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An Evaluation of Performance Measurements and Their Influence on Benchmarking in Nordic-Baltic Container Ports

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Abstract

Maritime transport has played a crucial role in global trade for many years; with seaports serving as gateways to endless opportunities and connections, the significance of port performance has grown substantially for both shipowners and cargo owners. Shipowners aim to reduce port stay to increase annual cargo throughput, while cargo owners demand punctual deliveries and greater flexibility. These considerations, along with the surge in global trade, have reshaped the port industry's landscape. Competition within the sector has intensified, especially in regions with geographically proximate ports. Consequently, productivity has become a critical factor for maintaining a competitive advantage. Scholars and industry professionals investigated measuring and improving productivity more accurately for an extended period due to the velocity of the shipping industry.

Many measurement methods depend on restrictions and indicators that affect the port's productivity in the broader range, but they can not be changed in the short run. Accordingly, reflection on practical usage might remain limited. Hence, this study aims to identify, compare and contribute to port performance measurement methodology throughout this paper by conceptualising fundamental and detailed research questions on port performance measurement and benchmarking usage.

According to the research, this paper identified different practices in academia and industry in terms of port performance measurement. Academia uses complex frameworks, meanwhile industry practices partial productivity methods in addition to differences in conceptualising indicators and factors. Consequently, this paper created a potential linkage between the industry and academia thanks to existing literature and research in industry. Potential suggestions for improving port performance measurement methods and our understanding are provided to industry and academia by focusing on the operational details in addition to benchmarking practices to increase port attractiveness and competitiveness.

Keywords: Port performance measurement, port performance indicators, benchmarking, port productivity, partial productivity measurement, berth productivity, operational stoppages

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Contents

List of Tables

1. Introduction

1.1 Research Background

Throughout history, the shipping industry has played a pivotal role in driving global trade, with ships being responsible for transporting more than 80% of the world's trade volume (*UNCTAD*, 2022). In 2022, global container throughput at ports was marked as nearly 866 million Twenty-foot Equivalent Unit (TEU), and the global container shipping market size is marked as 9,820.12 million USD (Research Straits, 2023). The nature of international trade has become more dynamic, leading to increased competition across all sectors and environments with the global economy and trade increase. Accordingly, seaborne transportation has been playing a crucial role in international business for many years, and as it is one of the essential components of seaports serving as gateways to endless opportunities and connections, the significance of port performance has grown substantially for both shipowners and cargo owners. Hence, over the last three decades, there has been an inevitable increase of interest in theoretical and practical studies on port performance measurements and benchmarking (Bichou, 2006).

To fully understand the importance of ports, we can define the borders of the port. "*A port is a geographical area where ships are brought alongside land to load and discharge cargo – usually a sheltered deep-water area such as a bay or river mouth",* as Martin Stopford describes in Maritime Economics (Stopford, 2010 p.18). However, ports are much more complex and essential for the worldwide transportation chain. Ports are not only places where the loading and discharging of cargo are held but also centres for all types of logistic activities. Meeresman and Van de Voorde, (2010) cited in Schøyen & Odeck, (2017) state, "*Ports are critically important to a well-functioning transportation system and are an integral part of supply chains*." In addition to the statement that ports are an essential part of the global supply chain, the efficiency of ports contributes to global supply chain performance (Ha et al., 2017). Consequently, ports have evolved into logistic centres where many activities are held according to the improvement of the industry rather than being only a shoreline where the movement of goods from ship to shore and shore to ship is managed with high importance efficiency indicator to the whole supply chain.

As stated by many scholars such as Lozano et al., (2011); Quynh et al., (2011); Theys et al., (2010); Wanke, (2013) cited in Lu et al., (2015), the level of competition encouraged by expansion

in the world economy forced shipping companies, logistic service providers, ports, and all parties to lower costs and naturally boost efficiency to stay ahead of the competition. Companies have sought innovative strategies, catalysed initially by supply chain management and its key components. Ports, as one of the most important ones, also needed to bear pressure on decreasing transportation costs, the market for agility in transportation, and the political and structural changes (Bucak et al., 2020). This has compelled shipping companies to enhance their efficiency to meet the demands of modern commerce with high productivity in loading and discharging activities. Cullinane et al., (2004) in addition to berth and pilotage productivity, where effects are significant on vessel traffic.

Within this concept, measuring the most accurate port productivity or performance is challenging, and it has found respectable interest from scholars and international/national organisations. From an academic perspective (Bucak et al., 2020) reviewed 130 studies in their article, and Hardianto et al., (2023) limited their review to 400 articles, from an international organisational perspective, UNCTAD (United Nations Conference on Trade And Development) published a Review of Maritime Transport report every year where port performance and liner shipping connectivity enrol significantly. Also, the same report mentions key performance indicators for port performance and world fleet depending on recent changes in the maritime industry. In addition to UNCTAD, the World Bank publishes the yearly Container Port Performance Index, which examines port performance globally based on time spent at port. From the national organisation's perspective, the Waterline report of the Bureau of Infrastructure and Transport of Australia that evaluates the performance of Australian container terminals can be presented as an example.

There may be various motivations behind examining the most accurate port performance. Broadly, it is both internal and external when the business size and competition are considered. Accordingly, port and terminal operators, port authorities, and port users use performance for large-scale planning in their operations. Within this concept, benchmarking of the ports is an essential issue that port management faces (Sharma & Yu, 2009). Philosophically, ports need to utilise their resources to create a competitive advantage over their competitors, especially geographically approximate ports and regions. Port and terminal authorities increase attractiveness where competition becomes more crucial, and creating high port productivity is one of the main

port selection criteria from a user perspective (Vaggelas, 2019) (Rezaei et al., 2019). There are various methods in the literature regarding benchmarking analysis; however, this paper aims to evaluate benchmarking according to productivity; physical productivity measurements which refer to the productivity measurement that occurs during the physical movement of cargo. Bichou, (2006) will be taken as a base for benchmarking practices later in this paper, empowering with the port choice connection as it is identified as an essential indicator among others such as cost, location, capacity, hinterland, etc. (Rezaei et al., 2019).

Consequently, port performance is crucial for all shareholders of global trade, and measuring it most accurately with suitable indicators is challenging and crucial for benchmarking and port-choosing practices. Therefore, this study aims to create a clear picture of port performance measurements of container ports within the focus of physical productivity measurement, in addition to factors that affect indicators used in the measurement process in a limited Baltic-Nordic area.

1.2 Research Questions

The ambition throughout the journey of this master thesis is to answer the following research questions.

RQ 1: *What indicators affect port performance, and what factors affect the indicators used for performance measurement?*

RQ 2: *How do ports, especially Nordic Baltic ports, measure port productivity?*

RQ 3: *How can port productivity be used for benchmarking and creating a competitive advantage in relatively small-scale ports?*

RQ 4: *How can shipping lines evaluate port performance during port selection if various methods are under usage?*

1.3 Structure of The Thesis

As mentioned earlier, the interest in port productivity measurement is massive. However, it is unclear if the reflection of the methods scholars and international organisations have designed is visible in the industry. Within this motivation, current methods used in literature and international/national organisations will be examined in the literature review, and terminology will be defined. Thus a knowledge to cross reference can be visible.

To link the literature with the industry, data concerning productivity and calculation methods will be collected across relevant ports limited to Baltic-Nordic container ports. The factors and effects of the indicators that will be discussed in further sections of this paper will also aim to be collected from the ports. Recent productivity situations of past and present years will be used to show the current situation, methods of calculating will be used to identify the linkage with literature, potential ways of improving their methods will be discussed, and initial solutions will be proposed. The primary goal is to identify how ports assess their productivity and rigorously evaluate this data to assess the benchmarking effectiveness of these ports and their potential influence on port selection, particularly from the perspective of shipping companies. Secondly, this paper aims to propose a solution for the ports to asses their productivity more accurately to be used to create competitive advantage by using academic literature, qualitative and quantitative data and personal experience.

The data collection methodology will aim to encompass both quantitative and qualitative approaches. A numerical dataset, including productivity levels and calculation methods, will be asked from the industry for a respected area and analysed briefly to show the recent situation. Qualitatively, industry professionals will be consulted to gain insights about how ports assess their productivity, which methods are being used, and how this data can be used for benchmarking purposes with semi-structured interviews.

