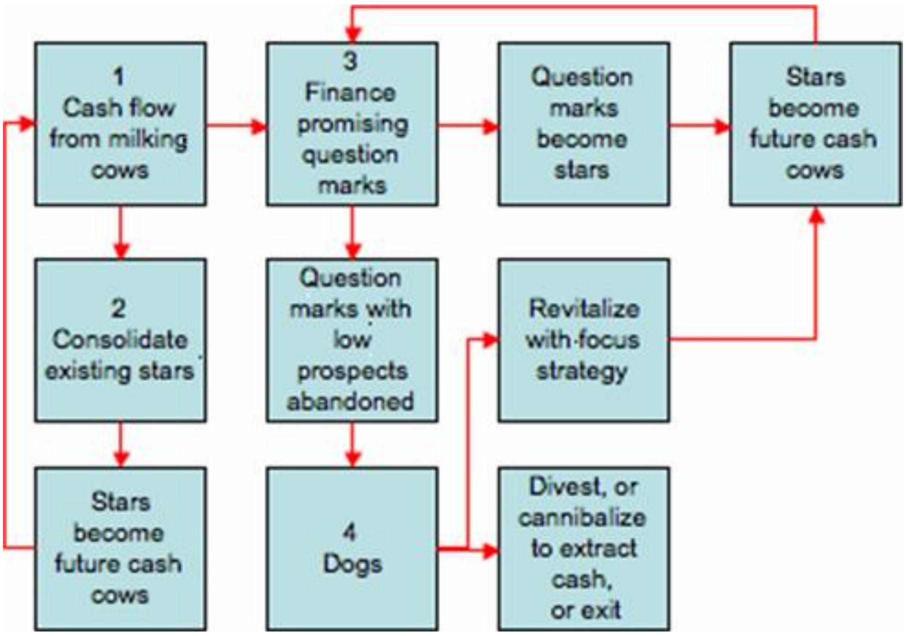

Figure 2.2.2: Strategy flow (Kar 2010)

1) Cash cows normally can generate far more revenue than their needs to maintain their market share. Therefore, every organization would like to own as many as possible. However, in the decline stage of their life cycle, they are “milked” for cash with as little investment as possible because excess investment will be wasted in a market with low growth rate. Cash flow provided by cash cows can be used to finance promising question marks to turn them into new stars, (Arrows in Figure 2.2.3 below illustrates this statement) to finance promotional (such as advertising) and research & development activities and to cover the administrative cost.

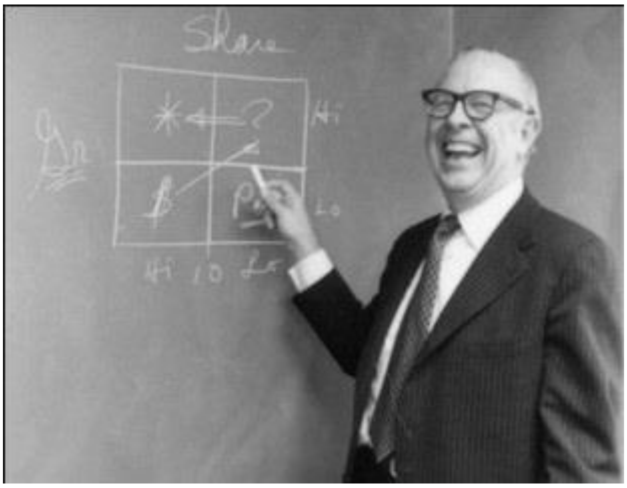

Figure 2.2.3: Bruce Henderson, founder of The Boston Consulting Group

2) Stars are market leaders and at the maturity stage of their product life cycle. Normally, they can roughly balance their net cash flow. Although they can

create a great amount of money, huge investment is also called for due to the strategy of keeping their high growth rate. When these SBU go into the decline stage of their life cycle, they will become cash cows. That is to say, stars are the future cash cows in a corporation's product portfolio to guarantee the future cash flow. They usually represent the best investment opportunity in a corporation and every effort should be made to maintain their market share. If the company fails to keep the competitive position of these stars, they will turn into dogs

3) Question marks are new products. They have potential to obtain success. However, huge investment is called for. If adequate market share is gained, they will turn to stars and have the potential to become future cash cows. By contrast, these SBUs should be divested or shut down at some points. Normally, most of corporations do not have enough cash to finance every question mark. A trade-off should be made to select SBU(s) with high potential to success.

4) Dogs have low market share and growth rate. They normally cannot generate profit for their company and have low potential to become stars due to their poor competitive position. Therefore, a corporation should make every effort to avoid their assets remaining in dogs and sell off SBU(s) in this category unless there are enough reasons to keep them. For instance, some dogs may support other SBUs in star or cash cow category; the company has enough reasons to believe a dog can be revitalized after a turnaround plan. However, such plans are normally expensive.

The top management can utilize this matrix to interpret the performance of their business units by market share and growth rate. Because maintaining a balanced product portfolio is the objective of a company, decision makers can harvest mature products (SBUs in cash cow category) in declining industry to finance new ones (normally question marks) in growing industry.

2.2.2. Advantages and limitations

The BCG growth-share matrix is a well-renowned model used by many multi-product companies because it has many advantages: (Wheelen and Hunger 2009)

1) "It is quantifiable and easy to use;
2) It encourages top management to evaluate each of the corporation's business unit individually and to set objectives and allocate resources for each;
3) It stimulates the use of externally oriented data to supplement management's judgment;
4) Its graphic depiction facilitates communication."

However, BCG matrix also has some limitations: (Wheelen and Hunger 2009)

1) "The use of highs and lows to form four categories is too simplistic;
2) The link between market share and profitability is questionable;
3) Product lines or business units are considered only in relation to one competitor: the market leader;
4) Market share is only one aspect of overall competitive position."

2.2.3. Applying BCG matrix to port industry

BCG growth-share matrix is a general method which can be applied to nearly all industries. Brands can also be regarded as SBUs so that BCG matrix can be used to research the method of brand maintenance (Betts and Taran 2003). This method has also been used in port industry, i.e., (Lin 2009) and (Haezendonck, Verbeke, and Coeck 2006). In Lin (2009), the author applied BCG Matrix to Yangshan Deep-water Port of Shanghai and proposed strategic develop plan for the port authority. According to the result of growth-share matrix (See Figure 2.2.4 below), he suggested the development of container should be given priority due to its star position and promising prospect in this field. The cash flow generated by coal and ore (cash cows) should be used to improve services for cereal, including renewing corresponding quays, constructing new cereal depots and developing related value-added services (i.e., cereal processing services). By contrast, other bulk, like cement, should not be regarded as main business in the future.

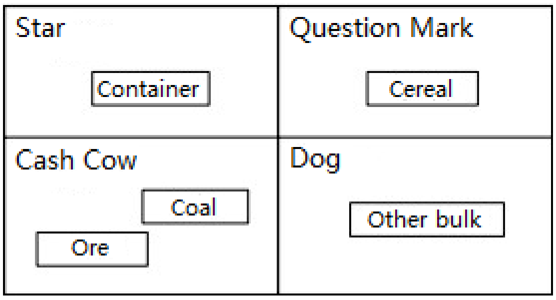

Figure 2.2.4: BCG Matrix for Yangshan Deep-water Port of Shanghai (Lin 2009)

In (Haezendonck, Verbeke, and Coeck 2006), the authors applied BCG growth-share matrix to sea ports in Hamburg-Le Havre range, including port of Amsterdam, Antwerp, Bremen, Dunkirk, Ghent, Hamburg, Le Havre, Rotterdam and Zeebrugge. Their research adopted the four-level BCG matrix which is initially developed to analyze traffic structure of sea ports by Verbeke (1992).

Level 1: "The PPA (product portfolio analysis) compares overall market shares and total growth rates of the ports under consideration (external positioning analysis).

Level 2: The PPA investigates the traffic structure of each individual seaport in the range (internal positioning analysis).

Level 3: Each commodity group in the range is itself viewed as a ‘portfolio of the included seaports’. … As a result, for each traffic category a classification of ports will result according to their market share in the range and their growth rate for that specific traffic category.

Level 4: This level differs from the third ‘level’ in such a way that here the X-axis represents the share of a specific category within a port, rather than the share of this category in the range. And this level introduces an additional dimension to the portfolio analysis: a circular shape with a surface proportional to the absolute traffic volume of the port considered in the total range.” (Haezendonck, Verbeke, and Coeck 2006)

The authors started with an analysis of all ports in Hamburg-Le Havre range, then to the traffic structure inside their focal port (port of Antwerp) and then to individual traffic categories. After that, a dynamic analysis was conducted: They applied BCG matrix several times to reveal the evolutionary trend of a single traffic category during a time period and evaluated the possibilities of future development. Since they do not use the original BCG matrix in their study, the normative implications of this tool, for instance, cash cow can generate stable cash flow and consume a little investment, is not valid. However, this four-level analysis enables these researchers to see the port performance from different levels (port level and traffic category level) when they compared with their corresponding competitors and the evolutionary trends of several focal traffic categories. These results cannot be provided by conventional BCG matrix. The objective of their research is to “gain further insights into port competition” and “improve the thinking and capabilities of the decision makers” (Haezendonck, Verbeke, and Coeck 2006).

In this thesis, I use BCG matrix as follows. There are six traffic categories in the port of Oslo, including passenger, wet bulk, dry bulk, container, Ro-Ro and parcel. Each of them can be considered as a SBU in the BCG matrix. After obtaining the traffic information in a range (defined as Oslo fjord in this research), all SBUs of the focal port (Oslo port in this research) can be plotted in the BCG matrix. It enables port operators to obtain insights into the structure of traffic flows of Oslo port and their competitive position compared with other ports in the Oslo fjord. In addition, it provides a starting point for making plan of future resources allocation for port of Oslo.

Thus the BCG matrix can be used to analyze and illustrate various traffic categories of a port. In this research I use BCG matrix to answer research question 1, finding the most important traffic category for Oslo port. To answer this question, original BCG matrix, the first three levels of Verbeke’s BCG Matrix and their dynamic analysis will be used in this thesis. More specifically, the original BCG Matrix is used to provide a general view of the competitiveness of each traffic category in Oslo port. In terms of

Verbeke's BCG Matrix, level 1 analysis finds the position of the Oslo port in Oslo fjord. After that, level 2 analysis finds the most crucial traffic category in Oslo port. Further, level 3 shows whether this traffic category is also competitive in Oslo fjord. In addition, a dynamic analysis using BCG matrix several times is conducted to see whether the traffic category found in level 2 has maintained its position in the past years.

2.3. Weighting rules

Because handling one ton of cargo of each traffic category can generate different revenue for port, the analysis result of comparing different traffic categories for a port may be misleading when nominal ton is used; therefore, the concept of value ton will be adopted in the BCG Matrix analysis. Value ton philosophy is to consider the impact of value added in the cargo handling process. There are four weighting rules in literature till 2002, namely Hamburg rule, Bremen rule, Rotterdam rule, Dupuydauby rule and Antwerp rule (Meersman 2002).

1) Hamburg rule suggests that "the value added created by one tonne of conventional cargo corresponds to that of five tonnes of dry bulk and fifteen tonnes of liquid bulk".

2) Bremen rule suggests that "the value added created by one tonne of general cargo (conventional cargo, Ro-Ro and containers) equals the value added of three metric tonnes of dry bulk and twelve tonnes of liquid bulk".

3) Rotterdam rule suggests that "the value added created by one tonne of conventional cargo equals that of approximately 2.5 tonnes of oil products, 3 tonnes of containers, 4 tonnes of cereals, 7.5 tonnes of other bulk, 8 tonnes of Ro-Ro traffic, 10 tonnes of coal, 12.7 tonnes of iron and 15tonnes of crude oil".

4) Dupuydauby rule "attributes the following coefficients to the different traffic categories: 12 to crude oil, 9 to liquid bulk, 6 to dry bulk, 3 to containers and roll on-roll off and 1 to conventional cargo, whereby the latter is considered as the benchmark".

Meersman developed the Antwerp rule in 2002 since the methodological foundation and data used for the other rules are kept confidential. That is to say, Meersman was not sure whether these four rules are suitable to his research. Antwerp rule assigns the following coefficients to different traffic categories: fruit: 1; "other conventional cargo: 1.6; forest products: 3; iron ore: 3.5; cars and vehicles: 1.5; other Ro-Ro: 3; container: 7; other dry bulk: 10; fertilizers: 8; iron and coal: 11; cereal: 12; other liquid bulk: 5 and crude oil: 47" (Meersman 2002).

The Hamburg rule and Bremen rule are too simple since the former only considers conventional cargo, dry bulk and liquid bulk, while the later does not distinguish conventional cargo, Ro-Ro and containers. By contrast, Rotterdam rule and Antwerp rule seems complicated for current study because only the information of conventional cargo, dry bulk, liquid bulk, containers and Ro-Ro is available for ports located in Oslo fjord from statistical yearbooks of Norway published by SSB. Therefore, Dupuydauby rule will be adopted into this study.

Unfortunately, the author fail to testify whether Dupuydauby rule is appropriate to this study due to the reason given by Meersman. That is to say, there might be a problem when this theory is applied to the current project. Keeping this limitation in mind, Dupuydauby rule enables us to consider the impact of value added concept in the cargo handling process for each traffic category. This rule is applied in Chapter 4.

2.4. Productivity and efficiency measures

In this section, the author describes several commonly used methods of measuring productivity and efficiency and discusses the advantages and disadvantages of them. After that, the most suitable approach is selected for this project. These methods are:

Partial productivity measures (PPM)
Date envelopment analysis (DEA)
Stochastic Frontier Approach (SFA)

2.4.1. Partial productivity measures (PPM)

Partial productivity measures (PPM) is the most traditional and popular method to compare the performance of different units (i.e., seaports or airports). This measure is conducted by calculating the ratio of two variables and, as the name indicates, it provides partial information for a selected aspect of performance, such as, cost efficiency or productivity. That is to say, the objects of this kind of measurement are components of the total productivity. Appendix I provides a collection of PPM indicators. Although this indicator list is made for airports initially, all indicators in this list can be applied to port industry. (verified by an interview with professor in transportation economics, Svein Bråthen, HiMolde)

2.4.1.1. Typical solutions of PPM

Seppo Saari (2006) proposed several solutions of (ways to use) PPM. They are:

1) “Single-factor productivity
2) Value-added productivity
3) Unit cost accounting
4) Efficiency ratios”

Single-factor productivity refers to a PPM measured by the ratio of output/outputs and only one input variable. A well-renowned single-factor productivity PPM indicator for port is WLU per employee. WLU refers to workload unit which is a combination of passengers and cargo handled by a port. When researchers regard the added value as output, the measurement of productivity is called value-added productivity. Unit cost accounting means productivity is evaluated by unit cost. Cost information normally can be extracted from annual financial statements of the focal company. Efficiency ratios refers to the ratio between the value produced and the cost generated for it (Saari 2006).

For each of these solutions, productivity can be calculated by the ratio between certain outputs and input variables. In terms of port productivity, the outputs include cargo throughput and passengers, while the major inputs are labor and capital (number of cranes, quay length and terminal area). Labor can be measured in both physical and financial way. For example, it can be measured in terms of number of employees or in terms of human resource cost.

2.4.1.2. Benefits and drawbacks

Using PPM to measure productivity is easy to calculate and understand. This characteristic of PPM explains its popularity. Managers also find this method useful, as it can provide information on the relative performance between ports.

However, these simple indicators have some inherent drawbacks. These drawbacks will give rise to misleading results unless certain remedial measures are taken. Rico Merkert et al. (2010) conducted an elaborate reference search and summarized four drawbacks. Although their research is focused on airport efficiency, their findings can also be applied to seaport industry since PPM is a common method and can measure performance for companies in any industry. Their findings are:

1) PPM analysis might be misleading when the compared companies have different vertical integration structures. To increase competitiveness, almost every seaport authority outsources certain functions to third party service providers. The motivations for outsourcing are various. Functions may be outsourced due to lack of qualified staff, financial reasons, political reasons and other risks. More specifically:

    A. Port operators fail to hire adequately experienced employees and/or are unable to manage certain process properly.
    B. Port operators believe it is much more economically efficient if they outsource certain functions

C. Port operators may look for a way to avoid the administrative burden. Such as, avoid recruiting additional employees and unnecessary labor disputes.
D. Port operators fail to adequately provide the needed capital to equip certain functions; therefore, they have to rely on service providers.
E. Port operators may seek to transfer risk. They are willing to outsource certain processes which may be risky or likely to result in public criticism. (Fawcett 2006)

Port operators are normally responsible for the overall management of the port and may outsource certain functions according to their own situation; therefore, there will be a great variation in the degree of outsourcing between ports. The result of PPM will be influenced by ports' outsourcing decisions. For example, a well-known PPM indicator, labor productivity, is used to compare the performance of port A, B, C, which is calculated by the ratio between output and employee number. Port A outsources only loading and unloading process to a third party service supplier. Port B outsources nearly all services. Thus, there are many actors operate in port B, including stevedores, customs brokers, pilot and towage companies and other companies providing channel maintenance, information systems and HR services. On the contrary, port C keeps all activities in house. Even in the area of retail activities. They do not use concession contracts and recruit employees directly to operate all stores in their port. Obviously, it is very likely that the PPM result of port B is better than A, followed by C. That is to say, a port that outsources a high percentage of activities will inevitably be regarded as having higher labor productivity than another port that keeps high proportion of activities in-house in terms of PPM, unless the later achieves an extremely outstanding performance. (Rico Merkert 2010)

Standardizing the data would be one feasible solution to this problem. By doing this, each port is considered as undertaking a uniform set of activities. In practice, researchers can assume ports only operate their core services and outsource the others to service providers, such as souvenir and duty-free shops. If certain ports keep these activities in-house, the related cost, labor and revenue should be excluded from PPM analysis. This method is researched by University of Westminster, Cranfield University and Jacobs Consultancy (Rico Merkert 2010).

2) Another drawback will appear when a port authority administrates several ports. There would be some central administration cost. If this cost is not assigned to each individual port, cost efficiency indicators will be misleading, such as, total operation cost per passenger. For instance, Karmsund Port Authority is a joint organization of port operations in the municipalities of kin, Bomlo, Haugesund, Rogaland, Sveio and Tysvær. Figure 2.4.1 shows this

situation. If we compare the cost efficiency between Bomlo port and Haugesund port, head office cost should be apportioned to these two subsidiaries.

Indeed, when researchers meet these two situations described in this section (degrees of outsourcing and port groups), they can standardize data, thereby conducting a more meaning and reasonable comparison. However, after adjustments the standardized data departs from reality. Therefore, another solution is to compute PPM indicators using the original data without standardizing. And then, researchers should explain the results considering the variation in degrees of out-sourcing and port structure. (Rico Merkert 2010)

Figure 2.4.1: Karmsund Port Authority

3) Economic regulation and operational restrictions can also influence performance comparison. Especially, if two ports are located in different countries. The one that operates in the context of heavy price control policy will be more difficult to make profits than the other one that operates in the background of deregulation. (Rico Merkert 2010)

4) The use of different currencies can impact the comparison results. Definitely, official exchange rates can standardize different currencies. However, this method ignores the difference in price levels between countries. Especially, two selected countries have a great different in living costs. Purchasing Power Parity (PPP) is a commonly used solution to this problem. This solution

considers relative price levels between countries, which enables researchers to adjust exchange rates in a more reasonable way. (Oum and Yu 1997) Besides, the special drawing right (SDR) can also tackle this problem and has been used in previous researches. (Rico Merkert 2010)

2.4.1.3. Previous studies using PPM

Jürgen Müller (2012)

Responding to the request from Norwegian Ministry of Transport and Communications, a project reported in Müller (2012) conducted a cost efficiency benchmarking study for all airports owned by Avinor AS (the Norwegian National Airport System).

The data analysis method and PPM indicators used in this research can be used for seaports because there are a great number of similarities between airport and seaport: they have same types of output, passengers and cargo. Besides, PPM is a general method to conduct productivity analysis for an organization and make comparison among several organizations. This method can be applied to seaport, airport and companies in other industries. Jürgen Müller (2012) divided all PPM indicators into four principal categories:

1) Profitability. Normally, outputs refer to some physical items including number of passengers and amount of cargo in terms of port industry. However, when profitability is considered, passengers can be regarded as input and revenue is output. Finally, Jürgen chose EBIT (earnings before interest and taxes) as an output variable. This is because, EBIT will not influenced by interest paid or received and income tax rate.

Categories	PPM indicators
Profitability	EBIT per passenger
Revenue generating capability	Aeronautical revenues per passenger
	Commercial revenues per passenger
Cost efficiency	Total operating costs per passenger
Labor productivity	Number of passengers per employee
	Total revenues per employee

Table 2.4.1: PPM categories and PPM indicators

2) Revenue generating capability. Aeronautical and commercial (such as duty-free shop) activities are the main activities in an airport. This project considered these two variables separately to evaluate revenue generating capability of airports.

3) Cost efficiency. Total operating cost efficiency is a normal used indicator to assess cost efficiency. Total operating cost normally includes depreciation.

4) Labor productivity. This research assessed productivity from both physical and monetary measures.

The decision whether or not apply these PPM indicators to the present project will be made according to the situation of Oslo port. Related discussions can be found in Section 5.2: The selection of PPM indicators.

2.4.2. Data envelopment analysis (DEA)

As mentioned in section 2.4.1, PPM is the most commonly used method to compare the productivity among organizations for several reasons, including easy to compute, only limited information required, easy to understand and easy to interpret. However, if only PPM is used to measure performance, the results may misleading. And hence the whole picture might not be captured by readers. Normally, efficiency is determined by a set of inputs and outputs factors. Besides, certain strategic decisions made by port authorities can immediately and dramatically influence productivity computed by PPM, such as, purchasing equipment to replace labors and outsourcing certain non-core activities. Therefore, in general, a more sophisticated measure is often used to give a complete picture of port performance.

I discuss DEA here in order to show that even if DEA is more comprehensive than PPM, it give only marginal additional information over PPM in order to answer my research questions. In addition, DEA require much more input data than is available for this master thesis project. The reason of adopting PPM in this thesis rather than more sophisticated methods (i.e., DEA and SFA) will be discussed in detail in Section 2.4.4.

2.4.2.1. Definitions for important terms

There are many words can express extremely similar meanings in informal occasions. They are productivity, efficiency and effectiveness. In section 2.4.1, productivity and efficiency are used interchangeably. However, an explicit definition should be provided for each term to avoid misleading before conducting this more sophisticated efficiency measure (DEA):

1) "Productivity refers to the ratio between output(s) and input(s)"(Rico Merkert 2010). Comparison is intuitively easy that the port with the relatively lower ratio is regarded as a poor performer. However, there is no frontier or benchmark to enable decision makers to determine whether this relatively better performer is efficient. This production frontier can be defined from a set of best practices utilizing different inputs or by economic or financial models. This is a flaw of PPM because PPM does not measure efficiency (see infra, definition of "efficiency").

2) "Effectiveness, unlike productivity, refers to the degree to which the outputs of a service provider achieve the stated objectives of that service" (Rico Merkert 2010). The port authorities or operators may announce certain objectives for daily operation. Effectiveness tells to what extent these objectives are met.

3) "Efficiency … refers to the degree to which productivities defined above … match the optimal productivity" (Rico Merkert 2010). Therefore, the term, efficiency, resolves the aforementioned problem of productivity.

2.4.2.2. Differentiation of efficiency concepts

There are three types efficiency normally used in the literature of economics: technical efficiency, allocative efficiency and cost efficiency. I describe these concepts before considering methods to measure efficiency.

1) "Technical efficiency … refers to the conversion of physical inputs, such as labor and capital, into outputs relative to best practice" (Rico Merkert 2010). More specifically, that a port operates on the frontier implies it is 100% technically efficient. Frontier refers to the observed efficient trade-off among inputs and outputs within a set of ports. If a port operates below the production frontier, it is a technically inefficient port. This port does not use resources optimally and waste some of them. Technical efficiency can be computed via the ratio between real performance and the best practice. (Rico Merkert 2010)

2) "Allocative efficiency … refers to whether inputs, for a given level of output and set of input prices, are chosen to minimize the cost of production assuming that the" port being examined is fully efficient (Rico Merkert 2010). This term puts emphasis on whether the examined port chooses the right mix of inputs. It is calculated in the same way as technical efficiency. 100% allocative efficiency implies a port has already minimized its costs. It is also worth to note that a 100% technical efficient port may not be allocatively efficient because this port does not use the right mix of input to minimize its costs. This point will be described in more detail later. (Rico Merkert 2010)

3) "Cost efficiency which refers to the combination of technical and allocative efficiency" (Rico Merkert 2010). If a port meets the requirements of technical efficiency and allocative efficiency simultaneously, this port is cost efficient. It is computed as the product of technical and allocative efficiency scores. Therefore, a port can achieve the target of 100% cost efficiency only if this port is 100% technical efficient and allocative efficient (Rico Merkert 2010).

To illustrate these three types efficiency more clearly, Figure 2.4.2 is used (Rico Merkert 2010). As can be seen from this figure, two input variables labor and capital are considered to produce services, such as loading service. Curve BA*C is isoquant: locus of points with minimum input use required to produce a given output. That is to say, Curve BA*C is also a technical efficiency frontier. The budget line A**C plots a set of capital-labor mix with the same input cost. Therefore, to produce the given output, the cost will be minimized when curve A**C (budget line) is tangent to curve BA*C (efficiency frontier). The port achieves cost efficiency at the tangency point, C, because this port meets the requirements of technical efficiency (point C on the budget line) and allocative efficiency (point C on the efficiency frontier) simultaneously. For a port operating at the point B, it is technically efficient but not allocatively and costly efficient. (Rico Merkert 2010)

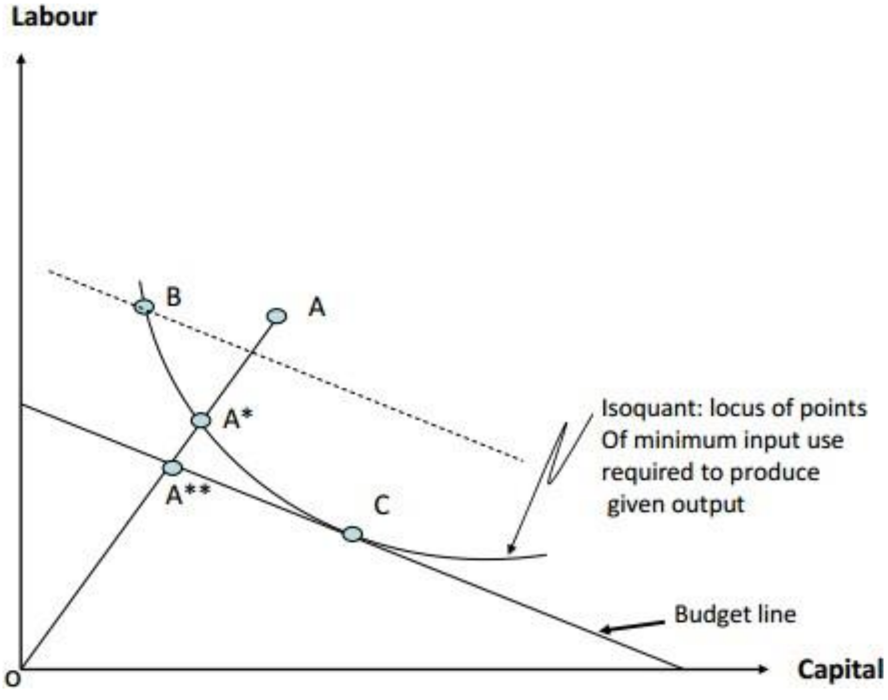

Figure 2.4.2: Three types of efficiency (Rico Merkert 2010)

2.4.2.3. Returns to scale

Returns to scale is another important concept in the field of efficiency measurement. "It refers to changes in output resulting from a proportional change in all inputs (where all inputs increase by a constant factor)" (Rico Merkert 2010). There are three types of returns to scale. See Figure 2.4.3. If output changes at the same proportion with the change of input, there are constant returns to scale (line OBY in figure 3). If output changes at a lower rate than the change of input, there are decreasing returns to scale. In contrast, if output changes at a greater rate than the change of input, there are increasing returns to scale. When there is a mix of returns to scale, variable returns to scale exist (line XaCBAZ in Figure 2.4.3) (Rico Merkert 2010).

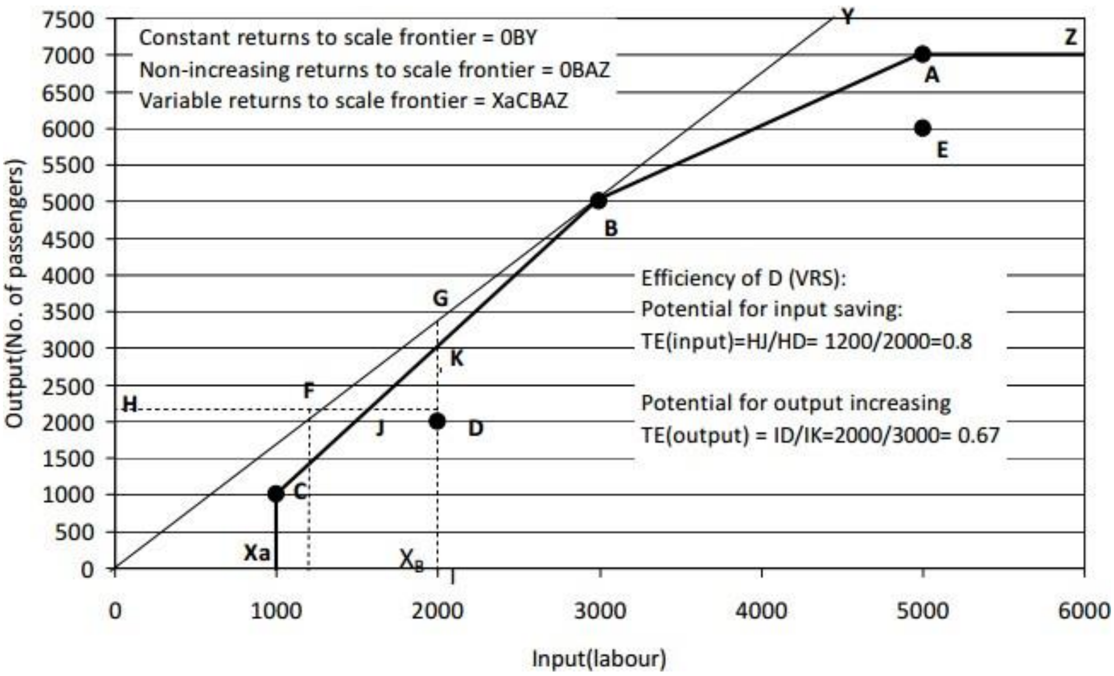

Figure 2.4.3: Returns to scale (Rico Merkert 2010)

2.4.2.4. The Data Envelopment Analysis (DEA)

In terms of efficiency analysis, DEA, a linear programming approach, is considered as one of the most successful and well-accepted techniques. This approach can be applied to nearly any industry and any organization or business unit within an organization. More specifically, DEA initially developed for the purpose of assessing the performance of non-profit organizations, since profits are not the objective of these organizations. From this point onwards, DEA has gradually realized by researchers and been applied to many industries, including transportation, health, agriculture, banking, etc. (Rico Merkert 2010). DEA can be used to assess the relative efficiency of a decision making unit (DMU) on the basis of the best observed practice within this group. This DMU can be a whole organization, such as Oslo port authority, one separate terminal within this port group, such as container terminal, or a business unit within container terminal, such as terminal activities (Rico Merkert 2010).

The principle of calculating relative efficiency utilizing DEA approach is easy: the best practice frontier should be firstly defined by a set of the most efficient DMUs within a group, the relative efficiencies of the remains, hence, can be calculated by their distance from this production frontier. A main advantage of DEA compared with

PPM is that a combination of inputs and outputs can be considered simultaneously. However, PPM is a single factor approach. Thus, DEA enables researchers and decision makers to see the whole picture of a port's performance relative to other ones in the same group. The input can be variable or fixed. The value of variable input can be changed in the short-run, while the value of fixed input can be changed only in long-run. Besides, DEA can be divided into output and input oriented. Output oriented DEA aims to determine the maximum output level given the current used input, while input oriented DEA allow researchers to determine the minimum input level given the observed output (Rico Merkert 2010).

2.4.2.5. Advantages and drawbacks

As discussed above, DEA is one of the most commonly used and successful approach in the field of efficiency evaluation. Indeed, it has many advantages:

1. DEA is easy to master and understand for decision makers. The relative efficiency of a DMU is its distance from the frontier.
2. DEA enables researchers to combine multiple inputs and outputs.
3. DEA enables managers to discover the cause of inefficiency. This is because, in terms of DEA, cost efficiency can be divided into technical efficiency and allocative efficiency. Further, technical efficiency can be decomposed into scale effects and non-scale effects.
4. DEA is also a tool for benchmarking. Defining the best practice frontier, researchers can divide a group of DMU into two groups: one operates on the frontier, which are 100% efficient. The other can see the distance from the best practice and try to improve.
5. DEA enables researchers to study efficiency over time using the Malquist productivity index. (Rico Merkert 2010)

Although DEA is the most successful approach to measure efficiency, it also has some drawbacks:

1. DEA measures relative efficiency only. The DEA score is the ratio between real practice and best practice. Hence, it is meaningless to compare DEA scores across different studies.
2. DEA is a deterministic rather than an econometrical approach. Therefore, it is sensitive to noise. However, SFA does better in this field (see section 2.4.3, SFA– an alternative approach to DEA). It is also worth to note that DEA has recently been developed the same ability.
3. DEA scores have a positive relationship with the number of inputs and outputs and a negative relationship with the sample size. More specifically, if the number of inputs and outputs increases, the number of DMU will decrease relatively. This means that decreasing observations relative to the number of inputs and outputs will reduce the opportunity to find a comparison partner for

each DMU. Therefore, each DMU has more possibility to be the observed best practice and obtains a higher DEA score. In contrast, increasing sample size can reduce DEA score for each DMU. There is a rule of thumb: "the number of DMU should be at least three times greater than the total number of inputs and outputs".

4. DEA requires much more information than PPM (Rico Merkert 2010).

2.4.2.6. Input and output selection in previous researches

This research does not adopt DEA as an analysis method. However, input and output variables selected in previous researches can be learned from. Therefore, the table below illustrates variables in several recent studies.

Paper	Inputs	Outputs
Schøyen and Odeck (2013)	Berth length, terminal areas, yard gantry cranes, straddle carriers and container handling trucks	Container throughput
Cullinane and Wang (2010)	Terminal length, terminal areas, quayside gantry, yard gantry, straddle carrier	Container throughput
Hung, Lu, and Wang (2010)	Terminal area, ship-shore container gantry, number of container berth, terminal length	Container throughput
Yuen, Zhang, and Cheung (2013)	Number of berth, total length, port land area, quay crane, yard gantries	Container throughput
Wu and Goh (2010)	Terminal area, total quay length, pieces of equipment	No. containers

Table 2.4.2: Input and output selection in previous researches

As can be seen from Table 2.4.2, the selected input variables are similar in all these papers. In terms of this study, the most commonly used ones, including berth length, terminal area, and number of cranes (ship-shore container gantry), are selected as input variables.

2.4.3. SFA – an alternative approach to DEA

Stochastic Frontier Approach (SFA) is another commonly used approach to assess port efficiency. A major difference between DEA and SFA is that the latter one is a parametric approach and the former one is not. SFA defines frontier by a well-defined production function which describes the maximum feasible outputs (Rico Merkert 2010):

$$y_i = f(x_i; \beta) + v_i$$

Where, y_i denotes the output of port i; x_i is the vector of actual amount of inputs of port i; β is a vector of estimated parameters; and v_i is random error (Rico Merkert 2010).

In terms of SFA, technical efficiency (E_i) can be defined as the ratio between observed output and maximum feasible outputs (Rico Merkert 2010):

$$E_i = \frac{Y_i}{f(x_i;\beta)+v_i} \text{ (Rico Merkert 2010)}$$

As in the case of DEA, a port can achieve 100% technical efficiency only if it achieves the maximum output. Other ports which do not achieve 100% technical efficiency can see their distance to the maximum output. A major advantage of SFA is that SFA is an econometrics approach which is inherently able to capture noise in the data. However, SFA also has some disadvantages. It requires a production function. In many situations, service output is hardly expressed in a mathematical way. Further, SFA will become very complicated when there are more than one output (Rico Merkert 2010).

2.4.4. Discussion and relevance for my research questions

PPM can potentially give the misleading results of the performance of the analyzed port. As a consequence, more researchers are willing to apply more sophisticated approaches recently, such as TFP, SFA (non-parametric methods) and DEA (parametric methods). The inherent advantage of these methods is that "they consider multiple inputs and outputs together to produce a single efficiency measure" (Rico Merkert 2010). That is to say, researchers who apply these more sophisticated approaches can avoid making assumptions that are required when they use PPM. If port performance is measured for a single point in time, DEA is a better technique than SFA for the reason that DEA does not require "assumptions on production/cost functions and cost minimizing behavior that SFA requires. In addition, DEA models can produce robust results with substantially smaller samples than SFA and without any information on the prices of the used inputs" (Rico Merkert 2010).

To sum up, all the methods mentioned above in this section can be applied to conduct the project of assessing the performance of Oslo port if adequate data is available. Further, DEA and SFA are more powerful methods than PPM and preferred by most of researchers recently. However, PPM is selected as a data analysis method in this project to answer my research question 2 since the more comprehensive methods only gives marginally more information related to my question, and since the data required for these methods are not available.. Although PPM has four drawbacks which are discussed in Section 2.4.1.2, they will not influence the result of this project. More specifically, there is only one focal port in this study and its vertical integration degree did not change during the last ten years; therefore, the first two disadvantages will not influence this study. In addition, the last two disadvantages only influence the results when compared ports are selected from different countries. Therefore, they also will not influence the results of this study.

Despite the limitations in PPM analysis, it has a great advantage compared other sophisticated performance measuring approaches, including DEA and SFA. PPM can narrow the analysis scope and cast light on this specific performance segment which cannot be considered carefully when SFA or DEA is implemented. In addition, it also enable researchers to compare performance over time, if the degree of vertical integration has not changed during this period (Rico Merkert 2010). This present project can benefit from this advantage of PPM because one purpose is to see the performance changes of Oslo port during the last ten years.

Although PPM requires much less information than the other two methods aforementioned, the task of data acquisition is still quite challenging since port performance involves many companies and they might be reluctant to share detailed statistics on operations. Traffic data is normally easily obtainable from annual reports of seaport authority. It is hard to get access into capital (i.e. number of cranes, terminal square meters, and quay length) and employee data. The author has to communicate with port authority and collect certain primary data. Thus, the success of obtaining all needed data is fully depends on supervisor's support and good-will. Expect of annual reports of Oslo port and statistic yearbooks published by SSB, primary data is collected for this analysis by interviews and direct observation. Given that all needed data is accessible, PPM is inherently easy to calculate, master and interpret. Considering the challenging of data requirements, the purpose of this project and the advantages and disadvantages of these three most commonly used performance measurement method, partial productivity measures (PPM) should be the best suitable approach to this project.

2.5. Performance measurements for port industry

Performance measurements are crucial for all types of organization, including privately owned corporation, state owned corporation and non-profits organization (i.e., Oslo port authority) because they illustrate the extent to which these organizations have achieved their targets. Therefore, a set of proper performance indicators are of importance to any organization.

2.5.1. Woo, Pettit, and Beresford (2008)

Woo et al. believe different interest groups in ports have their own preference on performance indicators and their preference may differ from one to another. Therefore, they selected four groups to conduct a survey, including port operating companies (POC), shipping companies (SC), public sector organizations (PS, i.e., government and port authority) and academics (AC). Although academics are not stakeholders of a port, they believe academics have knowledge on logistics and port industry and may have broader perspective of future issues. One hundred questionnaires were sent by email during their survey and 72 responses were received (Woo, Pettit, and Beresford 2008).

They generated a port performance measurement framework according to the 72 responses in the survey. This framework is shown in Table 2.5.1. As can be seen from this framework, they defined 7 indicator categories. Each of them includes two or four performance indicators.

Aspect	Selected Indicators
Efficiency	Throughput Throughput per crane Ship around time Average ship waiting time before unloading
Service Quality	Timeliness Reliability
Price	Total price (total cost derived in port) Cargo handling charge
Customer orientation	Responsiveness Flexibility
Connectivity	Waiting time for mode change Working time for mode change
Value-added activities	Cargo from value-added activities Value-added from value-added activities
Security and Safety	ISPS compliance Number of accidents in port

Table 2.5.1: Port performance measurement framework (Woo, Pettit, and Beresford 2008)

2.5.2. Woo, Pettit, and Beresford (2011)

Three years later, they published a follow up of their study. They generated a new and more comprehensive port performance measurement framework based on their previous work and other literatures. However, the indicator, port cooperation, was not identified from literature. Hence, and they did not specify it (See Figure 2.5.1). After generating this new framework, they use confirmatory study to validate this multi-dimensional port performance measurement framework. During this study, 100 questionnaires are sent to the same four groups, namely POC, SC, PS and AC. See Figure 2.5.1 in the next page.

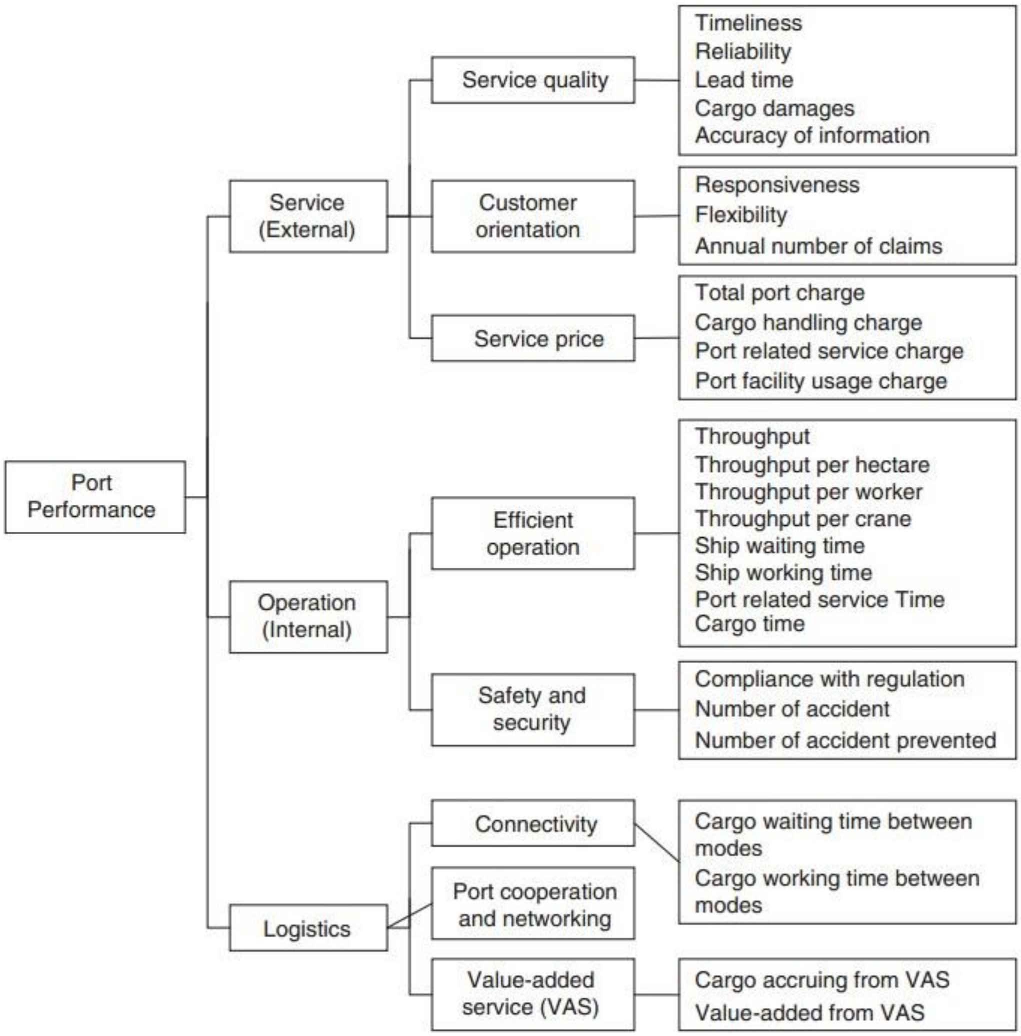

Figure 2.5.1: New port performance measurement framework (Woo, Pettit, and Beresford 2011)

This framework will be used in the current study. A comparison will be made between the currently used indicators by Oslo port authority and this framework and reasons of differences between them will be identified. Further, potential suggestions will also be made both for Oslo port authority and this framework.

3. Methodology

This chapter will present the research method applied to this project and the procedures of implementing this method. The objective of this chapter is to provide a theoretical foundation for this research.

3.1. Case study as a research method

The objective of this research is to explore the productivity of Oslo port and analyze how to improve its performance by performance indicators. As mentioned in Section 1.2, according to the six research questions and this overall objective of this project, case study should be considered as a suitable research method for this project because case study suits such an occasion that "a how and why question is being asked about a contemporary set of events, over which the investigator has little or no control" (Yin 1994). In this book, the author mentioned three types of case studies, explanatory case study, exploratory case study and descriptive case study.