The literature review section will be divided under subtitles to make the paper structure more straightforward. Quantitative data will only be used to understand the current productivity of the ports and how they measure it if the data set can be reachable. The qualitative section will focus on the opinions and insights of industry professionals on measuring beyond quantitative calculations by using interviews. Findings of semi-structured interviews will be presented in the

findings section, and practices within the industry will be aimed to enlighten. The discussion section will aim to create a linkage between industry and academic work and discuss potential collaboration to improve the port performance measurements that ports are using. As a final result, this section will summarise the thesis and potentially propose solutions and further recommendations for the following studies.

In conclusion, this study aims to significantly contribute to understanding the dynamics within the port industry and the broader global shipping sector. By incorporating practical data and insights from industry professionals, it seeks to enrich maritime studies and benefit current and future stakeholders. Furthermore, this paper may serve as a valuable resource for maritime industry professionals, assisting them in evaluating business opportunities and making informed decisions to enhance overall global trade performance.

2. Literature Review

2.1 Research Aim

The main aim of this section is to conduct a literature review that delves into various studies, perspectives, and terminologies associated with port performance measurement. Secondly, the review seeks to identify and analyse potential indicators employed by scholars in the past, which will help streamline further industry research and facilitate a comparison with industry practices. By exploring academic literature, the link between port performance, benchmarking, and the impact of port performance on competitive positioning will be more precise. It is particularly significant as it sheds light on historical changes in academia and the connectivity between international organisations and industry practices. Finally, the review aims to showcase how industrial practices can be improved by leveraging existing literature. Overall, this literature review is essential in advancing the understanding of port performance measurements and their relation with benchmarking.

2.2 Methodology

To conduct a thorough investigation on the topic at hand, a comprehensive review was carried out on the "Web of Science" database. Various terms were used to search for relevant literature to ensure that no critical information was missed. The most valuable keywords were identified and are presented in “Table 1: Research Keywords”. To limit the scope of the research, English-language articles, proceeding papers, early access materials, and review articles were selected. The results of each research keyword were carefully sorted by relevance and examined through their respective topics, abstracts, and keywords. Initially, 47 papers were identified for further review according to the suitability of this study. Among those, twenty-five articles were identified as more relevant to this study and used in this study. Twenty-two articles are used in the literature review and analysed in “Table 2: Literature Review”. In addition, reports from industry and related organisations such as the World Bank, the Bureau of Infrastructure and Transport of Australia, and UNCTAD were also searched through regular search engines to ensure all relevant information was considered. During the literature review, papers that are found relevant for this study will be elaborated under divided titles depending on the relativity.

No	Search Keywords	WOS (no. of articles)
1	Port Performance Measurements	**2594**
2	Container Port Performance Measurements	**66**
3	Port Performance Indicators	**698**
4	Container Port Performance Indicators	**101**
5	Performance Indicators for Container Handling Operations	**22**
6	Physical Performance of Container Terminals	**37**
7	Port Performance Indicators and Benchmarking	**41**
8	Container Port Benchmarking	**144**
9	Container Port Productivity	**249**
10	Port Operation Delays	**528**
11	Container Port Operation Delays	**79**

Table 1 Search Keywords

2.3 Port Performance Measurements

Over the centuries, the global economy has experienced a surge in trade due to the impact of globalisation and seaports have been playing a crucial role in this. Stopford, (2010) defines a port as a geographical area where ships are brought alongside land to load and discharge cargo. In other words, a seaport is a bridge, a physical link between the ocean and land (Dowd & Leschine, 1990). As the world economy experienced rapid expansion, shipping industries faced a significant challenge to keep up with the growing demands and expectations of the market. The introduction of the container by McLean in the 1950s revolutionised the industry and brought about a new era of standardisation in transportation. The use of containers allowed for more efficient and secure transport of goods, which significantly reduced costs and improved safety. This development marked a turning point in the history of shipping, enabling the industry to continue to grow and thrive in the face of increasing global trade. Stopford, (2010) states that the containerisation of liner services was one of the significant commercial innovations of the twentieth century. The Economist (2020), cited in Nikolaou & Dimitriou, (2021), containerisation has been the biggest driver of globalisation for the past 50 years and identifies ports and terminals as co-drivers of globalisation.

The significance of ports cannot be emphasised enough, and their importance in this field is directly proportional to the level of interest. As globalisation continues to fuel competition, ports have been compelled to enhance their performance, making performance evaluation a significant point of focus. Through the review of various papers and their supporting sources, it is apparent that measuring performance is of paramount importance. In addition to the importance of the measurement, the potential usage of the result is also equally important. Munim & Schramm, (2018) mentions on increasing productivity and identifying inefficiencies, Cullinane et al., (2004) point out the power as a management tool, Gaidelys & Benetyte, (2021) elaborate analysis of prior risk factors and the capacity of competitors, Gunasekaran and Kobu, (2007); Franco, (2017); Santos et al., (2012) cited in Liu et al., (2019) touches on usage to assess customer satisfaction in addition to internal capabilities. As parallel Ha et al., (2017) also point to the long-term stakeholder and management relationship to achieve a sustainable competitive position, Vaggelas, (2019) emphasise on benchmarking. The process of measuring performance in ports is a complex task that involves considering a variety of factors. As pointed out by experts in the field, this task is driven by different motivations that range from operational to financial standpoints. Regardless of the approach, the ultimate objective is to optimise output while minimising input. Ports play a critical role in connecting ships with the shore by managing cargo movements in both directions. To achieve this goal, evaluating quayside performance is of utmost importance. However, conducting this assessment requires taking into account other factors within the port, such as yard and gate operations. Traditionally, ports have measured their performance by comparing their real-time and optimum throughputs, such as total tonnage or number of containers handled (Talley, 2006). It is important to note that every physical activity in ports is geared towards generating revenue. Therefore, financial performance is equally vital when measuring the effectiveness of a port. By analysing financial data, port managers can identify areas where they can cut costs and increase profitability without compromising the quality of their services. As mentioned by Bichou, (2006), there are various categorisations of financial performance measurement, such as branch economy geography, port efficiency from transport and logistic cost perspective, and frontier approaches, such as Data Envelopment Analysis (DEA), to evaluate the efficiency of decision-making units (DMU).

Approaches to measuring port performance are advanced in correlation with the improvement of port activities and higher competition. Thus, in recent studies, broader variables are included in performance measurement applications. For instance Schøyen & Odeck, (2017) uses the DEA-based Malmquist productivity change index (MPI) with variables of berth length, terminal area, yard handling equipment, and terminal trucks as input and yearly container throughput as TEU. In addition to Schøyen and Odeck (2017), several studies also used the DEA method in their studies (E.g. Cullinane et al., (2004), Quintano et al., (2021), Diakomihalis et al., (2021), Lu et al., (2015), Schøyen et al., (2018), Rødseth et al., (2020)). DEA has gained widespread popularity due to its versatility in handling multiple variables and objectives and its ability to facilitate multi-dimensional assessments through flexible input and output preferences. While DEA remains a popular choice, other methods have been identified through literature reviews. These methods can be listed as: Nayak et al., (2022) Novel Index, Diakomihalis et al., (2021) ANOVA and ordinal logistic regression to measure financial performance, Rezaei et al., (2019) multi-criteria decision analysis and best-worst method, Gonzalez & Quesada, (2022) quality function deployment method. Bucak et al., (2020) reviewed 130 papers in their study, and 27% of all articles have used the DEA method; secondly, 12% multi-criteria decision analysis and %10 mathematical methods. In conclusion, these findings support previous literature that indicates the DEA method as the most used one, followed by multi-criteria decision analysis and mathematical methods. The following section will provide information about the productivity perspective and insight of the mentioned papers, such as which indicators they have used and their limitations.

2.4 Port productivity and indicators

As mentioned earlier, productivity can be defined as a result of inputs and outputs. From a port's perspective, this refers to how efficiently the port utilises its resources through cargo operation as defined by Talley, (2006) “ Throughput Performance Evaluation”. However, many factors might affect productivity, and since measuring it is crucially vital, defining indicators is equally crucial to have accurate outcomes. Talley, (2006) divides indicator selection into two categories; the operation objective specification and criteria specification. Operation objective specification briefly consists of defining indicators that the port can control within its resources,

and criteria specification consists of consistency, data availability and indicators' measurability. Within this perspective, most studies in the academic world and international organisations focus on operational objectives.