This research has an explorative nature due to the first part of my objective: to explore the method to find which traffic category is the most important to Oslo port authority; and to explore the method to judge whether the specific terminal in port of Oslo has improved its performance during the past ten years). In addition, this research also has an explanatory nature due to the second part of its objective (Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to the case study?).

According to Leedy and Ormrod (2012), explanatory case study is the most frequently used method in case study. The purpose of that is to test or generate a theory. The researcher should consider "in what way does his/her case study contributes to our knowledge about some aspect of the human experience" (Leedy and Ormrod 2012). By contrast, In terms of an exploratory case study, the investigator should carefully consider the following three questions: (Yin 1994)

1) "What is to be explored?
2) What is the purpose of this exploration?
3) What are the criteria by which the exploration will be judged successful?"

The first question refers to the research question 1 and 2, which are addressed when developing the research questions in Section 1.2. And Section 1.1 explains the purpose of this research. The criteria can be defined in the following ways:

1) Suitable information can be collected, which is enough to accomplish this research
2) Reasonable data analysis approaches are applied.

Data has been collected as described in Section 3.3 of this chapter. To answer research question 1, in terms of criteria 2, BCG Matrix is a reasonable approach since it is the most commonly used method. To answer the second research question regarding the historic development of port productivity for Oslo port, PPM is selected as a data analysis method as discussed in Section 2.4.4.

3.2. Research design

"In the most elementary sense, the design is the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions. Colloquially, a research design is an action plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions" (Yin 1994). To get "there" from "here", a number of steps should be taken, including presenting propositions, assessing the quality of research design, collecting data, etc. these steps will be discussed in detail in the following.

3.2.1. Five components of research design

In terms of case study, five component of research design should be considered carefully. The first three components are about what data is to be collected, while the last two tell the investigator what should be done after the data collection activities. "Although the current state of the art does not provide the guidance on the last two components, the complete research design should not only indicate what data are to be collected" (Yin 1994). The five components are:

1) A study's question

   The overall research question is to measure the productivity of Oslo port and analyze how to improve its performance by performance indicators, which can be specified in 6 sub-research questions:

   A. Which traffic category is the most important one for Oslo port?

   B. Whether Oslo port has improved its productivity for the most important traffic category during the last ten years?

   C. Does the performance indicators used by Oslo Port differ from the ones used by the framework published by Woo et al. in 2011? If so, what are the reasons?

   D. How can the performance of Oslo port be improved for the most important traffic category?

E. Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?

F. Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to this case study

2) Its propositions
Only research question 2 has proposition: The productivity of the specific terminal in port of Oslo has improved during the last ten years.

3) Its unit of analysis
Performance of port of Oslo for the most important traffic category

4) The logic, linking the data to the propositions

The relative literatures aforementioned in Section 2 and the collected data (both primary and secondary data) will together test the validity of this proposition and answer these six research questions.

5) The criteria for interpreting the findings

All findings in this research will be interpreted according to the specific situation of focal terminal. Comparing the productivity of the same terminal between different time periods can dramatically reduce the disadvantages of PPM.

3.2.2. Quality of research design

Testing the quality of a research design is an important step. There are four tests which are the most commonly used approaches. They are construct validity, internal validity, external validity and reliability. These four tests will be used to assess the quality of this current project in this section.

3.2.2.1. Construct validity

Construct validity refers to "establishing correct operational measures for concepts being studied (Yin 1994)". Yin (1994) identified three case study tactics for increasing the construct validity, namely, using multiple sources of evidence, establishing chain of evidence and having key informants review draft case study report.

Multiple sources of evidence are used in this study, including annual reports from ports and government department, statistical reviews, online database, scientific journals, master and PhD thesis in this field and interviews (also see Section 3.3).

3.2.2.2. Internal and external validity

Internal validity is a criterion for judging the quality of explanatory studies only, which refers to "establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationship" (Yin 1994). Figure 6.2 shows this relationship. In contrast, external validity deals with the problem of "whether a study's findings are generalizable beyond the immediate case study" (Yin 1994). Leedy and Ormrod (2012) mentioned a strategy, a real-life setting, that can improve the external validity of a research. The rationale of this strategy is that a study conducted in the context of real life is more valid than a case conducted in a laboratory where an artificial setting of environmental conditions is tightly controlled. Because this case study is conducted in the context of real life setting, the applicability of the findings of this research should be possible.

3.2.2.3. Reliability

The objective of reliability is to make sure that "if a later investigator followed exactly the same procedures as described by an earlier investigator should arrive at the same findings and conclusions" (Yin 1994). The criterion of reliability aims to minimize the errors of a study. Yin (1994) also proposed two ways to increase the reliability of a research, using case study protocol and developing case study data base. During the process of this case study, a case study data base is developed, which includes all the pieces of information (both primary and secondary data) used in this projects.

3.3. Collecting evidences

There are six sources of evidence normally considered during the process of data collection: "documentation, archival records, interviews, direct observations, participant observation and physical artifacts" (Yin 1994). All these six sources have its advantages and disadvantages. That is to say, a good case study should use as many sources of evidence as possible. The author went to Oslo port at 7th May 2013 to interview the terminal advisor of port of Oslo and observed the Oslo port directly. Due to the problem of accommodation cost, the author does not have enough time to use participant observation in this study. Aerolite could be a physical artifact for certain astronomical researches and this type of evidence is not suitable for my case. Therefore, in this study, the first four sources are used:

Types of sources	Evidences used under this type of source
Documentation	See reference and Section 3.3.2 below
Archival records	See reference and Section 3.3.2 below
Interview	Face to face interview Telephone interview
Direct observation	Direct observation

Table 3.1: Types of sources used in this study

3.3.1. Collecting primary data

"Primary data means original data that has been collected specially for the purpose in mind. It means someone collected the data from the original source first hand (NAVEEN 2012)" Compared with secondary data, it has several advantages in these fields, including validity, reliability and authenticity. However, time consuming and high cost are the two main disadvantages of collecting primary data.

Sources for primary data are limited and it is difficult to obtain due to lack of cooperation. Normally, there are five ways to collect primary data: experiments, survey, questionnaire, interview and observation. In terms of this project, interview and observation are used for data collection.

3.3.1.1. Face to face interview

Face to face interview has greater advantage than telephone interview because the interviewer can observe the body languages of respondents, thereby getting a better understanding. Mehrabian (1981) pointed out that body language can deliver as high as 55 percent of all information in a communication. During the period of this research, two face to face interviews are arranged, interview with Carl Johan Hatteland, terminal adviser at Port of Oslo and interview with Geir Berg, Business advisor at SITMA which is a leading consulting company in logistics, strategic and operational development of value chains. However, as mentioned above, collecting primary data calls for high cost. Therefore, telephone interview is also used in this project. The main interview guides can be found in Appendix II. In addition, several meetings with Professor Svein Bråthen are hold, from which the author obtained many useful advices.

3.3.1.2. Telephone interview

Telephone interview can also enable researchers to ask open ended questions and get explanation of them, which suits to case study because it is characterized by how and why questions. Interviewees can help the author understand what is going on in a port (their vertical integration structure, ownership structure, information flow, terminal layout, etc.). Several telephone interviews are conducted during this project with Carl and Geir and Olav Madland, CEO at Seamless which is the information system provider of Oslo port authority.

3.3.2. Collecting secondary data

"Secondary data is the data that has been already collected by and readily available from other sources." (NAVEEN 2012). That is to say, secondary data is reused by other researchers before. Hence, such data are cheaper and more quickly obtainable than primary data (NAVEEN 2012).

As mentioned above, secondary data is cheaper compared with primary data, however, its importance should not be ignored, especially when primary data is difficult to obtain. Sources of secondary data used in this project include:

1. Companies' annual reports and financial reports
   a) Annual reports of port of Oslo form 2003 to 2012
   b) Annual statistic for the Port of Oslo form 2003 to 2012
2. Online information
   a) Official websites including SSB, Seamless and port of Oslo
   b) Articles from other websites
3. Books, journals, brochures and magazine
4. Master and PhD theses in this field
5. Maps
6. Government records
   a) Statistical Yearbook of Norway from 2003 to 2012

3.3.3. Difficulties of data collection

Collecting data is an extremely time consuming activity. Obtaining adequate information from a large number of ports is unfeasible for master thesis due to the short working period.

The various actors in a port use their own internal information systems. Information sharing between actors is difficult because they are reluctant to share information and the technical problem exists in exchanging information between systems (Berg 2013). Therefore, each port operator's information system does not contain information of the performance of other actors in a port.

For one piece of information, different sources may provide different value and this problem is not rare. Hence, many data should be double confirmed during interviews, which is also take times. For instance, Table 3.2 and Table 3.3 below illustrate the total cargo throughput in port of Oslo in 2010 and 2011, which are obtained from *Statistic Yearbook of Norway 2011 and 2012* and *annual statistic for the Port of Oslo 2010 and 2011* respectively. There is huge deviation (around several thousand tons) between these two sources in terms of annual cargo throughput. And this deviation is always there during the last ten years.

Year	Total cargo throughput	Wet bulk	Dry bulk	Containers	Ro-Ro (self-propelled)	Ro-Ro (non-self-propelled)	Parcels
2010	5404628	2085850	1019315	1302555	350432	407517	238959
2011	5708578	2074757	1337172	1346906	348675	374795	226273

Table 3.2: Total cargo throughput in port of Oslo in 2010 and 2011
All information of this table is found from *Statistic Yearbook of Norway (SSB 2012, 2011)*

Year	Bulk (1000 ton)	General cargo (1000 ton)	Total (1000 ton)
2010	3105	2303	5408
2011	3416	2299	5715

Table 3.3: Total cargo throughput in port of Oslo in 2010 and 2011
All information of this table is found from *annual statistic for the Port of Oslo (Oslohavn 2011a, 2010a)*

Another complicating issue in this research is that a lot of the information had to be translated from Norwegian to English because most of information is provided in Norwegian.

4. Product portfolio analysis

The purpose of this chapter is to narrow down the research scope of this study by finding out the most important traffic category in port of Oslo. Boston Matrix will be used as a major theoretical foundation to support the research in this chapter. In addition, due to the differences in revenue between handling each type of cargo, the value added concept is involved in the analysis by replacing nominal tons with value tons.

This section starts with an introduction of Oslo port, including its ownership and organizational structure. After that, output information of six seaports located in Oslo fjord will be illustrated in detail, which is obtained from Statistical Yearbook of Norway published by SSB from 2003 to 2012. Further, the original BCG Matrix analysis will be conducted to provide a general view of the competitiveness of each traffic category in Oslo port. And also a more detailed analysis will be made using Verbeke's BCG Matrix in order to obtain more detailed information about port competition from different levels.

There are cooperation and competition between ports. On the one hand, the port authority is interested in attracting new customers from other ports and gain market share. On the other hand, they cooperate to increase cargo throughput in total. Although the competition in port industry is not as fierce as that in FMCG (fast-moving consumer goods) industry, ports also compete with each other in terms of price, space and storage condition, etc. When excluding the geographical monopoly issue, for instance, a company shipping a container from abroad to Molde can unload this container at Moss or Oslo. More specifically, if this company is willing to have a relatively longer free storage time for this container, it can choose Moss port. If it prefers faster handling, it can choose Oslo port (Hatteland 2013).

4.1. Port of Oslo

This section will provide a general overview of the focal port in this study, port of Oslo, including certain main figures, ownership structure, organizational structure and traffic categories.

4.1.1. General overview

Port of Oslo is one out of five Norwegian ports that are designated as especially important in the development of efficient and safe sea transport of passengers and freight (Oslohavn 2010d). For each normal day, there are 50 to 70 vessels sailing in and out of the port of Oslo with freight and passengers (Oslohavn 2013d). A set of data is listed on the website of Oslo port to illustrate that it is a leading port in Norway. Some characteristics are:

- "Half of the Norwegian population lives less than a three hour drive from the Port of Oslo.
- Short distance to railway and main road
- State-of-the-art, efficient cargo terminals
- Nearly 6 million travelers each year
- Three daily ferry arrivals from Denmark and Germany (Oslohavn 2013d)"

Port of Oslo is a State-of-the-art port open 24/7. There is a short distance from their terminals to the main road network. 53,300 pairs of shoes and 54,700 kilograms of coffee are part of what arrives at port of Oslo from sea every day. And there are nine container ship calls per week and approximately 125,000 TEUs unloaded annually at this port. Their RTG (Rubber tyred gantry crane) and SSG (Ship to Shore gantry crane) cranes can load or unload up to 27 containers per hour. Trains leave this port and bound for Gardermoen airport every day carrying aviation fuel. Actually, 50 percent of Norway's consumption oil, including petrol and diesel, pass through this port. Further, around one million tons of dry bulk, i.e., grain, sand, cement and salt is unloaded there every year (Oslohavn 2011d).

Oslo port is a major intersection in the Norwegian transport hub (Oslohavn 2011d). A great number of cargo vessels and cruises call at Oslo every year from many countries. Port of Oslo is the largest ferry port in Norway (Oslohavn 2013a). In addition to passengers, it is also an intermodal port that is able to handle all types of cargo. More specifically, in 2011, it handled 5,708,578 tons of cargo in total, including 2,074,757 tons of wet bulk, 1,337,172 tons of dry bulk, 1,346,906 tons of containers, 723,470 tons of RO-RO and 226,273 tons of parcels (SSB 2012).

4.1.2. Ownership structure

Oslo port authority is the managing body for the Oslo port. The legal enterprise form of this authority is municipal enterprise (KF). That is to say, Oslo havn KF is a municipally-owned company which reports to the City of Oslo's department for transport and the environment. Their purpose is to "offer efficient and environmentally sound sea transport and monitor the traffic in the port area" (Oslohavn 2013c). Oslo port is a landlord port and its port authority hires many operators which are responsible for the work at terminals. The only exception is cranes operation. Many crane drivers work for Oslo port authority and port users buy this service paid by the number of container lifts (Hatteland 2013).

The Board consists of 10 members. Akershus, Hedmark and Oppland counties appoint one member and an alternate. Two members elected by and from all employees. City Council selects up to six representatives, including the Chairman and Deputy Chairman. The city council also elects one representative user who should be an expertise of port and transport. The Board is elected for a term of four years, so that the term following municipal elections period (Oslohavn 2013f).

The term of current board is from 2011 to 2015. According to the rules mentioned above, the current board consists of six politically appointed members, one user representative, two representatives of the employees and a county appointed member.

4.1.3. Organizational structure and service providers

Oslo port is a landlord port like many other ports in Norway. However, they have many more employees than others. For instance, Ålesund port has 12 employees currently (Ålesund-havn 2013) and Karmsund port had 15 employees in 2011 (Karmsund-havn 2011). By contrast, port of Oslo had 171 employees last year (Oslohavn 2012a). The reason of that is mainly because Oslo port offers services on their own and others do not. They hire many crane drivers to handle containers (Hatteland 2013) and sell this service to their customers, such as, terminal operators. What's more, Oslo port authority is not a pure landlord port compared with its Germany counterparts. It also cares about the performance of their terminal operators and the future development of their terminals. That is to say, they hire many employees for planning and construction (Berg 2013). An organizational structure of Oslo port can be seen from Figure 4.1 in the next page:

The container terminals of Oslo port have all service providers mentioned in Section 2.1.2. The main service providers are the two container terminal operators: Oslo container terminal (OCT) is the operator at Ormsundkaia, while Sjursøya container terminal (SCT) works at Søndre Sjursøykai. The port authority signs contracts with them and gives them right to operate the container terminals and serve shipping lines. Oslo port authority keeps crane operation in house because they want to control the port development plan and therefore they are reluctant to give terminal operators long term contracts. Crane operations have high cost that cannot be covered in short term by each operator. That is to say, Oslo port authority makes the long term investments in crane infrastructure (Hatteland 2013).

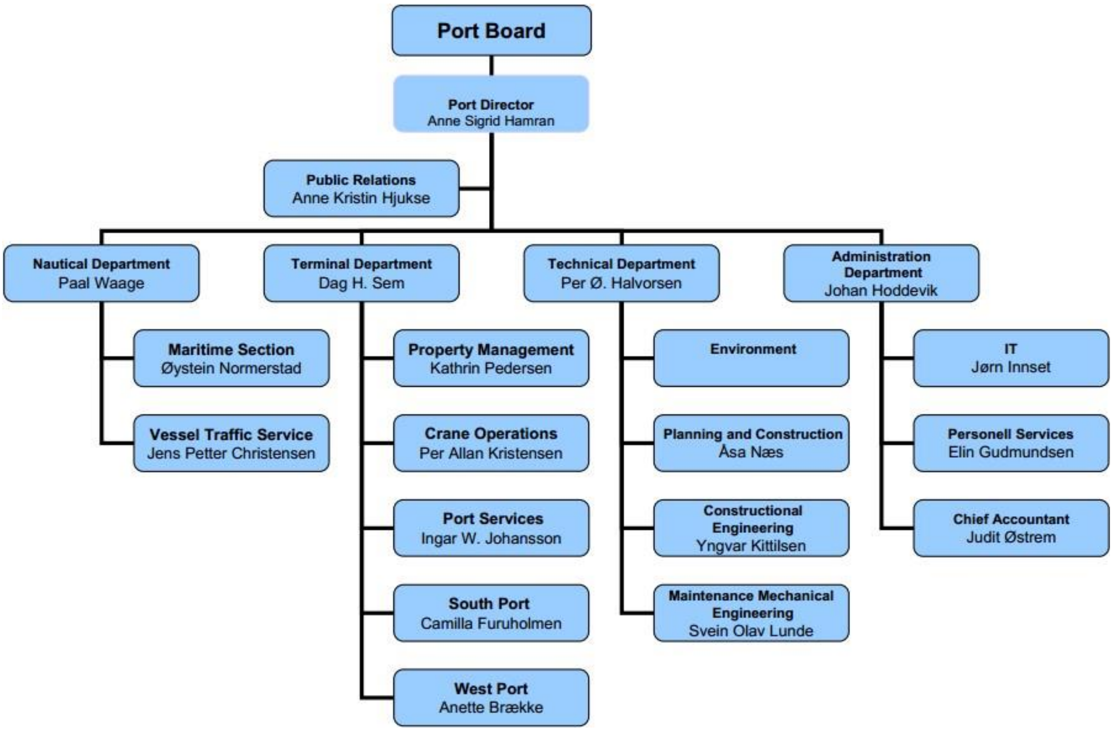

Figure 4.1: Organizational structure of Oslo port (Oslohavn 2013b)

4.1.4. Traffic categories

Oslo port has six traffic categories, including passengers, dry bulk, wet bulk, containers, Ro-Ro and parcels. The main commodities in each traffic category are listed in the Table 4.1 below:

Traffic categories	Main commodities
Passengers	Passengers
Dry bulk	Grain, sand, cement and salt
Wet bulk	Oil products. Such as, aviation fuel, petrol and diesel
Containers	Containers
Ro-Ro	Only cars for pure Ro-Ro ship
Parcels	Parcels

Table 4.1: traffic categories in port of Oslo

4.2. Output information for all ports located in Oslo fjord

The six major ports located in Oslo fjord are selected for this product portfolio analysis. They are:

1) Borg Port Authority,
2) Moss Port Authority,
3) Oslo Port Authority,
4) Drammen Port Authority,
5) Tønsberg Port Authority,
6) And Larvik Port Authority

Table 4.2 and 4.3 illustrate the cargo throughput in the year 2002 and 2011 for all six seaports located in Oslo fjord. For more detailed information, please see Appendix III and IV. All information showed in these two tables is derived from Statistic Yearbook of Norway 2003 and 2012 published by SSB. The author double checked the numbers of Oslo port, but not the other due to time constraint of the master thesis project. That is to say, there could be small errors. However, the results of BCG Matrix analysis will not be influenced due to the huge differences between ports in terms of cargo throughput. Small differences between numbers showed in these two tables and the reality will not influence market share and growth rate to a large extent.

Year 2002	Total	Wet bulk	Dry bulk	Containers	Ro-Ro	Parcels
Borg Port	3,478,058	1,226,284	1,597,482	308,551	0	345,741
Moss Port	1,030,286	61,920	430,585	197,671	10,876	329,234
Oslo Port	6,063,538	1,961,781	1,279,232	1,088,131	1,291,157	443,237
Drammen Port	1,274,748	123,844	759,221	1,160	105,519	285,004
Tønsberg Port	9,200,705	9,071,060	107,008	144	0	22,493
Larvik Port	1,407,370	43,730	462,970	248,331	295,644	356,695
Total	22,454,705	12,488,619	4,636,498	1,843,988	1,703,196	1,782,404

Table 4.2: Cargo throughput by traffic category by port authority in 2002; Unit: ton (SSB 2003)

Year 2011	Total	Wet bulk	Dry bulk	Containers	Ro-Ro	Parcels
Borg Port	2,753,453	988,829	1,124,865	319,670	0	320,089
Moss Port	425,944	0	100,726	304,280	0	20,938
Oslo Port	5,708,578	2,074,757	1,337,172	1,346,906	723,470	226,273
Drammen Port	2,968,403	186,478	1,166,848	105,235	125,209	1,384,633
Tønsberg Port	10,216,426	10,169,015	44,474	0	0	2,937
Larvik Port	1,781,384	0	435,988	724,939	561,002	59,455
Total	23,854,188	13,419,079	4,210,073	2,801,030	1,409,681	2,014,325

Table 4.3: Cargo throughput by traffic category by port authority in 2011; Unit: ton (SSB 2012)

Table 4.4 below shows container throughput from 2004 to 2011 for the same set of ports in Oslo fjord. Because Tønsberg port has very small container throughput during these eight years, it will not be considered in the analysis for container traffic.

Port	2004	2005	2006	2007	2008	2009	2010	2011
Borg	371,102	410,901	368,745	206,854	319,052	344,139	308,524	319,670
Moss	227,455	266,152	307,039	263,451	302,892	240,611	275,137	304,280
Oslo	1,226,822	1,088,840	1,042,842	1,149,482	1,247,319	1,171,608	1,302,555	1,346,906
Drammen	0	102	267	7,141	49,292	66,738	83,793	105,235
Tønsberg	0	0	0	10	0	0	0	0
Larvik	426,792	449,012	433,722	495,963	645,134	622,289	646,045	724,939
Total	2,252,171	2,215,007	2,152,615	2,122,911	2,563,689	2,445,385	2,616,054	2,801,030

Table 4.4: Container throughput by port authority from 2004 to 2011; Unit: ton (SSB 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012)

4.3. Product portfolio analysis for six ports in Oslo fjord

Two types of BCG Matrix will be used to find out the most important traffic category in Oslo port. The result of original BCG Matrix gives a general view of the competitiveness of each traffic category in Oslo port. In addition, Verbeke's four-level BCG Matrix provides further insights into port competition.