To extend the context in this perspective from an academic direction Talley, (2006) mentions indicators for physical productivity as it is limited within this thesis context and divides into two. From an equipment perspective: cargo handling rate, number of ships and amount of cargo handled, containers handled per crane and cargo handled per man-shift are used. The indicators from a labour perspective are the number of employees, the average age of the labour force, average hours worked per week by employees, and idle labour time. This indicates a single-port approach and can be modified by the port itself according to its resources. However, since competition is vital, more and more nowadays, ports also should see the situation of their competitors, and for this, multi-port performance evaluations are used. As an example of multi-port performance evaluations, Lu et al., (2015) cover the top 20 container ports of the world with variables such as yard area, number of terminal trucks, yard crane, quay crane, berth length and throughput per berth, which are only elaborating from operational perspectives. Nayak et al., (2022) divided into five dimensions to examine major seaports of India instead of only the operational dimension. Lu et al. (2015) and Schøyen & Odeck (2017) focus on the operational perspective and physical/technical infrastructures. Nayak et al.., (2022) chose indicators such as average berthing occupancy, total vessel handled, berth throughput, etc., which are more related to berth productivity and quay performance under the physical/technical infrastructures category to represent operational productivity. A similar and more detailed approach by Ha et al., (2017) is divided into six dimensions: core activities, supporting activities, financial strength, user satisfaction, supply chain integration, and sustainability growth. As more related to this thesis topic, core activities that include productivity included 11 indicators, including berth and operational performance as one despite Nayak et al., (2022), which is seen as more suitable to elaborate core activities as one. Tongzon and Heng (2005) and Kavakeb et al. (2015), cited in Bucak et al., (2020), elaborate operational indicators from a speed perspective since that can eliminate some of the costs. Esmer (2008) cited Bucak et al., (2020) as a parallel to other studies that illustrate operational indicators such as the rate of the container loaded and unloaded, crane productivity, the crane automation level ship turnaround time, total working time, labour force

productivity, yard utilisation, equipment usage efficiency. Gonzalez & Quesada, (2022) uses parallel variables to assess port productivity, categorising them as time management indicators, capacity management indicators and gang productivity indicators. Approaches to the identification of indicators are various in the literature. Aronietis et al., (2023) developed indicators according to trends in the liner shipping and container port industry, such as connectivity and accessibility, shipping cost, efficiency, environmental impacts, and regulatory environment.

Even though this paper focuses on physical productivity measurement as previously cited in the literature with complementary indicators, there is an additional topic that received the attention of the scholars rightfully. Ports are improving and diversifying their services, becoming a vital component of supply chain management. For example Bichou, (2006) and Schøyen et al., (2018) focus on the importance of logistics performance and potential value addition to port performance and benchmarking. Similarly to Ha et al., (2017) logistic performance was also used as an indicator of port performance.

In addition to the contribution of the scholars shared previously, international organisations create annual reports for the maritime industry. World Bank Group publishes the Container Performance Index every year. World Bank, (2023) examines container port performance based on vessel time in port. However, many indicators might affect the vessel's port stay, such as gross crane productivity, vessel size and call size, crane intensity, berth productivity, etc. World Bank, (2023) uses those parameters as indicators to rank world container ports according to their performance. *UNCTAD*, (2022) states port performance indicators such as Port calls and Turnaround Time, Port waiting time and cargo handling, port authority performance, liner connectivity index, Impact of the War in Ukraine, Fleet productivity, and Fleet greenhouse gas emission. This report shows the general situation of the shipping industry within the dedicated indicators, which are designed as the most significant indicators for the year. It is helpful to see the industry's situation; however, usage on a single port based is not available even though the indicators might be used as a reference for further studies. As a last example, the Bureau of Infrastructure and Transport Research Economics of Australia publishes a Waterline report annually that provides the performance report of Australian container ports and divides port performance indicators into three categories: quayside, landside and whole container terminal (Bureau of Infrastructure and Transport Research Economics, 2023).

Consequently, interest in port productivity correlates with the number of studies and reports. Indicators to measure port performance and productivity may differ according to the aim of the measurement. Hence, some scholars and reports only approach from a single perspective, and some others create indicators for all core activities of the port. It is found particularly challenging to decide on indicators since many of them can depend on individual ports even though general activities of the ports are similar. However, it has been seen that the evolution of the port performance measurement with key performance indicators has advanced throughout research history. Despite the chosen indicators being significantly relative to the port activities in the literature, the background and events that affect those activities are not broadly investigated, which carries a lot of importance to improving the productivity of the chosen indicator, which will be aimed to clarify during the journey of this Master's thesis.

2.5 Benchmarking of Ports

There may be various motivations behind performance measurement. It is essential to evaluate the performance of the company internally and externally. To meet with trade-driven economic development, ports are under pressure to improve their productivity on an increasingly competitive basis Sharma & Yu, (2009) and it is an appropriate basis to be used for planning future development (Gonzalez & Quesada, 2022). Benchmarking as an evaluation method is the process of comparing the organisation's performance against a competitor in the market. It is a continuous quality improvement process that an organisation may assess its strengths and weaknesses, see its position against competitors, realise best industry practices, and can create strategic decisions accordingly, Franceschini and Maisano, (2018); Min et al., (1997); Sharma et al., (2021) cited in (Gonzalez & Quesada, 2022). Within this perspective, performance measurement is a natural resource for benchmarking activities, and this benchmarking may be categorised as internal benchmarking, competitive benchmarking, processes benchmarking and generic benchmarking (Bichou, 2006), (Gonzalez & Quesada, 2022). Since this paper focuses on the performance of regional ports, most of this section will be related to competitive benchmarking.

Sharma & Yu, (2010) evaluated the performance of 70 container ports within decided indicators. Results are based on attractiveness and highlighting the correlation between investing in advanced terminal infrastructure and high attractiveness, and suggest infrastructure

improvements for less attractive ports to have competitive benchmarking power. From a similar perspective Sharma & Yu, (2009) assessed 70 container terminals based on infrastructure using the DEA method. Different from the study which was published a year later by the same authors, it focused on the entire infrastructure of the port based on general port activities and stratified analysed ports in tier according to their score so for practical usage ports within the same level of productivity can implement their competitive benchmarking which seems more accessible for the industrial professional to use this study for practical purposes. From a different perspective, Aronietis et al., (2023) use indicators that have been shared in an earlier section to create a method for benchmarking on country and port base, to be used in further research. Thanks to the broadness of the indicators that have been created, the suitability of the framework might be considered high in many circumstances. Gonzalez & Quesada, (2022) on the other hand, analysed three different ports in different areas to generalise the study to the other ports; however, the sample size when it is compared with other studies is limited. It is also meaningful to mention how port performance and competitive benchmarking are related to port choice since, from a revenue perspective, being a desirable port is naturally and directly related to productivity and benchmarking. Rezaei et al., (2018) analyzed seven seaports of Europe and 5 landlock hinterland countries to elaborate port performance and benchmarking from a port choice perspective using 17 criteria. Transport costs and times along the transport chain are found to be dominant factors for port competitiveness, correlating with the studies of Bichou, (2006) and Schøyen et al., (2018), which emphasises the importance of the supply chain as a performance indicator. Satisfaction and reputation are also mentioned as essential criteria for port choice. However, as the context of Rezaei et al., (2018) study, restricted to the hinterland countries, logistic performance and connectivity are more important indicators than physical port productivity.

2.6 Literature Matrix

No	Name of the study	Author&Year	Data Source&Sample Size	Research Method	Context	Key Findings
1	Performance based stratification and clustering for benchmarking of container terminals	Sharma & Yu, (2009)	Data was collected from 70 container terminals.	A Decision Tree Based Data Envelopment Analysis (DEA)	Port performance measurement for Benchmarking Optimization	The accuracy of the Decision Tree Based DEA is underlined since it creates an opportunity for ports to optimise their benchmarking effectively. The paper suggests that low-scored ports should invest in port equipment to attract new-generation vessels.
2	Market access and seaport efficiency: the case of container handling in Norway	Kenneth Løvold et al., (2023)	8 Container terminals in Norway	Stochastic semi-nonparametric Envelopment of Z variables Data (StoNEZD)	Market Access and port efficiency	Hinterland market access significantly correlates with port efficiency in Norwegian container ports.
3	Benchmark optimization and attribute identification for improvement of container terminals	Sharma & Yu, (2010)	Data regarding 70 container ports collected from the Containerization International Year Book, The Drewry Annual Container Market Review, and specific field studies of container ports	A decision-based DEA	Port efficiency and benchmarking optimisation	The results are based on attractiveness. They highlight the correlation between investing in advanced terminal infrastructure and high attractiveness and suggest improving infrastructure for less attractive ports to have competitive benchmarking power.
4	Chapter 22 Port Performance: An Economics Perspective	Talley (2006)	Tongzon (2001) relative technical efficiency of 16 international container ports, including four Australian ports, for 1996.	Data Envelopment Analysis (DEA) (CCR and Additive version)	Effect of technical efficiencies on port performance and competitiveness	The study identified the most and least efficient ports based on their utilising resources to achieve maximum throughput levels and also highlighted the importance of assessing and improving the technical efficiency of ports to enhance their overall performance and competitiveness in the maritime industry
5	Chapter 24 Review of Port Performance Approaches and a Supply Chain Framework to Port Performance Benchmarking	Bichou (2006)		Literature review	Port performance and supply chain integration to emphasise benchmarking	Conceptualising the port system from the perspective of logistics and SCM can be relevant to port performance and benchmarking.

6	Measuring the contribution of logistics service delivery performance outcomes and deep-sea container liner connectivity on port efficiency	Schøyen et al., (2018)	The sample size consists of 26 ports observed over three periods,	Data Envelopment Analysis (DEA)	Port efficiency and connectivity with the supply chain and benchmarking	The study investigates the relationship between logistic service delivery outcome and port efficiency of small and medium-sized container ports in Northern Europe and benchmarks the efficiency differences. Major findings are that ports in countries directly called by deep-sea transcontinental container liners tend to overperform in operational performance but underperform in scaling their operations efficiently compared to other ports.
7	An Application of DEA Windows Analysis to Container Port Production Efficiency	Cullinane et al. (2004)	Containerization International Yearbook and Lloyd's Ports of the World were used as resources to collect the world's leading container ports, which ranked in the top 30 in 2001. Two hundred observations were collected over eight years, from 1992 to 1999.	Data Envelopment Analysis (DEA) (Window)	Port efficiency	It can be categorised into 3: Efficiency Fluctuation, which indicates container port efficiency fluctuation over time; Need for Long-Term Perspective change on efficiency and competitiveness resulting from significant investments; Importance of DEA Windows Analysis.
8	Port productivity: Benchmarking analysis of strategic ports	Gonzalez & Quesada, (2022)	Anonymous	Quality Function Deployment (QFD)	Port Productivity and Benchmarking Analysis	The study underlines the importance of capacity management, time management, and gang productivity as key customer expectations that port administrations must consider for increasing port productivity. Overall, the importance of benchmarking analysis in port productivity improvement and the recommendations for enhancing operational efficiency in ports.
9	Measurement of port performance from users' perspective	Vaggelas, (2019)	Data collected with ICT tools from eight ports in Europe between February and July 2017	The study creates a framework to evaluate data collected Via ICT and applies GAP analysis.	Port performance measurement from the user's perspective	This study underlines the significance of considering port users' perceptions in evaluating port performance, identifying areas for enhancement, and implementing strategies to improve port services based on user feedback

10	Port performance measurement in the context of port choice: An MCDA approach	Rezaei et al., (2019)	A survey was conducted in Asia–Central and Eastern European trade lanes among approximately 200 potential respondents, including freight forwarders, shippers, and carriers. Thirty-eight responses were received.	Multi-Criteria Decision Analysis, Best-Worst Method (BWM), Literature Review	Port performance measurement in the context of port choice	Transport costs and times along the transport chain are the most influential factors of port competitiveness. Satisfaction, reputation, and flexibility criteria are critical decision criteria for port choice. Multimodal and hinterland access can impact the competitiveness of the port and its attractiveness to users.
11	Performance assessment of major European ports: an empirical investigation	Quintano et al., (2021)	Data from 24 European container ports was mainly obtained from Eurostat, Amadeus, and World Port Source.	Data Envelopment Analysis (DEA) and Shephard's Distance Function	Port efficiency assessment	Unlike other studies, Quintano et al. touch on legal forms and passenger numbers and the effects of port efficiency. A positive variation in the total number of passengers affects efficiency positively.
12	A novel Index-based quantification approach for port performance measurement: A case from Indian major ports	Nayak et al., (2022)	Data from 12 major Indian ports were collected from reputable and reliable secondary sources such as the Center for Monitoring Indian Economy (CMIE), Indiastat, yearly reports, and port websites.	Novel Index-based quantification and Principal Component Analysis (PCA)	Port performance measurement	The study creates a new Port performance index with a multi-dimensional approach and adds new indicators to the literature. The study highlighted that a port with high financial returns may not necessarily be efficient,
13	Port Efficiency and the Financial Performance of Greek Public Ports Before and During the Economic Crisis	Diakomihalis et al., (2021)	Ten Greek public ports with an anonymous source for 16 years period	Financial Ratio Analysis, Ordinal Logistic Regressions, One-way ANOVA Analysis, Data Envelopment Analysis (DEA), Multi-Stage DEA Approach	Port Performance Measurement with Financial Aspect	Financial ratios affect port performance positively in economic crisis conditions.

14	Comparing the productivity of Norwegian and some Nordic and UK container ports – an application of the Malmquist productivity index	Schøyen & Odeck, (2017)	Data was collected over six years from port authorities, terminal operators, and port statistics for 20 Nordic and UK container ports.	Data Envelopment Analysis (DEA) based Malmquist Productivity Index (MPI)	Port Productivity	Sample Norwegian ports perform better efficiency scores compared to their international counterparts, even though some seem to be overperformers in terms of productivity growth over time. However, they are not statistically significant overperformers. There is no evidence of differences in productivity between Norwegian and Nordic ports and the ports in the UK.
15	The Trend of Parameters for Evaluating Port Performance: A Systematic Literature Review	Hardianto et al., (2023)	400 articles	Literature review	Parameters of Port Performance Measurement	Interest in the literature on sustainability factors and indicators related to environmental concerns during port performance measurement is growing.
16	Dimensions of the Port Performance: A Review of Literature	Bucak et al. (2020)	130 articles	Literature review	Port Performance	Various dimensions are identified, such as cost performance, quality performance, responsiveness, intermodal transportation systems, and value-added services. The study also suggests that social indicators are an essential topic.
17	Maritime Data Collection Framework for Container Port Benchmarking	Aronietis et al., (2023)	MarineTraffic is used to collect data	Framework Development	Port performance and benchmarking	The developed framework at both country and port levels was found to be positive, as was its practical applicability and effectiveness in benchmarking port performance.
18	Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators	Ha et al., (2017)	Quantitative data were gathered from terminal operating companies, information systems/databases managed by port authorities, and the Korean government and a survey was conducted among terminal operators and port users to gather qualitative data.	DEMATEL (Decision Making Trial and Evaluation Laboratory) and ANP (Analytic Network Process)	Port Performance Measurement	The study creates a framework to evaluate port performance by underlining the importance of evaluating the interdependent relationships of PPIs in port performance measurement and the importance of involving other stakeholders, such as users, port authorities, and the government, in weighing the indicators.
19	Port efficiency and emissions from ships at berth: Application to	Rødseth et al., (2020)	Annual data for 25 ports in the Norwegian port sector between the years 2010 and 2014	Data Envelopment Analysis (DEA)	Port efficiency and emission relationship	The study highlights the relationship between port operation efficiency and emissions produced at berth. Unlike other port efficiency studies, this paper benchmarks efficiencies and

	the Norwegian port sector		gathered from Statistics Norway's			inefficiencies in terms of emission and connects with the importance of port productivity.
20	The impacts of port infrastructure and logistics performance on economic growth: the mediating role of seaborne trade	Munim & Schramm, (2018)	The data for 91 seaport countries with yearly container traffic of 200,000 twenty equivalent units (TEUs) was gathered from the World Bank.	Structural Equation Modeling (SEM)	Impact of port infrastructure quality, logistics performance, and maritime trade on the national economy of seaside countries	The quality of port infrastructure significantly affects the logistic performance of the ports, and logistic performance directly affects the country's economic growth.
21	The Evaluation of Operational Efficiency of the World's Leading Container Seaports	(Lu et al., 2015)	The data consists of 20 of the world's leading container ports, gathered from literature as secondary data and primary data gathered by interviews and site surveys.	CCR, BCC, and Super-efficiency DEA	Operational efficiency of Seaports	The study mentions a correlation between high technical efficiency and the attractiveness of ports.
22	Analysis of the Competitiveness of the Performance of Baltic Ports in the Context of Economic Sustainability	Gaidelys & Benetyte, (2021)	The data between 1999 and 2020 was gathered from the Bloomberg database, Lithuanian, Latvian, Estonian, and European statistical databases and data from port companies.	Formula development	Port Competition Analysis	modernisation efforts and the construction of new terminals have enabled the Port of Klaipeda to gain a leadership position which can be extended to other ports as technical improvements have a positive effect on port competitors

Table 2 Literature Matrix

3. Data and Methodology

3.1 Research Design

This study aims to examine existing literature on port performance measurement and compare industry methods within the parameters of this study. In accordance with interpretive science philosophy, insights from the industry will be gathered through semi-structured interviews with regional professionals in the port industry. While the primary research will be conducted using qualitative methods, quantitative methods will be utilised if any access can be granted to data by professionals. The motivation behind this is to provide a comprehensive overview of the industry's current state regarding operational productivity and understanding of insight with the assistance of actual calculations. By including both methods, this study aims to contribute to academia and industry in the best possible way. The driving force behind this study is to provide industry insights to enrich and expand the academic world, as Rezaei et al. (2018) noted. This research is motivated by inductive reasoning and has the potential to benefit research and professionals within the same parameters.