4.3.1. Original BCG Matrix analysis

The result of original BCG Matrix is derived from Table 4.2 and 4.3. Market share in Table 4.5 and Figure 4.2 in the next page refers to the relative market which can be calculated by the ratio of market share of a traffic category in Oslo fjord to that of the largest other competitor. As discussed in Section 2.2.1, 1.5 times is used in this research to separate areas of high and low relative market share. Growth rate refers to the average annual growth rate of each traffic category during these 10 years. As can be seen in Figure 4.2, a bold vertical red line and a bold horizontal red line are included, which distinct the relatively high and low market share and annual growth rate respectively. Traffic volume is adjusted by Dupuydauby rule: The value added created by one ton of conventional cargo equals that of approximately 9 tons of liquid bulk, 6 tons of dry bulk and 3 tons containers and roll on-roll off. By involving the value added concept, ball size in Figure 4.2 represents the revenue generated by each traffic category.

Traffic category	Market share	Growth rate	Volume
Wet bulk	0.204027	0.561483	230,528.6
Dry bulk	1.145969	0.443953	222,862.0
Containers	1.857958	2.156407	448,968.7
Ro-Ro	1.289603	-5.627790	241,156.7
Parcels	0.163417	-6.502570	226,273.0
Average		-1.191420	

Table 4.5: BCG Matrix

As shown in Figure 4.2, three traffic categories in Oslo port, dry bulk, Ro-Ro and container are market leaders in Oslo fjord. However, Although dry bulk and Ro-Ro have higher market share than the second best actor in their own traffic category, the former generate smallest revenue for Oslo port in all 5 traffic categories and the later lost huge market share during the last ten years (-5.62% average annual growth rate). Together with the information illustrated in Table 4.2 and 4.3, Oslo port had 1,291,157 tons of Ro-Ro turnovers in 2002, which were approximately 4.4 times than the second best player, Larvik port, in that year (295,644 tons). By contrast, in the year of 2011, Ro-Ro turnovers in Oslo port downed to 723,470 tons which was only nearly 1.3 times than Larvik port (561,002 tons). If this trend goes on, Ro-Ro of Oslo port will lose its market leader position in the near future. That is to say, dry bulk and Ro-Ro are not the most important traffic category in Oslo port, although they are currently market leader in their fields respectively.

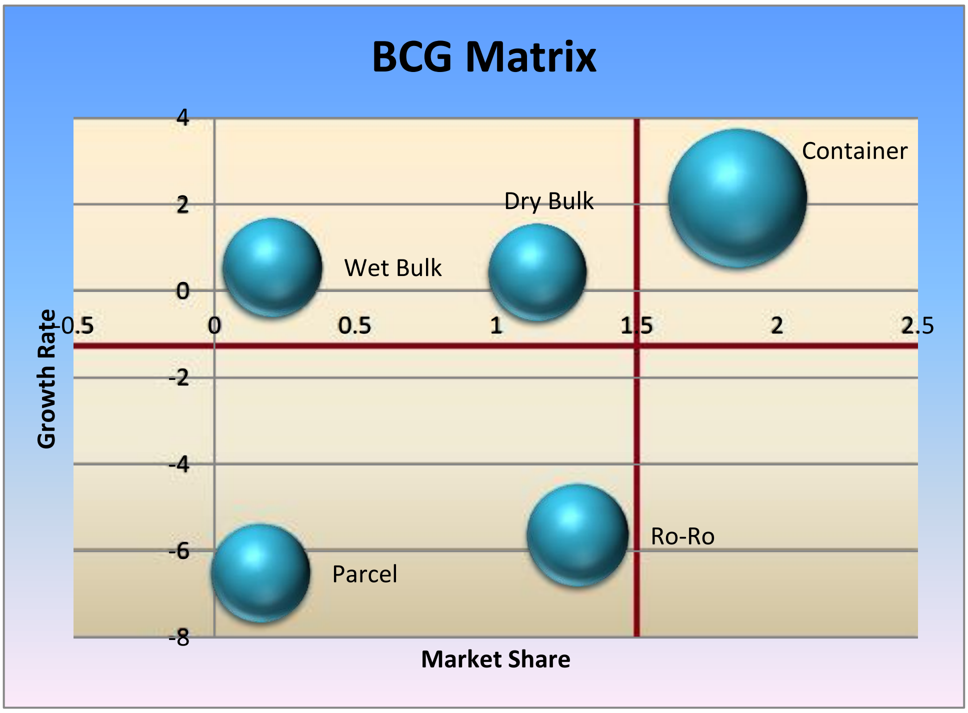

Figure 4.2: BCG Matrix

Container has nearly two times market share (1.86) than the second best player in this market and has a higher than average annual growth rate during the last ten years. In addition, because the ball size in Figure 4.2 represents the revenue generated by each traffic category, a conclusion can be easily drawn that container creates the biggest revenue for Oslo port. That is to say, container is the most important traffic category in Oslo port currently, in terms of its market share, growth rate and revenue generating capability.

4.3.2. Verbeke's BCG Matrix

Verbeke's four-level BCG Matrix provides more detailed information for decision making. As discussed in Section 2.2.4.2, the first three levels of this analysis will be used. The bold vertical red lines and horizontal red lines in this section can also distinct the relatively high and low market share and annual growth rate respectively.

4.3.2.1. Level one: portfolio of seaports for total traffic

The portfolio in this level is composed of six seaports with all their traffic categories in the Oslo fjord. Worth to note that market share in Verbeke's BCG Matrix refers to absolute market share rather than relative market share. For instance, market share of Oslo port is 24.4 means port of Oslo had 24.4% market share in Oslo fjord in 2011. In addition, cargo throughputs in 2011 and 2012 for all seaports have been adjusted by Dupuydauby rule. More details can be seen in Table 4.6 and Figure 4.3.

Port	2011	2002	Market share	Growth rate
Borg Port Authority	723,993	851,092	12.9	-1.6
Moss Port Authority	139,152	477,394	2.5	-11.6
Oslo Port Authority	1,369,789	1,667,514	24.4	-1.9
Drammen Port Authority	1,676,642	460,861	29.9	13.8
Tønsberg Port Authority	1,140,240	1,048,271	20.3	0.8
Larvik Port Authority	560,767	620,041	10.0	-1.0
Total	5,610,583	5,125,173		
Average			16.67	3.22

Table 4.6: BCG Matrix – Level 1

As can be seen in Figure 4.3, all ports have been positioned in this BCG Matrix based on their market share and average annual growth rate. And this level of BCG Matrix analysis does not provide any information about traffic structure inside a port and commodity groups in Oslo fjord. They will be analyzed further in level 2 and level 3 respectively.

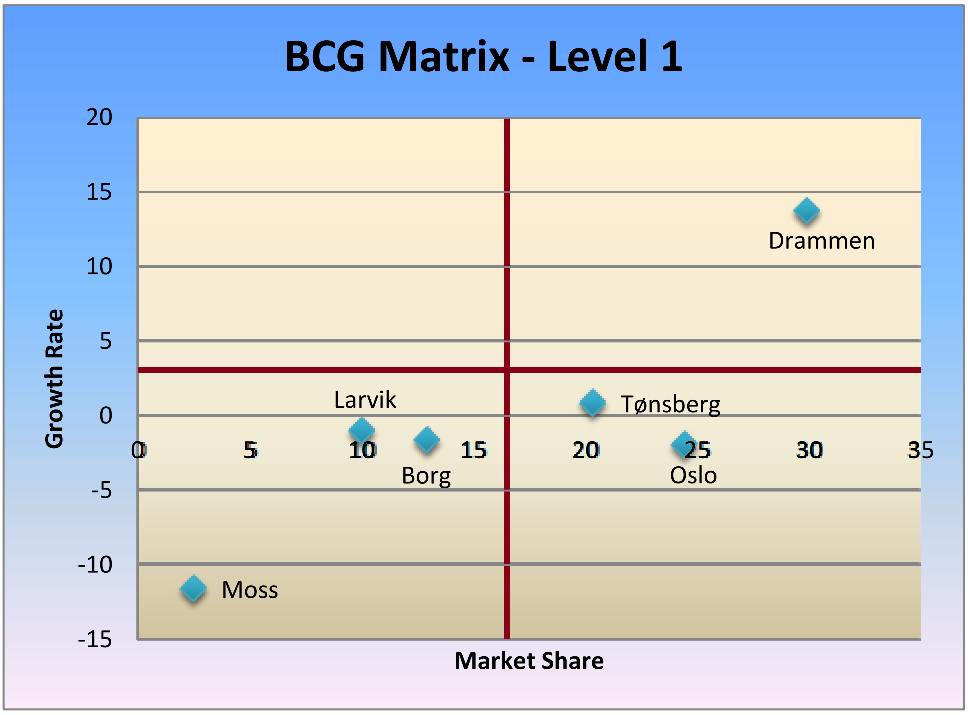

Figure 4.3: BCG Matrix – Level 1

When considering the concept of value ton, Drammen port has the biggest market share and fastest growth gate in this range, followed by Oslo port (24.4 % market share) and Tønsberg port (20.3% market share). However, generally speaking, Oslo port and Tønsberg port have lower than average growth rate in the past ten years. That is to say, the focal organization of this project, Oslo port, is the second biggest seaport in Oslo fjord in terms of value ton with 24.4% market share.

4.3.2.2. Level two: portfolio of traffic categories for Oslo port

Traffic volumes of five traffic categories in Oslo port are regarded as a portfolio in this level. They are container, wet bulk, dry bulk, Ro-Ro and parcel. The X-axis is the market share of each traffic category within Oslo port, while the Y-axis represents their corresponding growth rate.

After some calculation based on information provided in Table 4.2 and Table 4.3, Figure 4.4 is derived. When considering the concept of value ton, container is obviously the most important traffic category in Oslo port in terms of market share and growth rate. Therefore, container will be selected as the focal traffic category in the next level analysis to see whether it also performs best in Oslo fjord (its competitiveness).

Traffic category	2011	2002	Market share	Growth rate
Wet bulk	230528.6	217975.7	16.82949522	0.561483
Dry bulk	222862	213205.3	16.26980638	0.443953
Containers	448968.7	362710.3	32.77648624	2.156407
Ro-Ro	241156.7	430385.7	17.60538931	-5.62779
Parcels	226273	443237	16.51882285	-6.50257
total	1369789	1667514		
Average			20	-1.19142

Table 4.7: BCG Matrix – Level 2

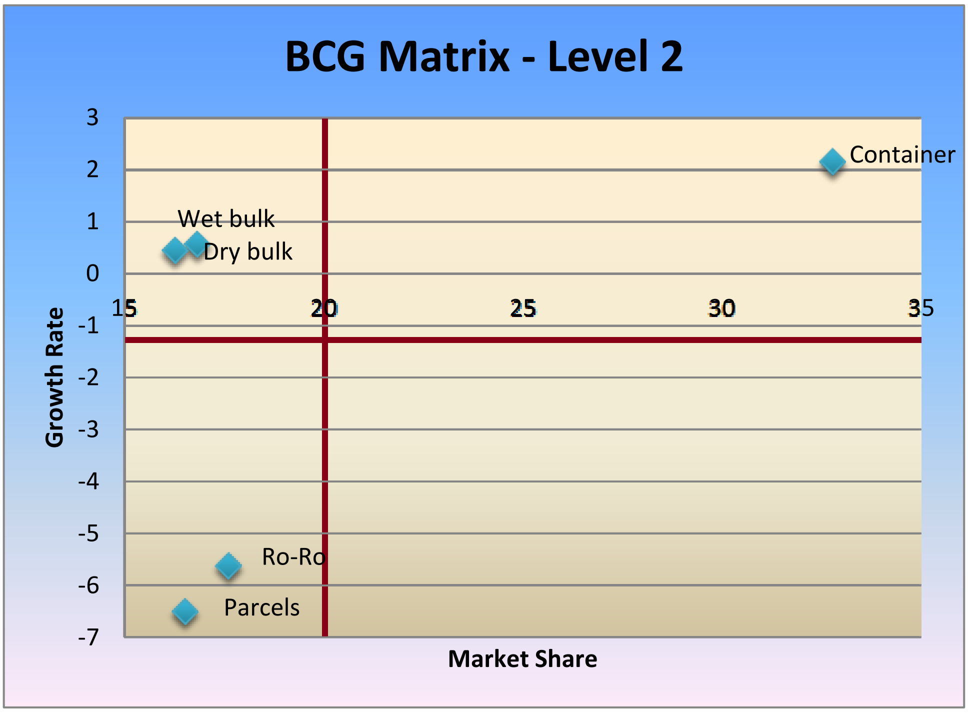

Figure 4.4: BCG Matrix – Level 2

4.3.2.3. Level three: portfolio of seaports for the selected traffic category

Due to the extremely small container throughput in Tønsberg port during these ten years (See Table 4.4), it will not be considered in the analysis of this level. Hence, container throughputs in the remaining five seaports in Oslo fjord are considered as a portfolio. They are Borg port, Moss port, Oslo port, Drammen port and Larvik port. The X-axis in Figure 4.5 is the market share of each seaport within Oslo fjord in terms of container traffic, while the Y-axis represents their corresponding average growth rate from 2002 to 2011.

After calculation based on information provided in Table 4.2 and Table 4.3, Figure 4.5 is derived. Oslo port obviously has the largest market share (48%) in this range in terms of container traffic, although its growth rate is a little bit lower than average.

Port	2011	2002	Market share	Growth rate
Borg Port Authority	319670	308551	11.41258751	0.354648
Moss Port Authority	304280	197671	10.86314677	4.407824
Oslo Port Authority	1346906	1088131	48.0860969	2.156407
Drammen Port Authority	105235	1160	3.757010814	56.95322
Larvik Port Authority	724939	248331	25.881158	11.30817
Total	2801030	1843844		
Average			20	6.622659

Table 4.8: BCG Matrix – Level 3

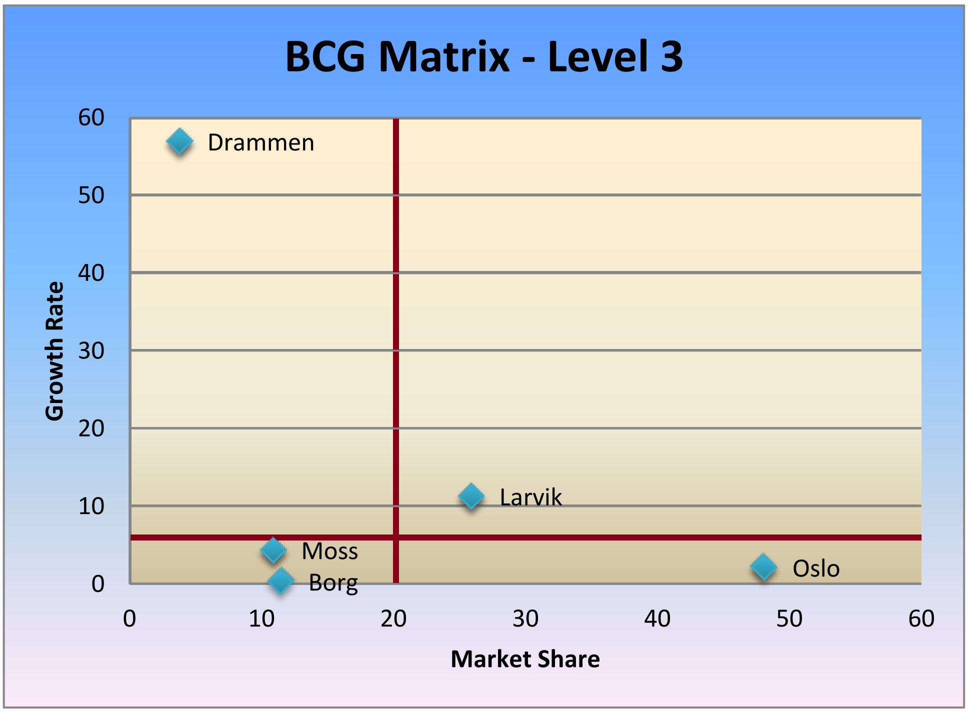

Figure 4.5: BCG Matrix – Level 3

4.3.2.4. Dynamic portfolio analysis

A dynamic BCG Matrix analysis enables the author to see the evolutional trend of a traffic category over several time periods. In terms of this study, the container traffic in Oslo port is selected to conduct a dynamic analysis and find the evolutional trend during the last eight years (from 2004 to 2011). The X-axis in Figure 4.6 is the market share of Oslo port's container traffic in Oslo fjord in different years, while the Y-axis represents their corresponding annual growth rate from 2004 to 2011. The reason why only information of eight years is considered in this dynamic analysis is information in 2003 is not available.

A dynamic positioning analysis for container traffic of Oslo port is presented in Figure 4.6. As shown in this figure, container terminals of Oslo port have been holding around 50% market share in Oslo fjord in the last eight years, although its growth rate fluctuates during this period. That is to say, it is always the market leader during this time period. In addition, there is a more or less decrease trend in terms of container market share. If each time period is defined as two years, this decrease trend is easier to notice. See Figure 4.7. Oslo container terminals lose their market share partially due to its limited stacking storage area, which will discussed further in Section 6.1.1. Other reasons will be also discussed in later chapters based on in-depth research on Oslo container terminals.

	2004	2005	2006	2007	2008	2009	2010	2011
Growth rate	6.18	-11.25	-4.22	10.23	8.51	-6.07	11.18	3.40
Market share	54.474	49.16	48.45	54.15	48.65	47.91	49.79	48.09

Table 4.9: Dynamic portfolio analysis – one year per time period

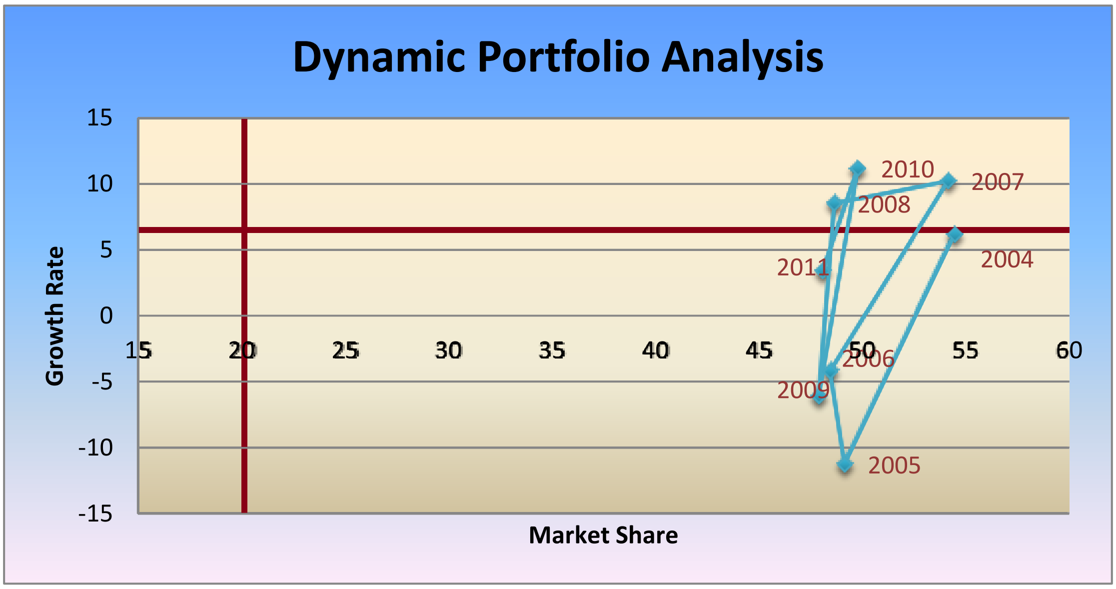

Figure 4.6: Dynamic portfolio analysis – one year per time period

	2004-2005	2006-2007	2008-2009	2010-2011
Growth rate	0.021714	2.746977	0.957846167	7.220414
Market share	51.83724	51.27624	48.29090167	48.90936

Table 4.10: Dynamic portfolio analysis – two year per time period

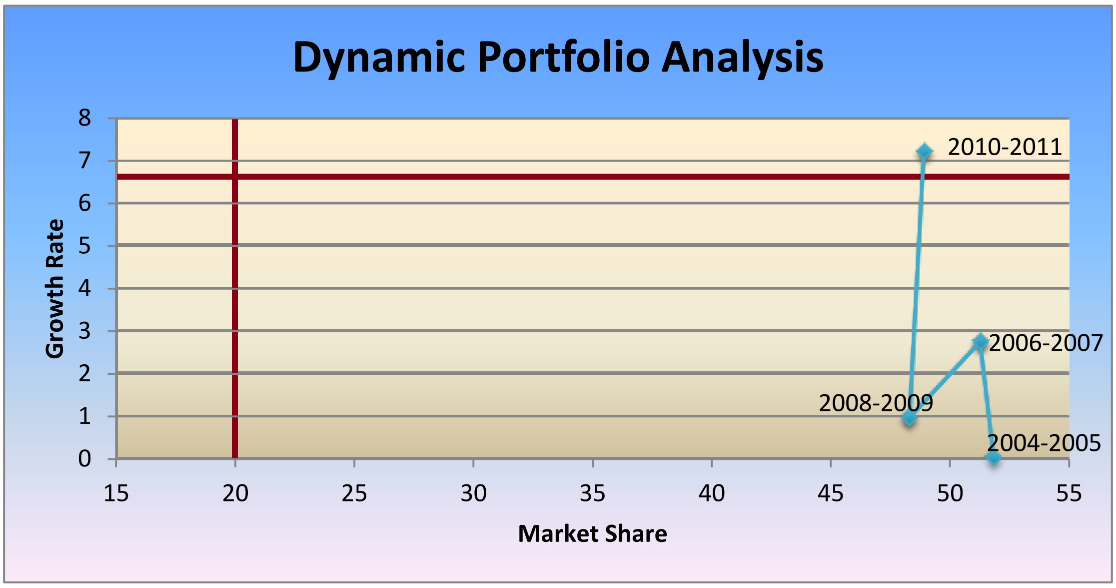

Figure 4.7: Dynamic portfolio analysis – two year per time period

4.4. Conclusion

Recall that the objective of this section is to narrow down the research scope of this study by finding out the most important traffic category in port of Oslo. By conducting a set of product portfolio analyses, container traffic is regarded as the most crucial traffic category in port of Oslo. More specifically, original BCG Matrix analysis provides a general view of the competitiveness of container terminals of Oslo port in Oslo fjord. It shows that container traffic is the most important traffic category in Oslo port due to its market share, growth rate and revenue generating capability.