3.2 Evaluation of the Literature Review

The literature review section of this study explores various research works that have been conducted to illustrate significant progress in academic interest and understanding that has contributed immensely to the industry. Despite the value and usefulness of this work, there has been a limited disconnection between practical usage and academia. Therefore, this study aims to establish a connection between the industry and academia and bridge this gap. Several studies have been conducted, including Nayak et al. (2022), Schøyen & Odeck (2017), Lu et al. (2015), Schøyen et al. (2018), Kenneth Løvold et al. (2023), Sharma & Yu (2010), and Sharma & Yu (2009), which have used various indicators to assess the efficiency and productivity of ports. These indicators include berth length, number of quay and yard cranes, and the size of the terminal area, which can be summarised as technical and physical infrastructures. It is noteworthy that these indicators have a direct impact on the efficiency and productivity of ports, but changing them can be challenging due to capital, geography, politics, environment, and other limitations. Therefore, the focus should be on how the port performs and maintains satisfactory productivity, regardless of physical and technical infrastructure restrictions. To this end, studies such as Ha et al. (2017) and Gonzalez &

Quesada (2022) have used various metrics, including crane productivity, yard and berth utilisation, vessel turnaround, waiting time, and other measurements, to investigate terminal measurement methods and create possible advisories. It is elaborated that these indicators have more suitable aspects to the concept of this study since used indicators are more related to productivity that the port produces regardless of the limitation. Restrictive factors can be used as complementary factors by other studies to investigate more of the port's performance and show how the port performs at the level despite restrictions. In other words, investigating the measurement methods of the terminals and understanding the factors affecting indicators such as crane and yard productivity, vessel turnaround, truck turnaround, and initial utilisation of the resources will assist in accurate measurement and potential inefficiencies. Directly, if the port can improve the factors affecting indicators, it will automatically have more accurate measurements and potentially increase productivity. Studies and reports that have been reviewed in this study had a lack of information on this aspect, and no other study was found that investigated factors that affect these indicators. By doing so, the linkages between academia and industry can be ensured, and potential value for both worlds can be added. The data that will be collected during the study will aim to enlighten presented topics.

3.2 Aim of the Research

The main goal of this research is to delve into the various practices surrounding port performance measurement. The study is centred around the limitations of current methods and aims to gain insight into the specific indicators, techniques, and constraints used by industry professionals. Answering formulated research questions will be the main focus in addition to the challenges that might come across during the research. To accomplish this, interviews with experts in the field will be conducted to obtain in-depth information about the measurement processes, key indicators, and contributing factors. Furthermore, the reasons behind these methods will be analysed to gain a complete understanding of the factors influencing port performance. The research results will be presented in the findings section, providing a thorough analysis of all collected data to give a comprehensive overview of port performance measurement practices.

3.3 Research Method

For this research endeavour, the chosen methodology involves using semi-structured interviews. The purpose of conducting these interviews is to obtain valuable insights from individuals who possess extensive knowledge and experience within the industry and to develop a comprehensive understanding of the subject matter. However, it is essential to note that due to time constraints of the data collection process, there may be limitations on the number of interviews that can be conducted, as well as the length of each interview. Despite these constraints, it is intended to conduct at least one interview that specifically pertains to the port, which will be instrumental in obtaining relevant information for the study.

3.4 Data collection

3.4.1 Sampling

This study delves into the Baltic Nordic region, encompassing countries with coastal areas along the Baltic Sea, such as Denmark, Germany, Poland, Russia, Lithuania, Latvia, Estonia, Finland, and Sweden. This area includes numerous seaports, with Denmark alone having 32, providing insight into the size of the total potential samples. However, the study will solely focus on the region's major container terminals, selected based on their annual TEU figures, where only the four busiest container ports will be examined to increase data collection and response rate.

Although Norway lacks a direct coast to the Baltic Sea, it is included in the study due to its geographical proximity and connection with the other two Nordic countries, Denmark and Sweden, which are coastal states for the Baltic region. Five ports in Norway are included in the study due to a lack of 2023 Q4 data and total TEU similarity. Other Nordic countries (e.g. Iceland and Greenland) are not included due to irrelevance to geographical proximity.

The sampling method is based on a table issued in Ports of the Baltic Sea, (2024). According to the source, only the top 4 busiest container ports from every country within the region were selected as a sample to limit the scope. However, in some cases, the selection was limited due to a lack of appropriate samples, and in some countries, the selection was kept more comprehensive to increase the chance of response and due to closeness to the selection criteria.

Thus, the sample port selection is based on the study's aim to evaluate the performance of the major container terminals in the Baltic-Nordic region.

The individuals to be interviewed will be selected based on a judgemental sampling method considering their job position and expertise. This means those who are responsible for or knowledgeable about measuring their port's performance will be included. However, it is known that not only the ports are measuring their performance for benchmarking purposes, but shipping lines, as a crucial secondary element, also evaluate the port's performance as a service receiver. Therefore, individuals from shipping lines who work in related departments, such as operation and logistics, were also consulted about the region or port they operate. This approach ensures that the study is comprehensive and covers all aspects of the performance measurement of the ports in the Baltic-Nordic region.

Sample Ports

Country	Port	Annual TEU	Year
Sweeden	Stockholm	50591	2022
	Gävle	164822	2022
	Norrköping	106931	2022
	Gothenburg	914000	2023
Denmark	Frediricia	111000	2022
	Copenhagen	102000	2022
	Aarhus	756757	2022
Norway	Oslo	103277	2023 excluding Q4
	Larvik	23615	2023 excluding Q4
	Brevik	54270	2023 excluding Q4
	Ålesund	23073	2023 excluding Q4
	Kristiansand	22081	2023 excluding Q4
Poland	Gdansk	2050000	2023
	Gdynia	873892	2023
Lithuania	Klaipeda	1050804	2023
Latvia	Riga	465391	2023
Estonia	Tallin	221405	2023
Russia	St. Petersburg	336713	2022
Finland	Hamina, Kotka	561577	2023
	Helsinki	407995	2023
	Rauma	209875	2023

Table 3: Sample ports

Source: "Ports of the Baltic Sea" (2024) (Statbank Norway, 2024)

3.4.2 Method

This study's research methodology involves conducting semi-structured interviews with port and shipping line employees. Various communication channels, such as professional social media platforms like LinkedIn, port and shipping line webpages, and convenience sampling, will be used to reach relevant sample groups.

To ensure that interviewees comprehended the study's objectives and questions, a brief overview of the paper's concept and the questions that sought answers were provided to them. Interview questions were available upon request before the actual interview so that participants could prepare and provide well-thought-out responses.

Given the sample size, the interviews will be conducted via an online platform such as Zoom or Microsoft Teams, depending on the individual's preference. This approach would enable research to reach more people and facilitate a more efficient process. However, if online meetings are not feasible, other methods, such as telephone conversations or written replies, will be accepted to maximise the response rate. Employees will be contacted in advance via email, telephone, and messaging apps to arrange a meeting time that works for both parties. It will also be guaranteed that the interviewees are aware of the confidentiality and anonymity of their responses, which will be detailed in this section.