After that, a three-level BCG Matrix analysis and a dynamic analysis adopted from Verbeke's BCG Matrix are conducted. These analyses provide more detailed information about port competition from different levels. The results suggest that Oslo port is the second biggest seaport in Oslo fjord in terms of value ton with 24.4% market share. Further, container terminal of Oslo port is not only the largest terminal inside its own port but also the largest container terminal in the fjord in terms of value ton. That is to say, it is market leader in 2011 and generates the most revenue among all traffic categories in Oslo port. What's more, the dynamic analysis shows it is always the market leader in Oslo fjord from 2004 to 2011. To sum up, although a slight decline trend in market share of container traffic of Oslo port is found during dynamic analysis, it is always the most important traffic category in Oslo port during the studied period.

Due to the differences in revenue between handling each type of cargo, the value added concept is involved in the analysis by replacing nominal tons with value tons. However, in Dupuydauby rule, a distinction was made between crude oil and liquid bulk. More specifically, the value added created by handling 12 tons of crude oil is equal to handling 9 tons of liquid bulk. The collected data for this BCG Matrix analysis does not allow the author to distinguish these two types of liquid bulk. This gives rise to a limitation of this analysis.

The author avoids to use specific terms in BCG Matrix, including star, cash cow, question mark and dog, in this section for the reason that certain normative implications (For instance, Cash cows can generate far more revenue than their needs to maintain their market share.) corresponding to these terms are not be universally proved to be true when they are applied to port industry, although some strategic plans for seaport have been made based on these implications in some researches. Section 2.2.4.1 provides one such example.

5. Productivity measures for container terminals of Oslo port

Section 4 provides reasons for focusing on container terminals of Oslo port. An additional reason is that containerized shipping of goods is increasingly popular in recent years. According to the data from World Bank, container traffic through sea port over the world is 471,991,510.3; 541,911,221.4 and 572,207,570.8 TEUs in the year 2009, 2010, 2011 respectively (WorldBank 2013). The corresponding annual increasing rate is 14.8% in 2010 and 5.6% in 2011. This increase is mainly due to the benefits from containers. A container is a universally standardized box made of steel or similar material, which can protect goods inside in their good condition. Normally, it is waterproof and can protect cargo from outside forces which may come from surges and accidents. Further, it facilitates intermodal transportation. These standardized packing boxes are designed very space efficiently and can be loaded on trains, trucks and container ships (Hinkelman and Putzi 2005). Due to the increasing importance of container transport and its crucial role in Oslo port, this section will focus on the container terminals in port of Oslo and use partial productivity measures (PPM) to evaluate their performance during the last ten years (from 2003 to 2012). And find reasons which influence their productivity.

This chapter introduces related inputs and outputs information of container terminals in Oslo port in detail firstly. After that, PPM indicators will be selected and used to measure the performance changes of this terminal in the last ten years. Reasons of these changes will also be discussed in detail. Information will be obtained from different ways, including primary data (i.e., face to face interview and telephone interview) and secondary data (i.e., annual reports from different organizations, magazines, journals and online information).

5.1. Input and output information

Figure 5.1: Bird's-eye view of port of Oslo

This section illustrates certain inputs and outputs information which are important to depict the performance of Oslo container port and will be the basis of PPM analysis in the later section (Section 5.3: Partial productivity measures for Oslo port). Normally, all inputs and outputs can be divided into two aspects, physical inputs/outputs and financial inputs/outputs. For instance, numbers of employees can be considered as an input from the physical aspect. By contrast, HR cost is its financial counterpart. However, financial indicators are of minor importance for ports in Norway because all port authorities in Norway are non-profit organization and do not need to pay tax (This issue will be discussed further in Section 5.2: The selection of PPM indicators).

5.1.1. Input information

In terms of this section, four types of physical inputs, employees, terminal area, ship-shore container gantry crane (SSG) and berth length, will be illustrated. They are the four most frequently used physical variables when assessing container port performance.

5.1.1.1. Employees

Table 5.1 illustrates the number of employees in port of Oslo during the past ten years, while Figure 5.2 shows the changes during that period of time. Every number is selected from Årsberetning - Oslo Havn KF from 2003 to 2012. The reason why Oslo port authority has much more employees than other landlord port in Norway has discussed in Section 4.1.3.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Man-year	191.5	191.5	177.8	170.3	165.6	158.2	161.1	161.3	161.3	175.5

Table 5.1: Number of man-year in port of Oslo during the past ten years
All information of this table is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

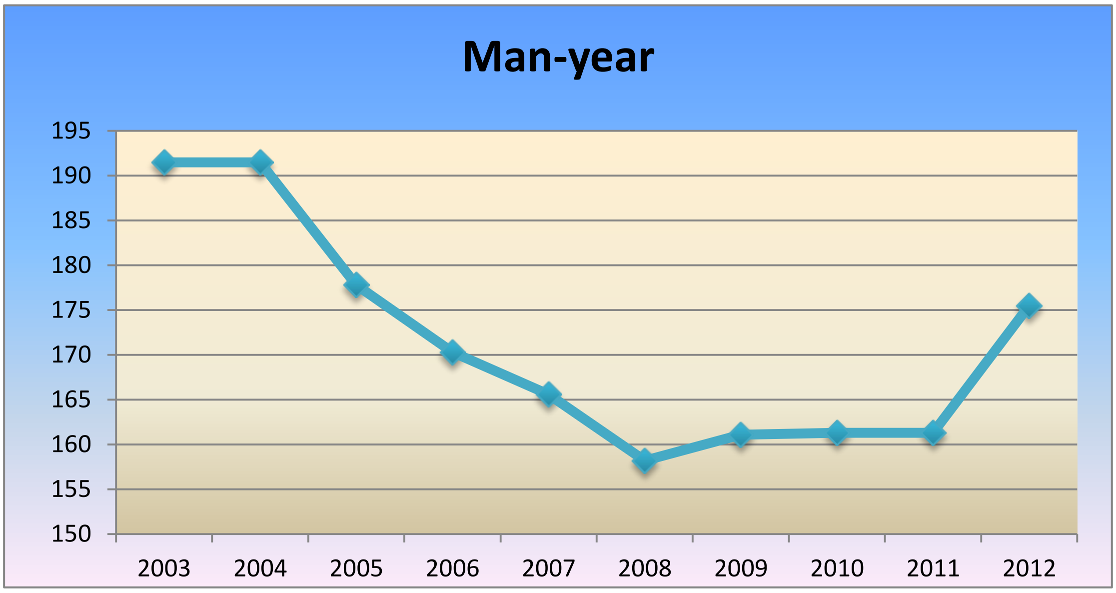

Figure 5.2: Number of man-year in port of Oslo during the past ten years
All information of this figure is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

There are ten decimals shown in Table 5.1 because they represent the number of man-year rather than the number of employees. It is the combination of the number of part-time employees and full-time employees hired by Oslo port authority in each year.

As can be seen from Figure 5.2, port of Oslo witnessed a dramatic decrease on the number of man-year during the period from 2004 to 2008. This is mainly because of several organizational changes. Although they did not achieve their initial goal, the number of man-year has indeed reduced sharply during these years. Their plan in 2003 was to reduce the number of employees to 150 by the end of 2008 and also reduce the number of managers and management levels. The purpose of this restructuring by the port authority is to make this port more efficient and enable this port to adapt the reduced workforce in the following years. This organizational restructuring and workforce adjustments refers to many departments, including technical department, terminal department and financial department (Oslohavn 2008a, 2007a, 2006a, 2005a, 2004a). Besides, actually, the port authority hired 6 and 7 new crane drivers in 2010 and 2011 respectively (Oslohavn 2010b, 2011b). However, the increase trend corresponding to these 13 new positions is not shown in Figure 5.2, since they use less part-time employees than before during that period. And this increase trend showed in 2012.

5.1.1.2. Terminal area

Currently, port of Oslo has 1,255,000 square meters of land area in total (Oslohavn 2013d). Since only container terminal is considered when measuring the performance changes of Oslo port during the last ten years, Table 5.2 is drawn to illustrate the size of Lo-Lo terminal area and Figure 5.3 shows the changes during that period of time. Every number is selected from Årsberetning - Oslo Havn KF from 2004 to 2012.

Year	Terminal area (square meter)	Year	Terminal area (square meter)
2003	190000	2008	150000
2004	190000	2009	166000
2005	168000	2010	185000
2006	168000	2011	150000
2007	168000	2012	167000

Table 5.2: Container terminal area in port of Oslo
All information of this table is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

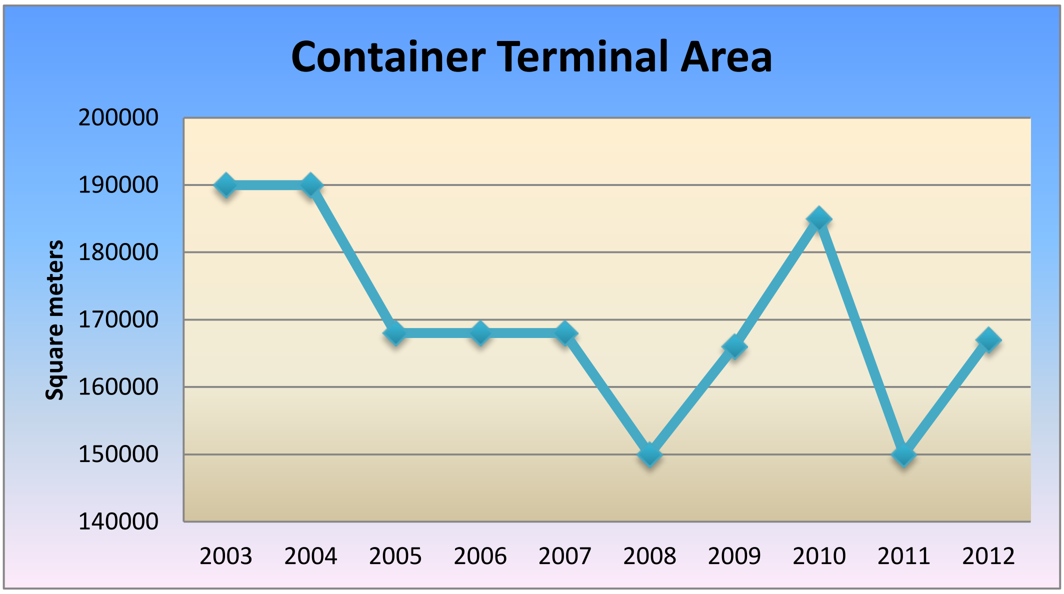

Figure 5.3: Container terminal area in port of Oslo
All information of this table is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

As can be seen from Figure 5.3, container terminal area fluctuates during the last ten years. This is mainly because of their reconstruction plan which is approved by city council on 26th October 2003 (Oslohavn 2008a). The area changes must be considered in the context of the ongoing restructuring processes in the harbor. Area situation is constantly changing, which affects the possibilities of land utilization.

According to this plan in 2003, a new container terminal at Sjursøya would be constructed and old container terminal at Filipstad would not use for container ships after completion of the new one. This reconstruction plan ensured the realization of their so-called Fjord City plan, which is approved by city council in 2000. This plan will make Oslo port more people friendly and area efficiency and can provide more housing units, parks for inhabitants. Sjursøya container terminal opened in January 2008 and it was smaller than Filipstad at that time. Hence, terminal area decreased in that year (Oslohavn 2008a). After that, port authority developed new spaces for Sjursøya container terminal in the following year (Oslohavn 2009a). The depot area of container terminals shrank in 2011 due to the Fjord City plan (Oslohavn 2011b). Currently, there are two container terminals in Oslo port, namely, Ormsundkaia and Sjursøya.

5.1.1.3. Cranes

There are three types of cranes used in port of Oslo. They are ship-to-shore container gantry crane (SSG) (Figure 5.4), rubber tyred gantry crane (RTG) (Figure 5.5) and reach stacker (Figure 5.6) (Hatteland 2013). Ship-to-shore container gantry crane is, as the name implies, a type of large dockside gantry crane used in container terminals of Oslo port for loading and unloading containers to and from container ships. By contrast, RTG and reach stacker can stack containers within the stacking areas of a container terminal. The cost of RTGs is much higher than reach stackers, however, the former is more area efficient than the later one (Hatteland 2013). To measure performance of loading/unloading activity, information of the use of SSG is called for, which is illustrated in Table 5.3.

Figure 5.4: SSG

Figure 5.5: RTG

Figure 5.6: Reach Stacker

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CONTAINER CRANES (SSG)	5053	6295	5589	5689	6550	6756	5939	6443	6739	6490

Table 5.3: Crane-hours for container cranes
All information of this table is found from Oslo port's annual statistic reports (Oslohavn 2003, 2004b, 2005b, 2006b, 2007b, 2008b, 2009b, 2010c, 2011c, 2012b)

5.1.1.4. Berth length

The author, in this section, would like to provide an overview of the quays in Oslo port and then illustrate berth length in container terminals. Total quay length in port of Oslo is 9922 meters (Oslohavn 2013d). However, this number does not help at all when calculating berth length productivity for container terminal in port of Oslo. This is because quays are not used only for handling cargo and passengers in a normal port. Table 5.4 in the next page shows several examples of them. There are 39 quays – large or small – in Oslo port, while only 16 of them are built for handling passengers and cargo (Oslohavn 2013e).

These 16 quays are shown in Table 5.5 in the next page. And this table illustrates their length and main products. Appendix V contains more information about their products and certain comments. Akershuskaia Syd is a major cruise quay in port of Oslo (Oslohavn 2013e). Hjortnes and Utstlkker II are major quays for Ro-Ro. As mentioned above, major container quays are Ormsundkaia and Søndre Sjursøykai. The total quay length of these two quays for container ships is 627 meters

Quay	Product
Langkaia	Charter boat, theatre boat with café and B&B
Loengakaia	Unloading of deposit masses, storage of small boats
Sørengutstlkkeren	City development area, quay not used for vessel traffic, Refueling of local ferries (temporally)
Verkstedsområde	Engineering area
Akershuskaia Nord	vintage ships, charter boats
Grønlia Nord	storage of ferries, barges and small boats

Table 5.4: quays for other uses in port of Oslo

All information of this table is found from the website of Oslo port (Oslohavn 2013e)

quay	Length	Type of product
Akershuskaia Syd	302 m	Passengers
Revlerkala	364 m	Passengers
Utstlkker III	192 m	Passengers
Vippetangen	278 m	Passengers
Rådhusbryggene	1,120 m	Passengers
Hjortnes	173 m	Passengers and Ro-Ro
Utstlkker II	368 m	Passengers and Ro-Ro
Ormsundkaia	322 m	Container
Søndre Sjursøykai	305 m	Container
Filipstad	468 m	Multi-purpose terminal
Grønlia Syd	262 m	Dry bulk
Kongshavn	157 m	Dry bulk
Nordre Sjursøykai	517 m	Dry bulk
Sjursøymoloen	110 m	Wet bulk
Tankskipsutstikkeren	350 m	Wet bulk
Kneppeskjær	339 m	General cargo
Total	5,627 meters	

Table 5.5: Quays for passengers and cargo

All information of this table is found from the website of Oslo port (Oslohavn 2013e)

There are four berths in these two container terminals, two for each. However, port authority does not record the information about berth length. This is because port authority believes berth length productivity, the ratio of container throughput and berth length, is not quite important for their port. Normally, ships do not need to wait for available berth. And it is more common that berth waits for ships. This situation may result from delay in previous stops of these ships and weather condition. That is to say, berth length productivity is more influenced by external environment factors (Hatteland 2013).

5.1.2. Output information – container throughput

Containers are the only product in container terminals in Oslo port. As most of studies have conducted previously (see Section 2.4.2.6), container throughput will be used to measure output of container terminals of Oslo port in this study. Further, container throughput can be measured in TEU (see Table 5.6) and tons (see Table 5.7). And Figure 5.7 shows the changes of container throughput in TEU during the same time period with Table 5.6.

Year	Number of TEUs	Year	Number of TEUs
2003	162,385	2008	190,307
2004	177,019	2009	178,943
2005	170,506	2010	201,893
2006	172,065	2011	208,799
2007	196,252	2012	202,790

Table 5.6: Container throughput (Number of TEUs) from 2003 to 2012
All information of this table is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

Year	Throughput (ton)	Year	Throughput (ton)
2003	1,166,000	2008	1,247,319
2004	1,226,822	2009	1,171,608
2005	1,088,840	2010	1,302,555
2006	1,042,842	2011	1,346,906
2007	1,149,482	2012	1,278,000

Table 5.7: Container throughput (amount of tons) from 2003 to 2012
All information of this table is found from Oslo port's annual statistic reports (Oslohavn 2003, 2004b, 2005b, 2006b, 2007b, 2008b, 2009b, 2010c, 2011c, 2012b)

As can be seen from Figure 5.7, the container terminal in Oslo port experienced a slight increase trend during the last ten years in terms of container throughput with decrease trends from 2004 to 2005, from 2007 to 2009 and from 2011 to2012 respectively. The decrease from 2004 to 2005 derived mainly from the termination of the Norwegian Forest's paper exports, which significantly reduced outbound freight volume and resulted in fewer vessel calls. And this issue also hinter the container throughput increase in 2006 (Oslohavn 2005a, 2006a). After that, the container throughput increased dramatically in the next following year. Cargo in containers traffic increased 14% in 2007. This is a stronger growth than annual growth rate in the years 2004 (9%) before the slump that resulted from the demise of Norwegian Forest's paper exports. The figure shows that there was a significant decline in 2008 and 2009 due to the general economic recession (Oslohavn 2009a).

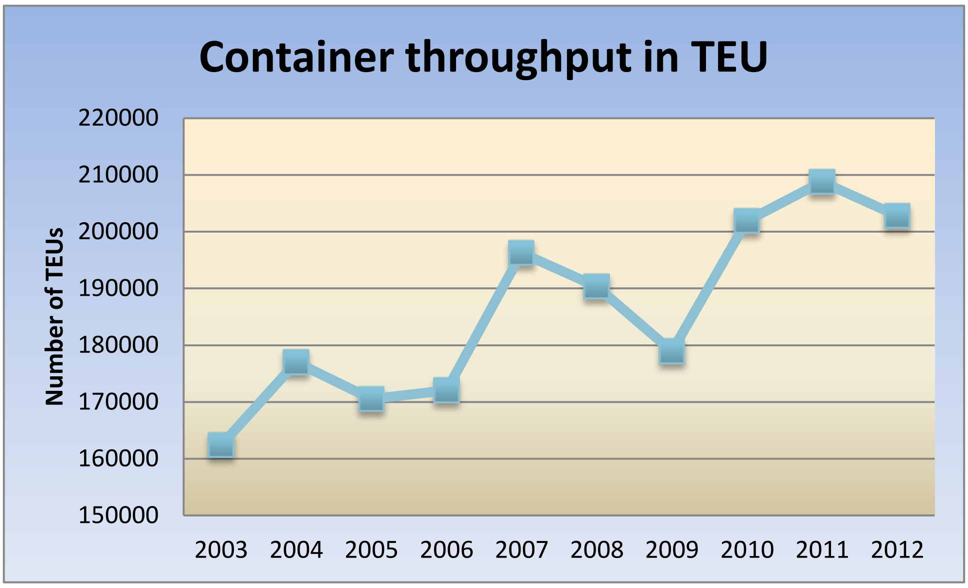

Figure 5.7: Container throughput (Number of TEUs) from 2003 to 2012
All information of this table is found from Oslo port's annual reports (Oslohavn 2004a, 2005a, 2006a, 2007a, 2008a, 2009a, 2011b, 2012a)

5.2. The selection of PPM indicators

Normally, PPM indicators can be divided into two general categories, namely, financial indicator and non-financial indicator. For instance, Jürgen Müller conducted a benchmarking study for Avinor AS (see Section 2.4.1.3). He considered profitability, revenue generating capability and cost efficiency of airports in several European countries. These indicators aim to measure their financial performance. In addition, labor productivity, berth length productivity, crane productivity and area efficiency are also important indicators when measuring the performance of container ports. What's more, even these indicators can be analyzed from both financial and physical aspects (see Table 5.8). Therefore, suitable indicators should be selected based on the situation of Oslo container terminals before conducting PPM analysis for this port.

Categories	Indicators designed from physical aspect	Indicators designed from financial aspect
Labor productivity	Amount of containers per employee	Container revenue per employee
Area productivity	Amount of containers per square meter of container terminal	Container revenue per square meter of container terminal
Cranes productivity	Amount of containers per crane	Container revenue per crane
Berth length productivity	Amount of containers per berth meter of container terminal	Container revenues per berth meter of container terminal

Table 5.8: Possible indicators for this study

5.2.1. Principles of port finance in Norway

“Port finances have been a closed system since 1738 in Norway. In other words, they have been kept separate from the finances of its owner, whether the state (before 1894) or the municipality (after1894). Port finances were to be earmarked for port purposes only, and were not to be considered as taxation” (Hatteland 2010). Port authorities in Norway are non-profits organizations and abide by the “self-financing principle” (Hatteland 2013). They create revenue from fees and use them to cover their own costs. The “non-tax/self-financing principle” refers that municipalities will not impose tax from revenues of port authorities and port authorities should use their revenues to provide services continuously to port users.

5.2.2. The selection of PPM indicators

Labor productivity is one of the most commonly used PPM indicators. It is normally defined as the ratio of total workload units (WLU) and the number of employees in this organization. Workload unit is a combination of different outputs. In terms of Oslo port, there are six product categories, namely, passengers, wet bulk, dry bulk, containers, Ro-Ro and parcels. Because this section focuses on container terminal in Oslo port only, labor productivity in this section will be defined as the ratio of amount of containers and man-year.

Because ports in Norway are non-profits organizations, certain PPM indicators, including profitability, revenue generating capability, are not suitable to this study. And other financial indicators mentioned above are of minor importance for ports in Norway. Considering the specific situations of Oslo container terminals and previous researches on partial productivity measures and efficiency of container terminals, the author selects three PPM indicators for this study to measure the productivity of container terminals in Oslo port. See Table 5.9.

Categories	PPM Indicators
Labor productivity	Amount of containers per man-year
Area productivity	Amount of containers per square meter of container terminals
Cranes productivity	Amount of containers per crane hour

Table 5.9: PPM indicators of this study

5.3. Partial productivity measures for Oslo container port

As discussed above, three PPM indicators will be analyzed in this section, namely, labor productivity, area productivity and crane productivity. By calculating these indicators, the changes of performance of Oslo container terminal over the last ten years can be seen. After that, the author will explain the results based on real situation of Oslo port which is obtained from primary information and mainly obtained from face to face interview and telephone interview with three informants of this project.

5.3.1. Labor productivity

Labor productivity is defined as the ratio of container throughput and man-year of port of Oslo:

$$\text{Labor productivity} = \frac{\text{container throughput in TEU}}{\text{man} - \text{year of port of Oslo}}$$

Here, container throughput is output and input factor is man-year of Oslo port. More specifically, container throughput in TEU is selected as output factor, rather than throughput in ton. This is because handling each TEU calls for similar efforts of employees and no matter how many tons does a TEU weights. In addition, Oslo port authority uses some part-time employees and they only work several months during a year. Man-year is the combination of the number of part-time employees and full-time employees hired by Oslo port authority. It is worth to explain that, number of man-year in this section represents all staff in Oslo port rather than container terminals. This is because it is difficult to assign administrative staff to each traffic category and the way of adjustment in itself changes the truth. Further, labor productivity calculated in this way can also explore the trend of its changes in this ten-year period because productivity is calculated in the same way for each year. After some calculations, Table 5.10 is obtained. And Figure 5.8 shows the changes of labor productivity from 2003 to 2012.