The efficiency and suitability of the selected research method will be evaluated at the end of the study. The selected method is believed to enable the study to gain valuable insights from port and shipping line employees. This information will assist in gaining a deeper understanding of the industry and its challenges and ultimately contribute to the development of effective solutions.

3.4.3 Process

The data collection process was held for six weeks among sampling ports, and nine individuals were contacted. Due to the time constraints of the research, national holidays, and individuals' personal schedules, four interviews with three from the port industry and one from the shipping line from different sampling ports have occurred. Thanks to the participants, data shared in the findings section became available and collected according to the limitations of ethical

considerations shared in this study. Thanks to the participant from the shipping line quantitative data set, “Average Port Call Record and Partial Productivity Measurements of Last 4 Years (2020-2023)” became accessible. Data was formulated and coded according to the stated ethical concerns of this study and participant preferences and initially used as described in the research design. Throughout the interview process, the importance of recording and evaluating operational stoppages and idle times(wastage) was seen as crucial. Thus, in order to emphasise the issue, more data for comparison was found helpful. Since interviews occurred among sampling ports, which are classified as feeder ports, an example is from a hub port where ocean vessels can call and feeder vessel feeds them (e.g Hub&Spoke networks) (Feeder Ship, 2024). With this aim, a hub port from South Europe was contacted, and the list of stoppages shared in this study became available for academic purposes.

3.5 Ethical Consideration

The ethical concerns of this study will be given the utmost attention to ensure transparency and confidentiality throughout the research process. To guarantee the confidentiality and privacy of individuals, interviewees will be anonymous, and no personal data will be collected during interviews. However, according to the focus of this paper, input from employees working at ports with related positions over performance measurement will be naturally regarded as the primary group, and employees from shipping lines with responsible positions on port performance measurement will be the second primary group. Hence, to show the data's relevance, only information regarding the industry area where the interviewee works, such as the Port industry or Shipping line, will be shared without any position or location that can be linked to an individual.

Interviewees have the right to withdraw their input or make changes after the interview. Undoubtedly, their approval will be requested for the data collected to be used in this study. Depending on their request, the findings from the interviews can be shared with the individuals before the thesis submission in addition to the submission version of this paper.

All data used in this study will be stored in a cloud account provided by the University of South-Eastern Norway to the author as a student account throughout this Master's Degree. It will not be stored on any hard drive, and it will be permanently deleted three months after the data

collection process and not used in any other study afterwards. Initially, the user will be deleted with the termination of the studentship period.

4. Findings

Throughout the research, in addition to the qualitative methods, a quantitative data set shows the actual calculated performance measurement and methods found useful to understand industry practices in more detail and emphasise differences with academic methods. Hence, Table 4 Average Port Call Record and Partial Productivity Measurements of the Last 4 Years (2020-2023) is forged through the quantitative data provided by the participant upon request. Raw data, which includes figures for four years periodically, has been simplified in terms of the scope of this study, coded to maintain anonymity and briefly formulated to combine all the years into one meaningful table. Even though the sample size consists of 21 locations, the data received includes 20 of the sample ports, and in order to protect the anonymity of the data, an alphabetic letter was assigned to all of them. Explanations of the respectful column are combined with explanations gained during the interview and (World Bank, 2023) "The Container Port Performance Index 2022" report, which also elaborates on port performance from a similar perspective.

- Number of Calls: Number of vessel calls for container loading and discharging purposes
- Number of Moves: Total Number of container moves
- Average Quay Crane: Number of quay cranes used during the operation (STS, Mobile Crane, Mounted Harbour Crane, etc)
- Berth Productivity: Total time spent between all-fast and departure divided into a number of moves.
- Quay Crane Productivity: Total number of operation hours divided into the number of moves per crane.
- Berth Time In Hours: Total time spent at berth between all fast and departure.
- Average Berth Time in Hours: Berth time in hours divided by the number of calls.

In addition to the explanation of the columns mentioned above, the calculation methods of berth and quay crane productivity are essential to understanding the dataset. Accordingly, columns marked as “Number of Container Vessel Call”, “Number of Container Moves”, and “Average Quay Crane” are included in the table. Quay crane productivity is calculated by dividing the total moves that occurred in the vessel call by the total time in hours within the first crane move and the last crane move. It represents the average productivity of each crane. Even though berth productivity is calculated using the same method, it is multiplied by the number of cranes worked or crane productivity of each crane is calculated separately and combined if not the same number of cranes are worked from beginning to end. However, the time frame starts with vessel berthing and unberthing. If cargo operations start immediately after the vessel is ready on the quayside and leave after the cargo operation is final, quay crane productivity and berth productivity will be very close figures unless there are specific lost time records, which will be mentioned in the following paragraphs. In reference to the data and explanations gained during the interview, the equations below are created for a more comprehensive understanding.

$$\text{Quay Crane Productivity (CMH)} = \frac{\text{Total number of container moves}}{\text{Total time (in hours)}}$$

$$\text{Berth Productivity (CMH)} = \frac{\text{Total number of moves}}{\text{Total time (in hours)}}$$

- “Total number of moves" represents the total number of container moves.
- "Total time (hours)" represents the total time between the first and last moves for quay crane productivity; for berth productivity, berthing and unberthing.

Average Port Call Record and Partial Productivity Measurements of Last 4 Years (2020-2023)							
Sample Ports	**Number Of Container Vessel Calls**	**Number of Container Moves**	**Number of Quay Crane**	**Berth Productivity**	**Quay Crane Productivity**	**Total Berth Time in Hours**	**Average Berth Time in Hours**
A	67	47410	2.10	50.48	31.88	953.75	14.08
B	28	8435	1.05	20.75	23.60	408.00	14.90
C	34	11099	1.60	25.98	19.70	578.75	16.10
D	51	9883	1.88	28.78	17.50	708.25	13.90
E	53	27735	1.93	24.63	14.38	1538.50	29.05
F	36	49187	2.80	57.33	23.00	886.75	33.55
G	102	136507	2.30	55.83	27.15	3236.75	32.15
H	74	68742	1.95	40.43	27.23	1776.25	23.60
I	57	11594	1.23	26.48	26.43	887.50	15.63
J	52	27306	1.90	34.23	26.63	1106.75	21.38
K	51	45716	1.73	23.10	20.88	2107.25	41.35
L	33	5400	1.00	13.98	17.88	385.75	10.28
M	37	9412	1.03	20.03	29.05	424.00	11.03
N	50	20753	1.73	25.25	23.40	845.50	16.80
O	48	19599	1.70	30.58	24.63	756.00	14.88
P	49	32104	1.75	25.35	21.83	938.58	25.83
Q	69	67965	1.90	31.83	19.28	2157.50	31.68
R	122	150026	2.55	44.00	19.98	4928.00	40.40
S	46	16250	1.75	21.98	20.20	747.00	16.70
T	59	37353	1.95	30.08	20.20	1251.00	22.03
Total	**1122**	**959068**	**2.03**	**36.00**	**22.23**	**27082.50**	**24.10**

Table 5 Average Port Call Record and Partial Productivity Measurements of Last 4 Years (2020-2023)

According to the interview results, shipping lines aim to reduce the port stay, which means maximising berth productivity. High berth productivity can benefit the shipping line by allowing extra port calls to generate more cargo, proceeding with eco speed to save fuel and decrease CO2 emissions, providing flexibility during the rotation, cost savings, and more. However, the most significant factor affecting berth productivity is quay crane productivity.

Quay crane productivity is calculated by dividing the total moves that occurred in the vessel call by the total time in hours within the first crane move and the last crane move per crane.

According to the table, even in the port with the lowest port stay, which is more than 10 hours, there is potential for many operation disruptions. Any disruption during the operation recorded by the port and informed to the shipping line is registered and considered during the productivity measurement. It is divided into two categories: stoppages and idle times. Stoppages are divided into three subcategories: vessel, terminal, and agency. These subcategories allow for the proper assignment of stoppages and correct identification of the point of disruption that affects berth productivity.