Year	Container throughput (TEUs)	Man-Year	Labor productivity
2003	162385	191.5	847.963
2004	177019	191.5	924.381
2005	170506	177.8	958.976
2006	172065	170.3	1010.364
2007	196252	165.6	1185.097
2008	190307	158.2	1202.952
2009	178943	161.1	1110.757
2010	201893	161.3	1251.662
2011	208799	161.3	1294.476
2012	202790	175.5	1155.499

Table 5.10: Labor productivity of Oslo container terminal during the last ten years

Figure 5.8: Labor productivity of Oslo container terminal during the last ten years

As can be seen from Figure 5.8, the Oslo container terminals experience a roughly increase trend during the last ten years in terms of labor productivity with a slightly decrease in 2009 and 2012. Their organizational restructuring and workforce adjustments (For more details, see Section 5.1.1.1) contribute to this improvement of labor productivity. It is seems that they have partially achieved the goal of becoming a more labor efficient port, although the target of 150-employee is not achieved till now. Worldwide economic recession gave rise to the downturn in 2009. And the decrease trend in 2012 was mainly due to the reduction in the amount of cargos. To testify this increase trend statistically, SPSS is used to make a linear regression analysis. See the results in Figure 5.9 and Table 5.11. As can be seen in Table 5.11, P-value is 0.001. It means null hypothesis is rejected and there is a true relationship between time and labor productivity. That is to say, labor productivity has indeed increased during the last ten years.

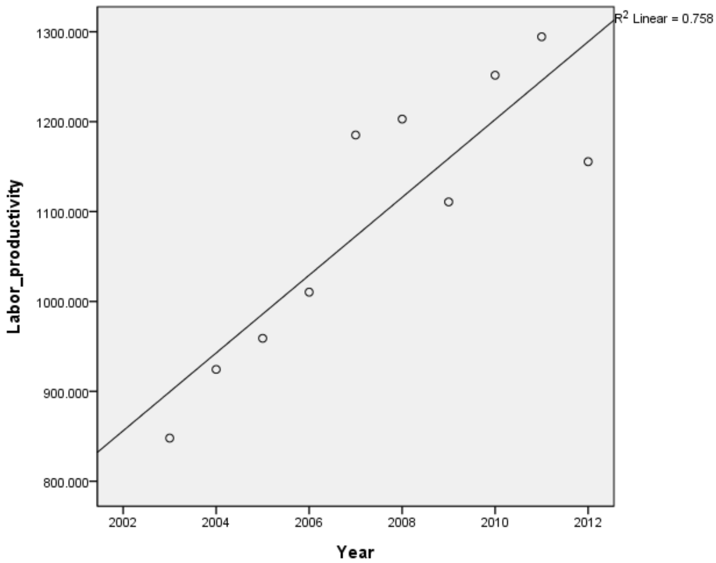

Figure 5.9: Scatterplot with regression line

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	154524.878	1	154524.878	25.082	.001[a]
	Residual	49286.000	8	6160.750		
	Total	203810.878	9			

a. Predictors: (Constant), Year

b. Dependent Variable: Labor_productivity

Table 5.11: Result of regression analysis of SPSS

5.3.2. Area productivity

Area productivity is defined as the ratio of container throughput and square meters of container terminal:

$$\text{Area productivity} = \frac{\text{container throughput}}{\text{square meters of container terminal}}$$

Here, container throughput in TEU is also regarded as output in this section and input factor is square meters of container terminal. After some calculations, Table 5.12 is obtained. And Figure 5.10 shows the changes of area productivity from 2003 to 2012.

Year	Container throughput (TEUs)	Terminal area (square meters)	Area productivity
2003	162385	190000	0.855
2004	177019	190000	0.932
2005	170506	168000	1.015
2006	172065	168000	1.024
2007	196252	168000	1.168
2008	190307	150000	1.269
2009	178943	166000	1.078
2010	201893	185000	1.091
2011	208799	150000	1.392
2012	202790	167000	1.214

Table 5.12: Area productivity of Oslo container terminal during the last ten years

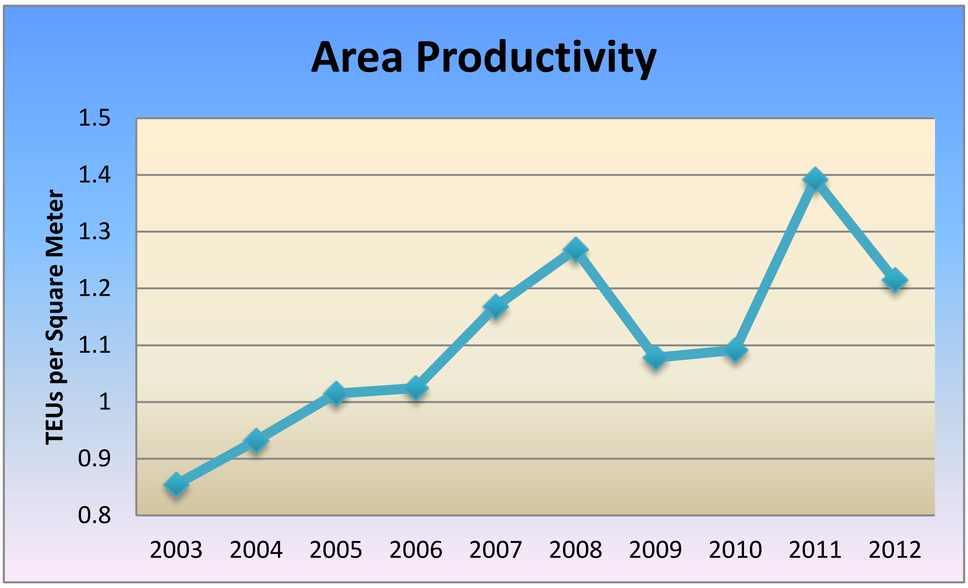

Figure 5.10: Area productivity of Oslo container terminal during the last ten years

As can be seen from Figure 5.10, the port of Oslo experiences a roughly increase trend during the last ten years in terms of area productivity with two dramatically decreases in 2009 and 2012. General economic depression resulted in the decrease in 2009. And the reduction in 2012 was mainly due to the drop in the amount of cargos. To testify this increase statistically, SPSS is also used to make a linear regression analysis. See the results in Figure 5.11 and Table 5.13. As can be seen in Table 5.13, P-value is 0.005. It means null hypothesis is rejected and there is a true relationship between time and area productivity. That is to say, area productivity has indeed increased during the last ten years.

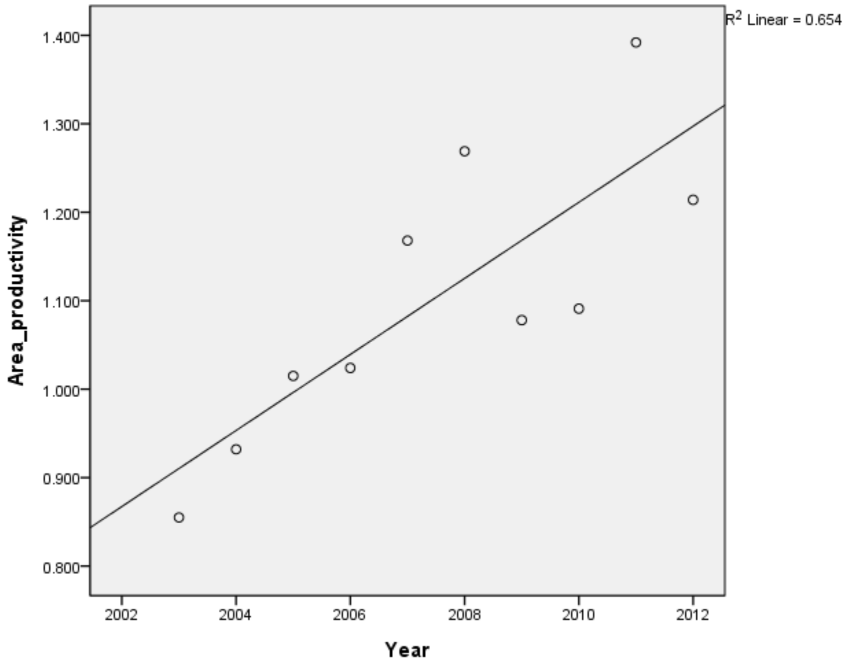

Figure 5.11: Scatterplot with regression line

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.152	1	.152	15.133	.005[a]
	Residual	.081	8	.010		
	Total	.233	9			

a. Predictors: (Constant), Year

b. Dependent Variable: Area_productivity

Table 5.13: Result of regression analysis of SPSS

Port authority has made two efforts to improve area productivity during the last ten years. Firstly, they purchased four RTG cranes and use them to replace some reach stackers (Hatteland 2013). In the storage area of Oslo container port, containers are unloaded from port chassis and stacked (or unstacked and loaded to port chassis) by RTGs and reach stackers. More specifically, arriving containers (imported) will be unloaded by SSGs from vessels, placed on port chassis, hauled to stacking area and stacked. By contrast, exported containers are unstacked from storage area, placed on port chassis, hauled to port's apron and loaded to ships by SSGs (see Figure 5.13).

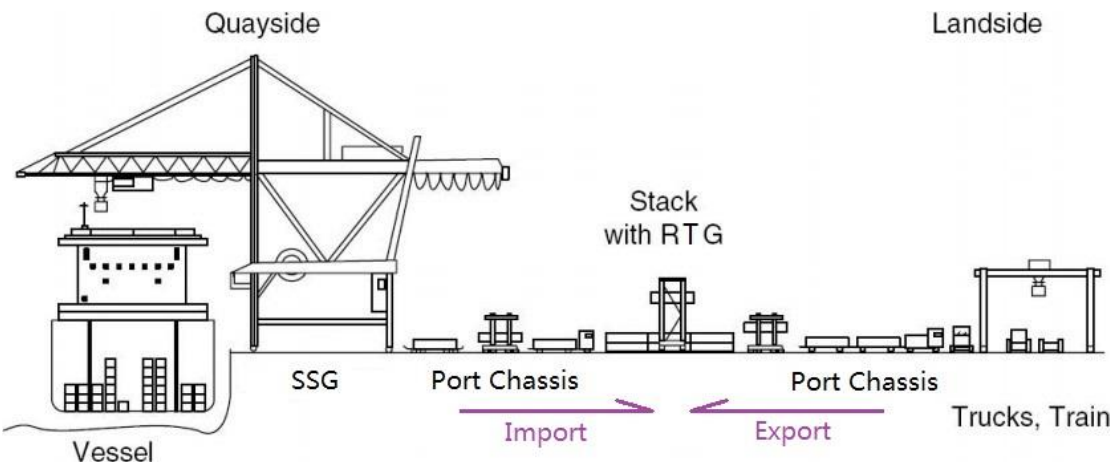

Figure 5.12: Schematic representation of container flow in Oslo port

Both of reach stackers (Figure 5.6) and RTGs (Figure 5.5) can stack intermodal containers within the stacking areas of a container terminal and place them to trains, port chassis and trucks. However, RTG is more efficient than reach stackers. RTG can pick and relocate containers in stacking area faster than reach stacker because it has selectivity capability advantage than the later. For instance, Figure 5.13 shows containers are stored in the way of block staking (five-row and four-tier). A RTG can easily pick up container 1, 2 and 3 and load them to trucks without the need to move. However, after unstacking container 1, a reach stacker has to go to the other side of this block to unstack container 3. In addition, extra empty area is called for when reach stackers move around in the stacking area. That is to say, RTG is more area efficient. Further, land is an expensive capital. Containers are stacked up to nine high in some seaport in the world. Reach stackers fail to reach containers at this high. But, RTG can. To sum up, RTGs require less space for operation and allow greater density in stacking area than reach stackers (Hatteland 2013).

Figure 5.13: Selectivity capability advantage of RTG

Secondly, Oslo port authority has improved their terminal operating system (TOS) which also can increase area efficiency by bettering housekeeping (Hatteland 2013). Housekeeping refers to internal transfer operations of containers. Remarshaling is one of the main reasons of conducting housekeeping. The remarshaling operation is a way in Oslo port (It is also a common practice in a normal port) to speed up loading operation of export containers onto a ship. Because export containers normally are scattered around a block, containers on the storage area should be rearranged to mirror their final positions on the container ship (see Figure 5.14). An advanced information system can provide a feasible working plan to convert the current layout of storage area into the desirable layout with the minimum number of container moves and travel distance. Due to each move of container requiring space, a better terminal operating system can improve the container flow, thereby increasing area efficiency (Hatteland 2013).

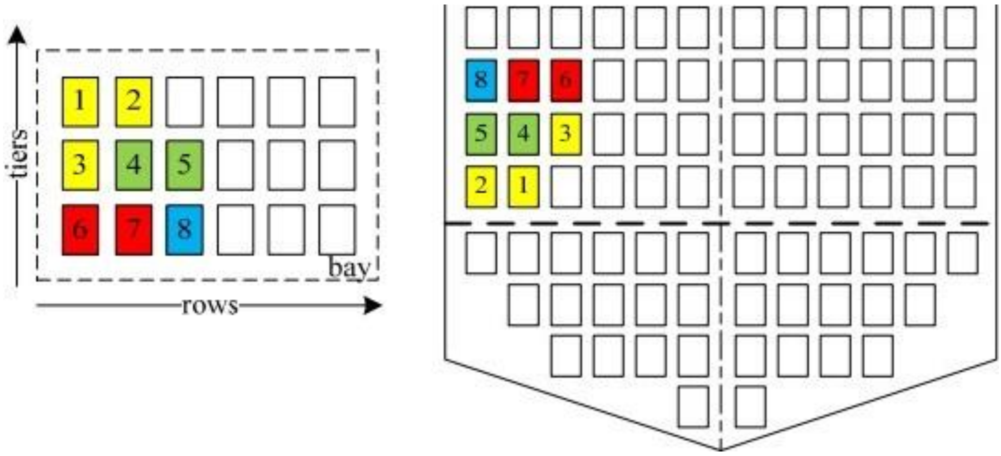

Figure 5.14: Bay view (vertical section) of a yard block (Left)
Bay view (vertical section) of a container ship (Right)
(Legato, Mazza, and Trunfio 2012)

As mentioned above, Oslo container terminal is the operator at Ormsundkaia and Sjursøya container terminal works at Søndre Sjursøykai. In addition, they use different operation systems. TOS of OCT is PICIT which is used for 10 years or more. SCT purchased its new system from Jade Master Terminal in 2010 (Hatteland 2013). These two systems have similar functions and can provide advanced approaches to optimizing space and minimizing equipment utilization in storage area. Further, the graphic user interface of their system can also increase productivity and reduce errors (MasterTerminal 2013, PICIT 2013). Each crane in Oslo container terminals is also installed TOS. Crane drivers can get information/tasks from TOS in their crane about which container should be lifted and where they should be moved to (Hatteland 2013).

However, Olav Madland, the CEO of Seamless, points out that necessary information is called for when TOS makes remarshaling plan, including information of where containers are going after they arrive terminals and when or in which sequence each of them is planned to leave. These types of information should be in place before each move, which allows system making plans in advance. If these types of event information missing or are not available in advance, not only area productivity is reduced, but also ship turnaround time and gate to gate time will increase. And it is not rare that, in terms of Oslo container terminal, necessary event information is missing (Madland 2013). This point will be discussed further in section 6.3. That is to say, although information system helps terminal operators increase their area productivity, there is also a great potential for improving their performance in this indicator if all necessary information is in place in advance.

5.3.3. Crane productivity

Crane productivity is to measure how many containers can be handled per hour during the loading and unloading activity. The performance of a container terminal on this indicator can influence its overall performance to a great extent. More specifically, a terminal with better performance in this aspect can serve more container ships (increase ship throughput) then a weak performer during the same time period and receive more revenue. In addition, if a container terminal is not willing to make profits (such as port authorities in Norway), it can offer a lower service price and attract and serve more customers.

Crane productivity is defined as the ratio of number of containers (number of lifts by SSG) and SSG crane hours. As discussed above, only ship-shore gantry crane is responsible for loading and unloading activities in Oslo port. Hence, crane hours of SSG will be considered as an input factor in crane productivity. In addition, every container is different in weight. Thus, amount of container measured in tons is not suitable to this case. And number of containers (both loading and unloading) should be regarded as output factor.

$$\text{Crane productivity} = \frac{\text{number of lifts by SSG}}{\text{SSG crane hours}}$$

Recall that numbers provided in Table 5.6 represent container throughput in twenty-foot equivalent unit (TEU) in Oslo port during the last ten years. However, approximately two third of containers through Oslo port are 40 feet containers and others consist of 20’ containers, 40’ high-cube containers and 45’ high-cube containers. A coefficient (1.57) provided by Oslo port authority can transfer number of TEUs into number of crane lifts (Hatteland 2013). Hence, Table 5.14 is obtained. After that, according to the formula provided above, the results in Table 5.15 illustrate crane productivity in Oslo container terminal during the last ten years. And Figure 5.15 shows the changes of crane productivity from 2003 to 2012.

Year	Number of Lifts	Year	Number of Lifts
2003	103430	2008	121215
2004	112751	2009	113976
2005	108603	2010	128594
2006	109596	2011	132993
2007	125001	2012	129166

Table 5.14: Number of crane lifts during the loading and unloading operation in Oslo container terminal from 2003 to 2012

Year	Number of Lifts	Crane Hours	Crane Productivity
2003	103430	5053	20.46903
2004	112751	6295	17.9112
2005	108603	5589	19.43156
2006	109596	5689	19.26455
2007	125001	6550	19.08412
2008	121215	6756	17.94183
2009	113976	5939	19.19111
2010	128594	6443	19.95871
2011	132993	6739	19.73483
2012	129166	6490	19.90231

Table 5.15: Crane productivity of Oslo container terminal during the last ten years

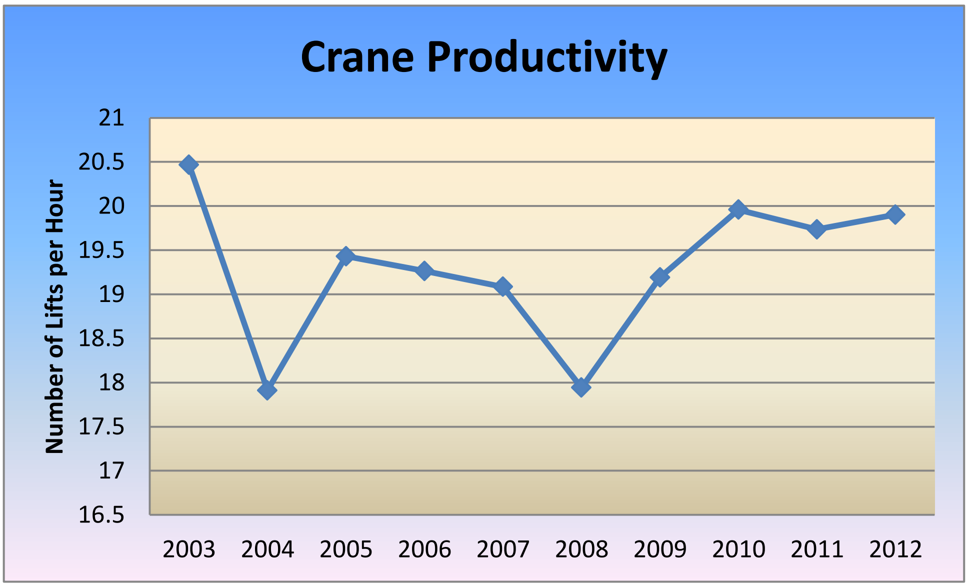

Figure 5.15: Crane productivity of Oslo container terminal during the last ten years

As shown in Figure 5.15, crane productivity was fluctuated around 19 lifts per hour in the last ten years. And their performance is about 20 lifts per hour currently (Hatteland 2013). Oslo container terminals seem do not improve or regress in this aspect. This is because crane productivity is more determinate by external environment and port authority can do little about it.

Stevedores' break is the main obstacle of increasing crane productivity. For instance, if stevedores work from 10 am to 2 pm, they need have a break from 12 pm to 1 pm. Crane drivers should wait during their break. If the break time is excluded from crane hours in Table 5.15, the net crane productivity in Oslo container terminal is around 27 lifts per hour (Hatteland 2013).

Ship design is another important external factor influencing crane productivity. Normally, after a container is moved to the quay side by port chassis, SSG attaches to the container and lifts it at waist-high. At this time, stevedores take proper container fittings and attach them to the container corners (Figure 5.16) before the crane moves the container to the correct position on the ship with hatch covers. See Figure 5.17. Fully automatic twist locks (which can automatically lock and unlock) can make the loading/unloading process more efficient then semi-automatic twist locks (which can automatically lock and should be manually unlocked) (Hatteland 2013).

In terms of a container ship with no hatch covers (Figure 5.18), the containers can be loaded directly into the cell guides and no fitting is called for. Loading and unloading process for a container ship like this is faster and more cost efficient because cell guides in this ship are fixed structures that can keep containers without any other equipment, such as twist locks mentioned above. This type of container ship can dramatically reduce labor cost and fitting installing time (Pacificmarine 2013).

Figure 5.16: A stevedore is installing an automated twist lock (Spreaders 2008)

Figure 5.17: Container ship with hatch covers

Figure 5.18: Container ship with no hatch covers

Although crane productivity is determinate by external factors to a large extent, Oslo port also takes efforts to increase the cooperation among SSGs, port chassis and RTGs. Great cooperation can reduce traffic congestions in port, thereby reducing waiting time and increasing crane productivity (Hatteland 2013). However, certain event information is called for to achieve such cooperation. That necessary information in landside service is unavailable gives rise to the fact that there is no increase trend in the last ten years in terms of crane productivity. This issue will be discussed further in Section 6.3.

5.4. Conclusion

This section introduces the related inputs and outputs information of container terminals in Oslo port in details, which provides the necessary information for PPM analysis in this section. After that, PPM indicators are selected based on the situation of Oslo container terminals and previous studies in this field and used to measure the productivity changes of container terminals in the last ten years.