Any disruption caused by the agency or vessel should not affect the quay crane performance of the port since the disruptive party is not the port. However, all stoppages and idle times should be included in the berth productivity calculation, which reveals the overall performance. For example, using the figures of Port A, we can see that if there were no stoppages or idle times, with an average crane of 2.10 and 31.88 Quay Crane Productivity, berth productivity should be close to 66.94, and with 67.25 port calls, the average port stay could decrease by 3.56 hours. However, berth productivity is calculated as 50.48, and the average port stay is 14.08. The effect of lost time (stoppages and idle times) can be seen as significantly vital, even from a single example. Accordingly, the above formulations need to evolve as follows.

$$\text{Quay Crane Productivity (CMH)} = \frac{\text{Total number of container moves}}{\text{Total operational time (hours)} - (\text{Stoppages (hours)} + \text{Idle times (hours)})}$$

$$\text{Berth Productivity (CMH)} = \frac{\text{Total number of moves}}{\text{Total time (hours)} - (\text{Stoppages (hours)} + \text{Idle times (hours)})}$$

- “Total number of moves" represents the total number of container moves.
- "Total time (hours)" represents the total time between the first and last moves for quay crane productivity; for berth productivity, berthing and unberthing.
- "Stoppages (hours)" refers to the total stoppage time due to certain obstacles, stops, breakdowns, or delays during operating hours.
- "Idle times (hours)" represents the total time when container operations have not occurred due to any reason.

Recording stoppages and idle times is crucial since otherwise, it will be considered as operation hours and directly decrease the quay crane perspective and unfairly decrease the berth productivity for the port if the responsible party for lost time is not the port. During the interview with one of the interviewees from the port, a list of stoppages is received to compare the port scales and the importance given to the matter. A hub port from the south of Europe, with an annual handling of 2 million TEU and a capacity of 4.5 million TEU, is contacted to acquire another list to have a cross reference for identifying differences between hub port and feeder port.

The size of the container vessel calls separates the feeder and hub ports in the “Table 5 List of Stoppages”. Feeder ports operate feeder-size vessels that feed ocean vessels in hub ports and distribute cargo from ocean vessels. The sampling ports of this thesis are feeder ports and hub ports for them, such as Bremerhaven, Antwerp, Rotterdam, etc.(“Feeder Ship,” 2024)

List Of Stoppages	
Feeder Port Example	**Hub Port Example**
Bunkering, supplies	Meal-time
Berth shifting	Breakbulk Cargo Operation
Waiting for pilots, tugboats or linesmen	Damage cell guide
Tidal/navigational restrictions	Change position
Vessel maintenance/repair	Change Vessel
Waiting for cargo connections (late delivery, hot connection)	Damage container
All gangs shifted to other vessel (other priorities)	Gear Box Handle
No gangs requested (avoid overtime payment and/or extra charges)	Hatch Cover Move
Crane gang shifted to other vessel (other priorities)	Boom up-down
Adverse weather creating unsafe circumstances	Accident
Waiting for cargo connections (late delivery, hot connection)	OOG operation without used by spreader
Instruction of Local Authorities	Missing twistlock
Power outage (due to external cause)	Manuel twistlock
Labour actions (strikes, only if national)	Other sts operation
Public Holiday	Stop. due to Port
Crane boom up/down on request pilot of a vessel passing by	Reefer Plug in-out
Fumes from vessel not workable	RTG Trouble
Fixing lines / securing gangway	Shift Change
Operations stopped by the Line: accident, emergency, planning changes	Hydraulic Hatch Cover
Noncontainerised cargo (breakbulk)	Vessel Repairment
Compulsory breaks (meals, prayers)	Slipped twin container
Power outage (due to external cause)	Vessel supply/garbage
Labour actions (strikes, only if national)	STS Trouble (Breakdown)
Twist lock problems while discharging (on board)	Twistlock Stuck
Twist lock problems while loading (on quay)	Vessel trim/list
Handling hatch covers	Waiting for Loading
Handling vessel gear boxes	Waiting Doc. List
Out of gauge (OOG) that can be handled with just a spreader	Lashing/Unlashing
	Weighing
	Stop. due to Weather
	Waiting for Discharging
	Planned Operation suspend(labour)

Table 6 List of Stoppages

The list of stoppages and idle times recording might differ from port to port. The above list includes a wide range of recording possibilities acquired from the feeder port that are only under usage in one location. In other locations where, participants stated that the range of stoppages and idle times are limited and include very traditional stoppages such as weather, waiting for documentation, meal breaks, shift changes, etc. The reason is stated as long-term relations with clients and stabilised operations. More broadly, it is stated in the interviews that a wide range of stoppages and idle times are unnecessary because they are not facing different obstacles since vessel calls are more routine-based, and if they happen, they are usually solved with a shipping line to prevent the next time. From this perspective, the size of the business, even among feeder scale ports, correlates with the importance given to the effort of recording and identifying stoppages. Accordingly, it is stated in the interviews that identifying a long list of stoppages is very labour-intensive and does not necessarily correlate with the needs of the port. Hence, it can be stated that the importance of stoppages and idle times, which means measuring port productivity most accurately, possibly correlates with the importance given and individual effort. However, in all interviews, it is unexceptionally stated that recording stoppages and idle times are vital to measuring port performance most accurately.

Interview Questions Codes and Themes

Questions	Codes	Theme
How is port performance measured in your location?	Partial Productivity Measurement (Berth Productivity/Quay Crane Productivity/Operation Productivity)	Port Performance Measurement
If productivity is measured as Berth /Crane, Gross/Net as partial which stoppages waiting times are noted.	External and Internal Factors (Port/Vessel/Agency)	
Do you believe recording stoppages and Idle times can have a positive effect on productivity calculation?	Unexceptionally significant importance	
While measuring which indicators are used?	Total moves per hour, per crane	Port Performance Indicators
Which factors are affecting the performance of selected indicators?	Yard occupancy and utilisation, Truck Turn time, crane productivity and intensity, vessel size and balance of moves	
Do you believe the quality of productivity measurement is good and do you know any other methods to calculate?	Meets with industry expectations	Measurement Quality
How do you use performance for benchmarking?	Internal benchmarking, competitive benchmarking, processes benchmarking	Benchmarking
Do you think port performance affects the competitive advantage and attractiveness of the port? In other words, are your customers using the port in your location thanks to its performance?	Berth Productivity, customer service, transparency, flexibility, pricing, historical presence	
In the importance scale, is the port performance at the top of the list, or are there any other indicators affecting port selection more than port performance?	volume of the port/hinterland and infrastructure and superstructure, pricing	

Table 7 Interview Questions Codes and themes

Throughout the interviews, the participants were asked above questions. Unexceptionally, ports and shipping lines use partial productivity methods such as berth productivity, quay crane productivity, and operation productivity to measure their performance. For recording stoppages only in one location, stoppages and idle times recorded with a wide range of lists in other locations

depend on manual registration and a limited list. However, it is unexceptionally stated that recording stoppages is vital in measuring port performance.

Indicators that are used also correlate with the business size; however, they are based on total moves per hour per crane in all locations. In busier feeder ports, factors considered are more comprehensive due to the size of the business; however, from a yard perspective, yard efficiency, yard occupancy level, truck turnaround time and yard utilisation can be mentioned as factors affecting berth and crane productivity. For the quayside, we can mention quay area efficiency, crane intensity, vessel size and range of moves, balance of discharge and loading, and crane productivity can be mentioned.

Regarding measurement quality, participants' replies correlate and state that their methods meet industry expectations. However, different measurement methods in the literature have not yet influenced the industry. For some ports, identifying the factors that affect indicators and a wide range of stoppages and idle times and recording these events are labour-intensive and potentially costly.

Even though subject ports are geographically close to each other, under the limitation of this paper, port interview responses correlate with the fact that the most crucial usage of performance measurement is internal benchmarking and process benchmarking. From a safety perspective, lost time injuries, a machinery perspective, Fuel and electricity consumption, equipment availability and maintenance, a financial perspective, cost per move, and an operation perspective, as mentioned before, berth productivity, crane productivity, crane availability factor, yard occupancy, truck turn time, yard/quay area efficiency can be given as example points for benchmarking. Competitive benchmarking activities only occur when there is more than one terminal operator in the port area, and in this case, berth productivity becomes crucial for ports and shipping lines. Even though pricing is mentioned in the interviews, it is not regarded as the most critical factor. From a shipping line perspective, berth productivity is important benchmarking since, due to short port stays, sea passages can be slowed, the CO2 emission of the vessel can be decreased, and fuel consumption can be decreased.

The findings will be elaborated briefly and linked to the literature review broadly in the following section. They will also be listed and summarised in the conclusion section.

5. Discussion

Academic studies, reports of international organisations, and interviews conducted in the research phase elaborate various perspectives and information. Specific methods of academia and industry might be correlated; however, as also stated in the " Evaluation of Literature Review" section of this paper, there are certain differences that both areas might find suitable.