From the productivity measures and discussions in Section 5.3, the author can draw a conclusion that container terminals of Oslo has improved its productivity in terms of labor and land use during the time period from 2003 to 2012. To achieve these results, port authority takes measures including restructuring organization, adjusting workforce and replacing part of reach stackers by RTGs and these two terminal operators (Oslo Container Terminal and Sjursøya Container Terminal) also have improved their own terminal operation systems. Crane productivity has not increased during this period because this indicator is influenced by external factors to a great extent, such as, breaks of stevedores and ship design. Nonetheless, port authority also makes efforts to increase crane productivity by bettering the cooperation between SSGs and RTGs. Further, the author also mentioned that necessary information missing is a major problem in Oslo container terminals, which hinders the productivity increase in land use and crane operation. This issue will be discussed in detail in the next chapter.

6. Performance measurements for container terminals of Oslo port

Performance measurements are crucial for all types of organization, including privately owned corporation, state owned corporation and non-profits organization (i.e., Oslo port authority) because they illustrate the extent to which these organizations have achieved their targets. Therefore, a set of proper performance indicators are of importance to any organization.

In this section, the author will compare the differences between the contemporary situation of performance measurements in container terminals of Oslo and the performance measures framework in literature and identify the reason of these differences. Further, certain performance indicator will be suggested to Oslo port authority based on the finding of this research. Finally, modifications are suggested for the port performance measurement framework provided by Woo et al. in 2011.

There are four research questions which should be answered in this chapter:

1) Does the performance indicators used by Oslo Port differ from the ones used by the framework published by Woo et al. in 2011? If so, what are the reasons?

2) How can the performance of Oslo port be improved for the most important traffic category?

3) Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?

4) Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to this case study?

6.1. The contemporary performance measurement in container terminals of Oslo

Four performance indicators are used by Oslo port authority to measure the performance of its service providers, two container terminal operators, OCT and SCT: container throughput, area efficiency, crane efficiency and gate to gate time, these performance indicators are the most frequently used ones by not only port authorities but also their stakeholders, including terminal operators, forwarding agents, shipping lines, etc. More specifically, terminal operators use them to assess their own performance; port authorities need to measure their services providers' performance and port users (i.e., forwarding agents, shipping lines, etc.) use these indicators (especially, crane efficiency and gate to gate time) to compare service quality between different ports.

Area efficiency (productivity) and crane efficiency (productivity) are also adopted in Chapter 5 as PPM indicators. Although productivity and efficiency has different meanings in terms of productivity measures, they are partially exchangeable in common sense. The term "efficiency" will be used in this section because it currently used in port of Oslo and the purpose of this section is to introduce the current situation of performance measures in container terminals of Oslo.

6.1.1. Container throughput

Container throughput of Oslo port is 208,799 and 202,790 in terms of TEU and 1,346 and 1,278 in terms of thousand tons in 2011 and 2012 respectively (Oslohavn 2011b, 2012a). For more information, please see Table 5.6 and 5.7 in Chapter 5. It is the most frequently used indicator and should be adopted by all container terminals in the world.

In terms of Oslo container terminal, throughput is constraint by the size of stacking storage area to a large extent, since both import and export containers needs to stay at terminal waiting for vehicles or container ships coming and collecting them. Export container through Oslo port will be given 7 days free time of storage. Containers can be delivered to terminal and stay there for 7 days without cost. In terms of import containers, there is two days free time. If a container stays at terminal longer than these limitations, the owner of this container will be charged a demurrage which is expensive. Hence, no one is willing to store containers in a terminal (Hatteland 2013). Oslo port has already lost certain customers and market share due to its limited storage area (no more area to store unloaded containers of new customers) and shortened free storage period. To increase area efficiency, Oslo port shortens the free storage period for import container to two days. However, 5-7 days are more common in Norwegian port industry (Berg 2013).

6.1.2. Area efficiency

Although area efficiency is adopted as a PPM indicator in Chapter 5, the method used to calculate this indicator by port authority is different from what the author did. The author considers container throughput in TEU as output factor because each TEU occupies the same size of area regardless the weight of this container, while the port authority regards container throughput in ton as output factor. Table 6.1 below illustrates area efficiency in 2011 and 2012 provided by Oslo port authority.

Year	Container throughput (1000 tons)	Terminal area (square meters)	Area efficiency (tons per square meter)
2011	1,358	150000	9.1
2012	1,278	167000	7.7

Table 6.1: Area efficiency of container terminals in Oslo port in 2011 and 2012 (Oslohavn 2011b, 2012a)

6.1.3. Crane efficiency

As calculated in Chapter 5, gross crane efficiency currently is 20 lifts per crane hour and net one is 27 lifts per crane hour. The target of gross crane efficiency is 20 lifts per crane hour currently. That is to say, Oslo port has already met this target. Therefore, the port plans to increase this target to 27 lifts per crane hour. This new target is determinate based on the analyses of terminal layout and certain simulations of crane efficiency, which testify this new target is technically achievable.

Crane efficiency is the key determinant of ship working time and ship turnaround time. And as discussed in Chapter 5, stevedores' break is one of the main obstacles of improving crane efficiency. If there is no stevedores' break, the ship turnaround time can be decreased by 25%. Getting rid of the break time can be achieved by using four stevedores a team replacing three stevedores a team. That is to say, the tradeoff should be made between decreasing ship turnaround time by 25% and increasing manpower cost by 33%. If shipping lines believe time is more crucial than the increased cost, they can ask for this alternative service. However, in practice, most of shipping lines are not willing to pay for this service (Hatteland 2013).

6.1.4. Gate to gate time

Gate to gate time means the total time used by a vehicle from getting in to getting out a container terminal. This indicator measures both the traffic congestions in a terminal and time used to identify the right container. This indicator is varying quite much in practice. Generally speaking, if there is no traffic congestion in terminal, 15 minutes should be taken from getting in to getting out. However, when there are very much traffic combination of internal and external vehicles, the productivity will slow down dramatically. For instance, when the terminal is handling a container ship, at the same time, there is a big pressure on collecting containers from external actors (landside service) (Hatteland 2013).

Port authority set a target for this indicator for 15 minute. That is to say, if there is no high pressure on internal traffic, the port can meet this target. Oslo port set this target according to the capacity of the terminal and their experience (Hatteland 2013).

6.2. Comparison between the current situation of performance measurement in Oslo container terminals and the port performance measurement framework

As can be seen from the Table 6.2 in the next page, there are huge differences between performance indicators used in Oslo container terminals currently and the performance indicators in the framework provided by Woo Pettit and Beresford in 2011. In addition, this table also briefly tells the main reason which gives rise to this situation: Oslo port authority is a landlord port and only provides very limited services. That is to say, indicators in customer orientation category are not applicable to Oslo port authority.

6.2.1. Service quality

Oslo port authority is a landlord port who does not serve port users (i.e., forwarding agents and shipping lines, etc.) directly. Terminal operator is responsible for the services to port users. From this aspect to say, performance indicators of service quality is not applicable to Oslo port authority. However, Oslo port authority is different with other landlord ports that do not provide any service, give operators long terms contracts (up to 40 years), and do not intervene with the operation of operators and development of terminals.(such as landlord port in Germany). Oslo port authority offers crane service and assesses the performance of terminal operators. That is to say, it needs performance indicators of service quality.

6.2.1.1. Timeliness, reliability and lead time

Timeliness means service is ready on time. Service users (i.e., shipping lines and trucks) do not need to wait when they arrive at terminal. Generally speaking, lead time refers to the time interval between the initiation and the completion of a production process. When applying it to port industry, lead time should be the service time, i.e., gate to gate time in landside service and ship turnaround time in terms of quayside service.

Reliability refers to the variation of service quality. Taking landside service as an example, gate to gate time could be reduced to only 5 minutes when there are no internal traffic congestions and the right container is easily achievable. However, when the quayside service and landside service are required simultaneously, the internal traffic pressure will be high. As a consequence, the queue in the stacking area gives rise to long waiting time. The gate to gate time in this situation could be up to 40 minutes. That is to say, reliability in Oslo container terminal is not high due to the large variance.

According to the discussion above, gate to gate time and crane efficiency can reflect timeliness, reliability and lead time of service to a large extent.

Categories of indicators	Performance indicators in the framework of (Woo, Pettit, and Beresford 2011)	Similar performance indicators used in container terminals of Oslo port	Brief comments
Service quality	Timeliness Reliability Lead time Cargo damages Accuracy of information	Gate to gate time and crane efficiency Not important Not important	Port authority is only the crane service provider and does not serve port users (shipping lines, etc.) directly. The customers of port authority are terminal operators from this aspect. Gate to gate time and crane efficiency can reflect timeliness, reliability and lead time of service to some extent.
Customer orientation	Responsiveness Flexibility Annual number of claims	n/a n/a n/a	Port authority does not serve port users directly and hardly be blamed.
Service price	Total port charge Cargo handling charge Port related service charge Port facility usage charge	Not important Not important Not important Not important	Ports in Norway are non-profits organizations. Service prices are determinate by cost.
Efficient operation	Throughput Throughput per hectare Throughput per worker Throughput per crane Ship waiting time Ship working time	Throughput Area efficiency Not important Crane efficiency Not important Crane efficiency	Crane efficiency is the major determinant of ship working time and ship turnaround time
Safety and security	Compliance with regulation Number of accident Number of accident prevented	Not important Not important Not important	Accidents are very rare during crane operation and covered by insurance.
Connectivity	Cargo waiting time between modes Cargo working time between modes	Not important n/a	Cargo waiting time is determinate by free storage period. Cargo working time is not suitable to container terminal.
Value-added service	Cargo accruing from VAS Value-added from VAS	Not important Not important	Oslo port authority provides very limited value-added service.

Table 6.2: Comparison between the status quo of container terminals of Oslo and the port performance measurement framework

6.2.1.2. Cargo damage

Container damage in crane operation happens rarely and will be covered by insurance. Besides, port operator is responsible for customers (i.e., shipping lines and forwarding agents), rather than port authority who is only the service provider. That is to say, cargo damage is not a major issue when considering improving performance. In addition, in most of time, cargo is damaged, rather than container damaged. For instance, there is temperature control overtime in refrigerator container. In this situation, cargo damage is mainly due to electricity breaks (Hatteland 2013).

6.2.1.3. Information accuracy

The port authority is the service provider of crane service. That is to say, it only needs to provide information about number of lifts to port operator. The information is quite simple and not easy to make mistakes. When it comes to the SSG crane services, Port operator receives orders from shipping lines about how many containers should be loaded and unloaded. After port operators forward these orders to port authority, port authority knows its workload and prepares capacity to meet the demand. In terms of RTG cranes, because the demand information is not available in advance, port authority will know the information about number of lifts after the service is provided. For example, if the container is on the top of a stack, only one lifts is called for. However, if the container is stacked under other three other containers, four lifts are needed (Hatteland 2013).

6.2.2. Customer orientation

Port authority does not serve port users directly and hardly be blamed. Terminal operators are responsible for customer services. That is to say, indicators in customer orientation category are not applicable to Oslo port authority (Hatteland 2013).

6.2.3. Service price

Service price is determined by cost of providing that service due to the self-financing principle. That is to say, service price is not a major problem considered by port authority. The port authority has made certain efforts to increase its efficiency, thereby reducing service price, including minimizing the conflicts between internal and external vehicles, reducing human resource cost and increasing area and crane productivity. All this efforts are discussed in detail in different sections of this thesis.

6.2.4. Efficient operation

As can be seen from Table 6.2, throughput, throughput per hectare and throughput per crane in the framework can be covered by container throughput, area efficiency and crane efficiency respectively. Ship waiting time is near to zero in Oslo port. It is more common in Oslo port that the berth and equipment wait for ships.

Ship working time is the total time of loading or unloading a ship. There is no similar performance indicator used in Oslo port authority for this term because the number of containers which should be handled varies from a container ship to the other. And crane efficiency can influence this indicator to a great extent (Hatteland 2013).

6.2.5. Safety and security

Port of Oslo has become an ISPS port since 2004. And all ports in Norway are ISPS ports. Accidents are very rare during crane operation and covered by insurance. That is to say, this performance indicator category is not a major problem for Oslo port when considering the overall performance (Hatteland 2013).

6.2.6. Connectivity

Cargo waiting time between modes

In terms of container terminal, this indicator should be container waiting time which refers to how long a container stay in the terminal before it leaves. Taking import container as an example, these containers can be stored in terminal two days for free. Hence, no one will collect then before the deadline. As a consequence, import container waiting time is 2.3 days in average. For the same reason, the export container waiting time is a little bit more than 7 days in average (Hatteland 2013).

Cargo working time between modes

This indicator, cargo working time, is not suitable for container terminal. In terms of container terminal, this indicator should be container working time which refers to how much the time is related to the handling a container (lifting a container) which only cost several seconds actually (Hatteland 2013).

6.2.7. Value-added service

All value-added services are related to the cost of infrastructure and require someone who is willing to pay. Before providing value-added services, the trade-off between cost and the potential revenue should be made. Currently, container terminals of Oslo offer three value-added services which are listed below. Providing such services is not a simple issue. The cooperation between different actors is called for, at least including, port authority, container terminal operators, forwarding agents, shipping lines and train companies (Hatteland 2013). Due to the limited number of value-added services, the related revenue and new customers are also very limited.

1) Providing power for cooing containers
2) Railway connections

3) Empty containers storage and refilling

   Empty containers can be stored for a long time in an empty container depot with low cost. For instance, company A has a container and sends it with cargo from Germany to Norway. After this container arrives at Norway, the customer will receive the cargo and empty the container. In this situation, company A has two choices. It can move this empty container back to the stack and send it out as an export container. Alternatively, if the company A is willing to refill this container again and send it back with cargo in, it can put it in the empty container depot and wait for an opportunity when a customer needs to send cargo to Germany. Company A can provide this container for its customer. The terminal operator will take this container out from the empty container depot and fill the cargo in (Hatteland 2013).

6.2.8. Conclusion

As can be seen from the Table 6.2 and the discussion above, the performance indicators used by Oslo port authority are a smaller set than the range of indicators found in the literature. This is natural since the literature considers total port performance, including terminal operators. By contrast, Oslo port authority is a landlord port providing a very limited number of service and not responsible for customer service.

6.3. The potential to reduce gate to gate time

To sum up, the author has discussed several feasible methods to improve the performance of first three indicators which are used by Oslo port authority:

Performance indicators	Improving methods
Container throughput	Increase area efficiency Increase stacking storage area
Area efficiency	Use RTG to replace reach stacker Improve terminal operating system
Crane efficiency	Reduce stevedores' breaks Better the cooperation between SSG and RTG

Table 6.3: Feasible improving methods

Therefore, this section will focus on identifying the improving method for the fourth indicator, gate to gate time. According to the primary information obtained from interview with informants, internal traffic congestion is the main obstacle of improving the performance on gate to gate time. Internal traffic congestion is mainly generated when handling ships and trucks at the same time. Making balance between internal vehicles and external vehicles can improve the performance on gate to gate time. More specifically, after an external vehicle comes in and drives under the RTG crane, the RTG crane needs to lift at least four containers normally to get the right container which should be loaded onto the truck. If, at the same time, an internal vehicle comes from the ship, it should wait in a queue behind the external truck. That is to say, the internal vehicle will fail to go back with container on time and the SSG should wait there. The consequence is that not only the crane efficiency of SSG is decreased, but also the gate to gate time and ship turnaround time are increased (Madland 2013).

Although the containers that come from ships may very well be collected before one that is already in stack and the internal vehicle should be given higher priority than external vehicles, the problem is that terminal does not know when a truck will come to collect an import container. When internal vehicles are driving between SSG and RTG with import containers, external vehicles may arrive and mix the traffic, hence causing queuing and waiting times. That is to say, information missing gives rise to the internal traffic congestion (Madland 2013).

Terminal operator does not know the information about when and in which sequence the containers are collected by external actors (such as, forwarding agents). Therefore, port operator fails to prepare in advance (Hatteland 2013). More specifically, when trucks come, truck drivers might ask for their container that could be positioned in the bottom of a stack, which generates many extra unnecessary lifts in order to get these containers (Madland 2013). If terminal operator has known this information in advance, it was easier to move the containers what the truck drivers want to the top of a stack before they come, thereby dramatically reducing the gate to gate time. This situation of information missing gives rise to the main obstacle of improving this indicator.

In practice, forwarding agents sent order to their truck drivers asking them to pick up containers at terminal. When they arrive at port and ask for their containers, the information goes to the crane driver. The truck driver has a booking reference which is connected to a container number. The container number is connected to an area reference and position in the stack. The Booking is also connected to a ship operator. Terminal operator usually put different ship operators' containers in different stack. For instance, Maersk's containers are put in Maersk Stack, etc. It is the forman that has the control on where each container is. They are good to memorize (Madland 2013).

Information is never perfect, although there is more or less full overview of information with regard to ship handling. By contrast, terminal knows nothing about in which sequence containers are collected by trucks until truck drivers come. Although loading information is available for ship handling in advance, in OCT, there is no buffer area in front of the berth which can be used to temporarily store containers to be loaded onto a ship. That is to say, it is impossible for operations of remarshaling in front of berth. As a consequence, terminal tractors move containers between ship and stacking area back and forth. SSG should wait for terminal tractors to load and unload containers to and from the ship. In SCT, there is a very limited area for storage when using straddle carrier (like 2-3 containers per crane). And this limited area also enables SSG put containers on ground under crane without the need of waiting for internal vehicles' back. Hence, it makes flexibility but it is also impossible for operations of remarshaling in front of berth, which hinder the improvement of performance (Madland 2013).

To sum up, necessary information missing of landside service (in which sequence the containers are collected by external actors) gives rise to internal traffic congestion which increasing gate to gate time and reduce SSG crane efficiency. See Figure 6.1 below.

Figure 6.1: The obstacle of improving performance on gate to gate time

Port authority has made some efforts with external actors to improve information flow on this issue. Such as, reward truck drivers who provide information in advance. A forwarding agent controls a fleet of vehicles normally. The truck drivers do not know the information until the agent give them orders (Hatteland 2013). That is to say, there is still a way to go for container terminals in Oslo. If information is available in advance, the performance will be improved dramatically in terms of time and cost. More specifically, the RTG can pick the right container up from a stack and put it on the ground. It can be load onto the truck directly when it arrives at terminal. The gate to gate time can be reduced to ten minutes in this situation (Hatteland 2013).

This is a common known problem for this kind of operation and is often attempted controlled by slot times for external vehicles. However, because port of Oslo is not so big, the operator believes it is not necessary to constrain landside customers in this way. And landside customers prefer a high level of flexibility (may occasional waiting time) to very predictable but rigid/constrained service (Hatteland 2013).

As mentioned before, Oslo port authority has a future develop plan which can enable Oslo container terminal to become one of the most efficient container port in Europe. In the new layout for a new container terminal in Sjursøya from 2015, the layout is based on a combination where straddle and shuttle carriers pick up containers under SSG and leave on ground under a RTG, thereby decoupling resources, creating a substantial buffer. In the new layout there are also no external vehicles in the terminal. RTGs put containers on ground and straddle and shuttle carriers pick up and deliver to waiting trucks outside the stacking area (Hatteland 2013).

6.4. Suggestion of new performance indicators for Oslo container terminal.

As can be seen from the discussion above, information missing (the problem of information sharing between terminal operators and forwarding agents) is the root cause which hinders the improvements of overall performance in container terminals of Oslo port, including area efficiency, crane efficiency, throughput and gate to gate time. See Figure 6.2 below.

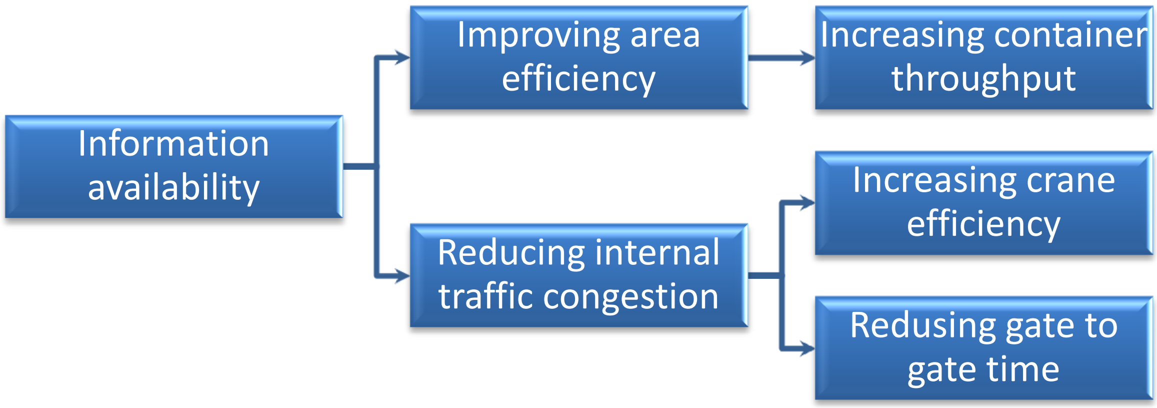

Figure 6.2: The importance of information availability

Information can improve the container flow, thereby increasing area efficiency. Because the size of stacking storage area is the constraint of container throughput in Oslo container terminals and storage area cannot be increased dramatically in short-term, increased area efficiency leads to increased container throughput. In addition, information provided by forwarding agents enables terminal operator to prepare containers before trucks come, which can dramatically reduce gate to gate time. Reduced gate to gate time leads to shorter queue in the stacking area which increases the possibility that port chassis coming from ship can go back on time, thereby increasing SSG crane efficiency. Due to the importance of information availability, it should be considered as a new performance indicator in the performance measurement framework used by Oslo port authority. Information availability can be defined as the information provided by forwarding agents or truck drivers can be available for port operator before truck comes. And this time period is sufficiently long to enable port operator to make preparation in advance, even if there is a huge pressure on quayside service simultaneously.

6.5. Suggestion and conclusion

The four research questions answered in this section are:

1) Does the performance indicators used by Oslo Port differ from the ones used by the framework published by Woo et al. in 2011? If so, what are the reasons?

2) How can the performance of Oslo port be improved for the most important traffic category?

3) Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?

4) Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to this case study?

To answer these four research questions, the current situation of performance measurement in container terminals of Oslo is compared with the port performance measurement framework provided by Woo, Pettit and Beresford. I find that the characteristic of Oslo port authority, landlord port, contributes to the situation that performance indicators used by Oslo port authority is only a smaller set of the range of indicators found in the literature. Most indicators in literature are not applicable or not important to Oslo port authority.

During interviews with three informants of this research (Carl Johan Hatteland, terminal adviser at Port of Oslo; Geir Berg, Business advisor at SITMA which is a leading consulting company in logistics, strategic and operational development of value chains; and Olav Madland, CEO at Seamless which is the information system provider of Oslo port authority), the author finds that the main problem which hinders the improvement of overall performance of container terminals in Oslo port is the information missing of landside service. Although there is still a way to optimize information in terms of quayside service, improving information quality in this side is of minor importance compared with landside service, because the later one is the bottleneck in current situation. After recognizing this problem, the author suggest a new performance indicator for Oslo port authority, information availability, which can be defined as the information provided by forwarding agents or truck drivers can be available for port operator before truck comes. And this time period is sufficiently long to enable port operator to make preparation in advance, even if there is a huge pressure on quayside service simultaneously.

Woo et al, provided a comprehensive port performance measurement framework in 2011, which is derived from previous literatures and surveys. However, this framework does not consider information sharing between stakeholders. At least, event information sharing between forwarding agents and container terminals and between shipping lines and container terminals are proved to be crucial in the case of container terminals of Oslo port. Therefore, the author would like to suggest a new performance measurement category, information sharing between terminal operator and port users, which should be a sub-dimension of logistics. See Figure 6.3 below.

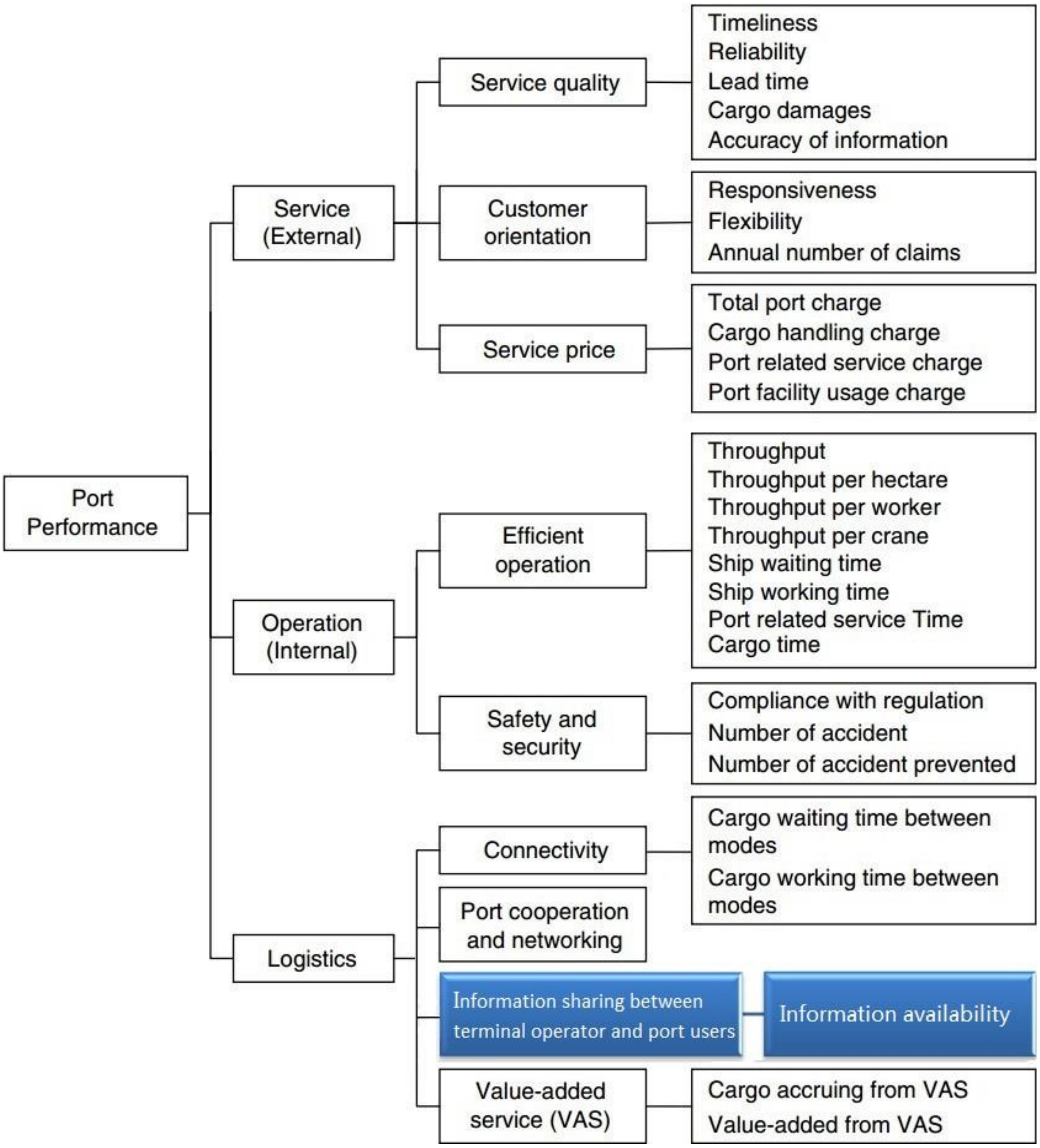

Figure 6.3: New port performance measurement framework

6.6. Further research

As discussed above, information sharing is the major problem faced by Oslo port authority. Actually, not only Oslo port, but also many companies in nearly all industries growingly aware that their business goals are difficult to achieve by their own; therefore, companies have to build up value based relationship through supply chain network, thereby increasing their performance and keeping competitiveness. And information sharing is an inevitable problem which organizations looking for cooperation have to face to. Generally speaking, information sharing problem can be divided into two sub-issues: First, some companies are reluctant to share information with their stakeholders. Certain reasons of this issue will be discussed in Section 6.6.1 below. Second, supply chain partners may use different information systems (i.e., Oslo port authority use Seamless and Oslo container terminal use PICIT), it is difficult to change information between different systems. This technical problem can be resolved by third party information service providers who operate between suppliers and customers as intermediaries and enable information flows between different information systems through their own technological platform. The author is willing to propose certain solutions based on the real reason why information is missing between Oslo container terminals and forwarding agents by conducting further research in the future.

6.6.1. The reasons why many companies in a supply chain are reluctant to share information

6.6.1.1. Matthew et al. (2007)

Matthew et al. (2007) demonstrate the reason why many firms in a supply chain are reluctant to share information with their partners from the aspect of game theory. They argue that social dilemma exists in supply chain alliance as a result of these two reasons:

1) Firms "must choose between doing what is in their own best interest or the group's best interest".
2) Every firm "choosing to do what is in their own best interest leads to an outcome that does not provide benefits for" each firm. (McCarterl and Northcraft 2007)

There are striking similarities between the situation in supply chain alliance and the situation described in Prisoners' Dilemma Game (illustrated in Figure 6.4). Both partners can make the decision between contributing (share information) and defecting (do not share information). In a Prisoners' Dilemma, it is in the best interest of each partner to defect no matter of the choice of the other. This is because no matter what partner 2 chooses, both are better off if partner 1 chooses to defect. (McCarterl and Northcraft 2007)

Prisoners' Dilemma Game		Partner 2	
		Contribute	Defect
Partner 1	Contribute	7, 7	3, 10
	Defect	10, 3	5, 5

Figure 6.4: Prisoners' Dilemma Game (McCarterl and Northcraft 2007)

Actually, there are three types of defects contributing to this dilemma. They are:

1) Free-riding problem: Free riding occurs when a partner tries to exploit the benefits of the alliance without its own contribution.
2) Hold-up problem: hold-up problem describes a phenomenon that a partner attempts to claim an unfair share of the value created by the alliance. This partner may contribute to its own creation.
3) Leakage problem: The leakage problem occurs when an alliance partner attempts to use the resources of the alliance to create for another organization. (McCarterl and Northcraft 2007)

Because these opportunistic behaviors exist in a supply chain alliance and trust among supply chain partners is consequently low, a partner's willingness to share information and make contribution will decrease. However, Matthew et al. (2007) proposed certain suggestions which can be implemented by supply chain partners to increase the likelihood of alliance's success. Firstly, increasing the communication frequency and amount is one of the solutions to increase mutual trust among partners. Besides, agreement time horizon, rewards and sanction policies can also contribute to alliance's success for the obvious reason that they increase the trust between partners. (McCarterl and Northcraft 2007)

6.6.1.2. Chu and Lee (2006)

Chu and Lee considered a situation in Bayesian game and also found that supply chain player is reluctant to share information in some occasions. There are two members in a supply chain: a vendor and a retailer. The vendor needs to make decision about stock level and hold inventory, while, the retailer can receive a signal about market demand in each period before the real demand is realized because the retailer is more close to the end customer. Hence, the retailer can reveal the forecast demand information to the vendor before production process starts at a cost. Absolutely, the retailer can choose to do not share this information. Chu and Lee assumed that retailer only reveals true information if this retailer chooses to do so. (Chu and Lee 2006)

After this research, they found that, in equilibrium, the retailer make the decision about information sharing only according to two things: (Chu and Lee 2006)

1) The cost of information revealing;
2) The content of forecast demand information: high demand or low demand

If the revealing information costs largely, the retailer will be reluctant to share this information no matter of the content of the information. If the cost is small, that the decision of sharing or withholding the information can be made depends on the content of this information: the retailer will share the information if a high demand is signaled. In contrast, the retailer will withhold the information if a low demand is signaled. (Chu and Lee 2006)

7. Limitations of this study

In terms of “value ton”, the author fail to testify whether Dupuydauby rule is appropriate to this study due to the lack of transparency. The information of how this rule is developed is not available and the methodological foundation and data used when developing this rule are kept confidentially. That is to say, there might be a problem when this theory is applied to the current project. Keeping this limitation in mind, Dupuydauby rule enables us to consider the impact of value added concept in the cargo handling process for each traffic category.

Actually, many factors have impact on the performance of a port. “It is argued that economic, political, societal and environmental processes evolve in close interdependency and need to be treated in conjunction” (Grossmann 2006). However, this research will not cover the political and societal factors.

8. Conclusion

The overall objective of present research was to measure the productivity of Oslo port and analyze how to improve its performance by performance indicators. To achieve this goal, the author has stated 6 research questions and utilized 4 sources of evidence. They are documentation, archival records, interviews and direct observations.

Research question 1: Which traffic category is the most important one for Oslo port?

The findings of BCG matrix analysis suggested that container traffic is the most important traffic category in Oslo port currently due to its market share, growth rate and revenue generating capability. Further, it has the largest market share (around 50%) in Oslo fjord during the studied period, from 2004 to 2011. By narrowing down the research scope, the author could focus on the most vital part of Oslo port and identify a bottleneck which hinders performance improvement of this traffic category.

Research question 2: Whether Oslo port has improved its productivity for the most important traffic category during the last ten years?

The productivity was measured by labor area and crane productivity. This study has found that container port of Oslo has improved its productivity in terms of labor and land use during the time period from 2003 to 2012. To achieve these results, port authority takes measures including restructuring organization, adjusting workforce and replacing part of reach stackers by rubber tyred gantry cranes and these two terminal operators (Oslo Container Terminal and Sjursøya Container Terminal) also have improved their own terminal operation systems. Crane productivity has not increased during this period because this indicator is influenced by external factors to a great extent, such as, breaks of stevedores and ship design.

Research question 3: Does the performance indicators used by Oslo port differ from the ones used by the framework published by Woo et al. in 2011? If so, what are the reasons?

The author compared the current situation of performance measurement indicators in container terminals of Oslo and the port performance measurement framework provided by Woo, Pettit and Beresford and found that the characteristic of Oslo port authority, landlord port, contributes to the situation that performance indicators used by Oslo port authority is only a smaller set of the range of indicators found in the literature. Most indicators in literature are not applicable or not important to Oslo port authority.

Research question 4: How can the performance of Oslo port be improved for the most important traffic category?

According to deeper analysis in Section six, the author realized that information missing (the problem of information sharing between terminal operators and forwarding agents) is the root cause which hinders the improvements of overall performance in container terminals of Oslo port, including area efficiency, crane efficiency, throughput and gate to gate time. Although crane productivity can be influenced by external factors to some extent, information availability can also dramatically increase the terminals' performance in this indicator. That is to say, the enhanced information sharing between terminal operators and forwarding agents can improve the performance of container terminals in Oslo port.

More specifically, information sharing can improve the container flow, thereby increasing area efficiency. Because the size of stacking storage area is the constraint of container throughput in Oslo container terminals, increased area efficiency leads to increased container throughput. In addition, information provided by forwarding agents enables terminal operator to prepare containers before trucks come, which can dramatically reduce gate to gate time. Reduced gate to gate time leads to shorter queue in the stacking area which increases the possibility that port chassis coming from ship can go back on time, thereby increasing SSG crane efficiency.

Research question 5: Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?

Due to the importance of information availability, the author suggests that it should be considered as a new performance indicator in the performance measurement framework used by Oslo port authority. Information availability can be defined as the information provided by forwarding agents or truck drivers can be available for port operator before truck comes. And this time period is sufficiently long to enable port operator to make preparation in advance, even if there is a huge pressure on quayside service simultaneously.

Research question 6: Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to this case study?

Finally, the author suggest a new performance measurement category, information sharing to the port performance measurement framework provided by Woo, Pettit and Beresford due to its importance shown in the case of container terminals of Oslo port.

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Appendix I: Collection of PPM indicators

All indicators shown in this table are collected from (Rico Merkert 2010)

Indicator	Data needed
Labor cost per passenger	Labor costs Passenger traffic
Labor cost per WLU	Labor costs Passenger traffic Cargo traffic
Variable cost per passenger	Variable costs Passenger traffic
Variable cost per WLU	Variable costs Passenger traffic Cargo traffic
Passengers per employee	Employee data Passenger traffic
WLU per employee	Employee data Passenger traffic Cargo Traffic
Overall labor productivity	Employees Passenger traffic Cargo traffic ATMs Non-aeronautical data
Passengers per gate	Passenger data Number of gates
Passengers per Terminal square meter	Passenger data Number of gates
Soft cost input productivity	Soft costs Passengers ATMs Non - aeronautical revenues
Variable factor productivity	Labor & Soft costs Passengers ATMs Non-aeronautical revenues

Appendix II: Interview Guide

For research question 1: Which traffic category is the most important one for Oslo port?

1. Why total cargo throughput decreases dramatically during the last several years?
2. How many types of dry bulks, wet bulk and Ro-Ro you have respectively?
3. Is there competitive relationship between ports located in Oslo fjord and some Sweden ports nearby, such as port of Gothenburg?
4. How strong in your mind the competition outside your port (on the scale from 0 to 5) and why?
5. Strategic distance: Which product(s) in your port face(s) to the strongest competition and from whom?
6. Which product is the most important to your port?
7. Do you try to improve the market share and growth rate of your container terminals? And what you have done?
8. What is the future development plan?
   Your brochure describes a plan about building a new freight port. Could you describe this plan in detail?
   Why you made this plan?
9. What is the focus of your new port? Container? Ro-Ro? ...

For research question 2: Whether Oslo port has improved its productivity for the most important traffic category during the last ten years?

1. Ownership
   Who own this port?
   Does port authority operate its port on its own or hire a port operator?
   Do you have private quay. If any, are they owned or rent by operator
2. Port structure
   How many actors operate in your port and your container terminals? Who are they?
   Who are your terminal operators?
3. Does your port have offshore operation?
4. Information collection
   Container turnover in the last ten years
   Numbers of berth length in the last ten years
5. What are the reasons of the change in terminal area?
6. How many types of cranes you have and what are they?
7. What you did to improve area efficiency for container terminal?
8. Do you have other kind of cranes to offer quayside services expect of SSG?
9. What is your current situation of crane efficiency (how many lifts per hour)? And what is your benchmark?
10. What did you do to increase your crane efficiency
11. Why crane efficiency did not improve in the last ten years

For research question 3: Does the performance indicators used by Oslo Port differ from the ones used by the framework published by Woo et al. in 2008? If so, what are the reasons?
Research question 4: How can the performance of Oslo port be improved for the most important traffic category?
Research question 5: Are there some potential to suggest new performance indicators to Oslo port for the most important traffic category?
And research question 6: Are there some potential to suggest new performance indicators to Woo, Pettit and Beresford's framework according to the case study of this specific terminal?

1. What is your strategic plan?
   What do you consider as the most important elements in your strategic plan?
2. What performance measurements are used by Oslo port?
3. To what extent do you think the performance measures capture the actual performance of Oslo port (on the scale from 0 to 5)? How sure are you about this?
4. What additional measurements do you need to improve performance?
5. Are there some mistakes in loading and unloading process?
6. Do your container terminals know in which sequence containers leave by truck, train and vessels?
7. Do your terminals know the final position of each container in ship?
8. Why information is missing here?
9. Expect terminal operators, do you have other customers?
10. Which information you need to provide to your customers?
11. How do you think your service price compared with other ports in Norway?
12. Have you made some efforts to lower your service price?
13. Are you an ISPS port? And when you became a ISPS port?
14. Are threesome cargo damage caused by terminal operators?
15. Port authority is responsible for crane operation. Why operators make more cargo damages?
16. What is your performance and benchmarks (if you have) on these indicators?
    Gate to gate time
    Container Throughput
    Area efficiency
    Crane efficiency
    Ship waiting time
    Ship turnaround time
    Cargo waiting time between modes
    Cargo working time between modes
17. Which kind of information do you share with other actors in your port currently (such as, stevedore)?
18. Is there any information that other actors could provide to Oslo port, which would help Oslo port to improve performance? If so, what info?
19. Could Oslo port authority share info to help other actors improve their

performance? If so, what info?

20. As far as I know, some information is needed when doing housekeeping and remarshaling, such as, information of where containers are going after they come and when or in which sequence each of them is planned to leave. Are there some other kinds of information is needed for bettering housekeeping
21. Do you get all information what I mentioned?
22. From whom you can get these types information?
23. Are there some situations that some necessary information is missing? And what are these situations?
24. What are the barriers for exchanging information?
25. What is the percentage of information missing?
26. To what extent gate to gate time and ship turnaround time can be decreased is all information is in place in advance?
27. Could you ask forwarding agents provide information to your terminal?
28. How long time it will take from truck drivers getting their order to arriving at your terminal normally?
29. If truck drivers give you information as soon as they get it, does this time enough for your operator to prepare?
30. To what extent do you think port cooperation is important and why?
31. To what extant do you think value-added services are important to your port and why?
32. How many value-added services you have? What are they?
33. How could total port logistics (operations) for Oslo Port be improved?
34. What is the potential for improved port logistics by Integrated operations / coordination / shared information among all actors, i.e. Oslo Port Authority, Oslo Container Terminal and Sjursøya Container Terminal?

Appendix III: Maritime transport statistics 2002 Loaded and unloaded cargo, by type of cargo Tonnes

(SSB 2003)

Port district	Cargo, total	Total		Wet bulk		Dry bulk	
		Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded
2002							
Borg	3 478 058	1 847 714	1 630 344	484 940	741 344	1 019 883	577 599
Moss	1 030 286	581 422	448 864	57 692	4 228	281 833	148 752
Oslo	6 063 538	4 462 501	1 601 037	1 916 519	45 262	1 018 068	261 164
Drammen	1 274 748	542 906	731 842	123 844	-	253 013	506 208
Tønsberg	9 200 705	4 886 770	4 313 935	4 821 717	4 249 343	55 528	51 480
Larvik	1 407 370	423 662	983 708	42 830	900	61 011	401 959

Port district	Containers[3]		Roro (self-propelled)		Roro (non-self-propelled)		Parcels	
	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded
2002								
Borg	104 740	203 811	-	-	-	-	238 151	107 590
Moss	95 363	102 308	4 685	6 191	-	-	141 849	187 385
Oslo	640 720	447 411	287 921	318 505	428 456	256 275	170 817	272 420
Drammen	1 126	34	97 473	7 746	160	140	67 290	217 714
Tønsberg	-	144	-	-	-	-	9 525	12 968
Larvik	76 098	172 233	135 677	159 967	-	-	108 046	248 649

Appendix IV: Maritime transport statistics 2011 (SSB 2012)

Loaded and unloaded cargo, by type of cargo Tonnes

Port district	Cargo, total	Total		Wet bulk		Dry bulk	
		Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded
Borg Port Authority	2 753 453	1 359 567	1 393 886	488 857	499 972	542 680	582 185
Moss Port Authority.	425 944	340 268	85 676	-	-	93 556	7 170
Oslo Port Authority	5 708 578	4 714 152	994 426	2 072 875	1 882	1 125 207	211 965
Drammen Port Authority . .	2 968 403	1 579 875	1 388 528	186 368	110	591 153	575 695
Tønsberg Port Authority . .	10 216 426	5 393 738	4 822 688	5 346 531	4 822 484	44 474	-
Sandefjord Port Authority .	213 215	146 632	66 583	-	-	-	-
Larvik Port Authority	1 781 384	492 516	1 288 868	-	-	18 380	417 608

Port district	Containers		Roro (self-propelled)		Roro (non-self-propelled)		Parcels	
	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded	Unloaded	Loaded
Borg Port Authority	166 190	153 480	-	-	-	-	161 840	158 249
Moss Port Authority.	231 908	72 372	-	-	-	-	14 804	6 134
Oslo Port Authority	913 470	433 436	226 458	122 217	243 555	131 240	132 587	93 686
Drammen Port Authority .	95 141	10 094	110 915	13 995	174	125	596 124	788 509
Tønsberg Port Authority. .	-	-	-	-	-	-	2 733	204
Sandefjord Port Authority	-	-	146 632	66 583	-	-	-	-
Larvik Port Authority	130 643	594 296	329 117	231 885	-	-	14 376	45 079

Appendix V: Quays for passengers and cargo in port of Oslo

All information of this table is found from the website of Oslo port (Oslohavn 2013e)

Type of product	Quay	Length	product	Comments
Passengers	Akershuskaia Syd	302 m	Marine vessels, cruise ships	Oslo's main cruise quay.
	Revlerkala	364 m	Marine vessels, cruise ship	
	Utstlkker III	192 m	Grain silo, local ferries	The archipelago ferries departure from here. Grain silos are nearby the ferries where store bulk grain.
	Vippetangen	278 m	Marine vessels, cruise ships	
	Rådhusbryggene	1120 m	Charter boats, sightseeing, Local / Inter-municipal ferry	
Passengers and Ro-Ro	Hjortnes	173 m	International ferries, general cargo Ro/Ro	Color Line's ferry terminal - daily departures for Germany
	Utstlkker II	368 m	International ferries, general cargo Ro/Ro	The Denmark ferry quay'. DFDS and Stena Line have daily departures to Copenhagen and Frederikshavn.
Container	Ormsundkaia	322 m	Loading and unloading of container ships	
	Søndre Sjursøykai	305 m	Loading and unloading of container vessels	
Multi-purpose terminal	Filipstad	468 m	Multi-purpose terminal Ro/Ro	
Dry bulk	Grønlia Syd	262 m	unloading of iron products, loading of scrap iron	
	Kongshavn	157 m	Unloading of sand	
	Nordre Sjursøykai	517 m	Loading and unloading of salt, fertilizer, animal feed, cement, molasses and various special cargo	
Wet bulk	Sjursøymoloen	110 m	Unloading of bio ethanol	
	Tankskipsutstikkeren	350 m	Tank ships, petroleum products	
General cargo	Kneppeskjær	339 m	General cargo	Ro/Ro quay, approximately 40 000 new cars arrive annually