First of all, as shown in the literature review section, the recent focus on academia is on comprehensive performance measurement, whereas industry practices focus on more customer needs and business size. Accordingly, the industry practices partial productivity methods that indicate focusing on specific perspectives. Hence, superstructure and infrastructure limitations are not considered in measurement. It briefly focuses on the fundamental definition of productivity measurement, the "input and output" perspective, which can be elaborated as maximum achievements within the available sources. However, it is also possible to see similarities, such as measurement methodology where crane productivity, yard and berth utilisation are used, as stated by Ha et al. (2017) and Gonzalez & Quesada (2022). In order to increase the footprint of the industry among academic studies in port performance measurements with an operational perspective, the average crane move per hour per crane can be used as the primary indicator, and other indicators mentioned in various studies can be accepted as factors that affect the indicator instead of accepting them as independent indicators. These can be noted as yard efficiency, yard occupancy level, truck turnaround time and yard utilisation quay area efficiency, crane intensity, vessel size and range of moves, balance of discharge and loading, crane productivity, etc. As stated in interviews, yard operation and quay operation are total inputs for a single output, which is the average quay crane move per hour per crane. However, it is noteworthy to mention that studies which mentioned earlier, such as Nayak et al. (2022), Schøyen & Odeck (2017), Lu et al. (2015), Schøyen et al. (2018), Kenneth Løvold et al. (2023), Sharma & Yu (2010), and Sharma & Yu (2009) are not using totally different methods although it is seen during the interviews that industry conceptualise input, output and variables differently. It is also seen that the influence of academic papers is not visible specifically among the sample ports. Hence, it is mentioned that identifying factors and having a vast method of calculation performance is labour-intensive and costly. From this perspective, it can be suggested that existing literature can be the solution for the industry, and already existing methods can be adapted to the company's dynamics and needs.

It has also been discovered that an important point is often overlooked in the academic world. Even though productivity is considered essential, events and disruptions during port operations are not mentioned. During the interviews, participants unexceptionally agreed that identifying and recording stoppages is vital to measuring port operation performance. World Bank, (2023) The Container Port Performance Index 2022 report mentions that only 60% of the total port stay can be attributed to cargo operation. Stoppages and idle times are regarded as "wastage." It also states that most idle hour variables have a significant number of missing values. This means there is a general lack of recording throughout the industry and significant waiting time. Bureau of Infrastructure and Transport Research Economics, (2023) mentions on the list (Box 2.1 Net crane time p 21) to identify as *"time allocated by the stevedore for container operation, assuming the container ship is ready for loading or unloading. Total time spent by each quay crane is allocated to a ship, less operational and non-operational delays are considered as stoppages and idle times and removed from gross productivity calculation but included to net productivity calculation".* Industrial reports briefly mention the importance of this point; however, it is overlooked in academia. It has also been discovered that ports have different types of stoppages and ways of recording, which easily cause different performance measurement methods. In other words, the same number of crane productivity might mean different berth productivities and directly different periods of port stays. Hence, it can be helpful for international organisations to prepare measurement guidelines and lists to standardise operational performance measurement so that attributed %40 of unidentifiable port stays can also be addressed and potentially improved by the parties. From a shipping line perspective, entering new markets where companies lack experience in port selection processes based on performance can be more accurate.

Hence, performance measurement is crucial, and it is seen that not all ports pay enough attention to the matter. It is suggested that using existing literature to broaden the measurement methods and factors and recording stoppages to reach the most accurate performance measurement is vital and can lead ports to assess themselves better within their limitations.

Benchmarking is an essential practice to increase port attractiveness. Sharma & Yu, (2010) suggest investing in new equipment to increase port attractiveness, while Gonzalez & Quesada, (2022), emphasise productivity Rezaei et al., (2018) on the other hand, emphasise transport costs and times along the transport chain, which correlates with the studies of Bichou, (2006) and

Schøyen et al., (2018) who emphasizes the importance of the supply chain as a performance indicator. During the interviews, it was unexceptionally stated that berth productivity is most significant from the port operator's perspective, although it is only crucial when there is more than one terminal in one port area/city or relatively the same hinterland. It is also seen that ports are attributing more importance to internal benchmarking and process benchmarking by focusing on labour source planning, power consumption, maintenance, etc., eventually controlling cost per move. Hence, ports' competitiveness depends on berth productivity and financial efficiency. However, it is also stated that flexibility, customer service, and future prospects of the port are relevant benchmarking, representing the importance of non-productivity/efficiency-related points. From a shipping line perspective, berth productivity, superstructure and infrastructure capabilities, which can offer more comprehensive logistic solutions and cost, can be mentioned. In light of the literature review and interviews, it can be stated that for port performance benchmarking, the most crucial point is berth productivity in the industry and also generously in the literature. Hence, measuring the most accurate port performance with the point suggested above might ensure and increase port attractiveness, eventually creating a competitive advantage. It is not only because high berth productivity causes short port stays that clients desire, but also, the productive use of resources can lead to efficiency, especially cost efficiency, where ports benchmark themselves. Within this sense, it is also essential to calculate the most accurate port performance for the allocation of resources and identify potential improvements. Accordingly, as suggested by Sharma & Yu, (2010) can be rephrased as investing in new equipment might be beneficial if needed for better productivity and potential long-term cost efficiency. Finally, due to the increased competitive environment of world trade, ports need to adapt and evolve according to customer needs and provide more comprehensive logistic solutions and services to increase competitive benchmarking, as stated by Bichou, (2006) and Schøyen et al., (2018) in addition to flexibility and agility.

6. Conclusion

Throughout this study, essential aspects of port performance measurement and benchmarking within the Baltic Nordic region are investigated and evaluated. First of all, personal interest in port business and performance measurement has driven the first draft of the research questions. Accordingly, research keywords were decided, and the literature review process started. Thanks to the broad literature on port performance measurement and benchmarking, the literature review enlightened the way for the research and formed the final version of the research questions. Throughout the literature review, related studies are examined and briefly mentioned. Even though recent literature is prioritised to show the historical progress of the literature review, past studies are also investigated and mentioned. It has been discovered that there are many studies that examine various measurement methods based on the created indicators frame inspired by the previous literature. However, studies that investigate industry practices and create links between existing literature were found to be insufficient. Hence, qualitative methods are used primarily as research methods. Based on interviewee participation, a quantitative data set became available and shared to emphasise industry practices and the current situation of the ports. In light of the literature review and qualitative research, the study is completed.

The first research question, "*What indicators affect port performance, and what factors affect the indicators used for performance measurement?"* has significantly broad approaches. According to the literature, many indicators are elaborated according to the purpose of measurement, such as operational, financial, equipment, yard, etc. Since the focus of this study is operational performance measurement, it is seen as contemporary to literature where a wide range of indicators are used, such as yard and berth size, number of equipment, yard utilisation and occupancy rate, truck turn time, berth efficiency etc. in industry measurement method is berth/crane/operational productivity, indicator move per hour per crane and factors which also mentioned in the industry are accepted as factors that affect indicator or can be stated as secondary indicators.

The second research question, "How do ports, especially Nordic Baltic ports, measure port productivity?" is answered as a partial productivity measurement: crane move per crane per hour, accepted as an operational performance measurement method.

The third research question *is, "How can port productivity be used for benchmarking and creating a competitive advantage in relatively small-scale ports?".* According to research results, ports are practising more internal and process benchmarking rather than external competition benchmarking. Thus, no sufficient result has been found regarding the significant importance of competitive advantage in relatively small-scale ports unless there are multiple terminal operators in a single port area. However, even though importance found as not significant Baltic-Nordic ports are focusing on increasing attractiveness and creating competitive advantage through their berth productivity and controlling cost efficiency based on crane productivity.

The fourth research question is, *"How can liners evaluate port performance during port selection if various methods are under usage?".* It is seen that liners measure their productivity internally. This measurement method parallels the ports method and is based on berth productivity, crane productivity and operation productivity. However, as explained during the interview, stoppages and idle times are registered based on port operation reports and vessel port logs. The main difference can only occur during the allocation process. Accordingly, recording stoppages and idle times will ensure a more accurate performance measurement of the shipping lines. Since no primary historical data is available during the port selection phase if a new market is phasing in, only indicators can be gained through industry and subject port. As stated by the interviewee on the priority list, port performance is not at the top as long as there is more than one terminal operator in the same port. Hinterland, cost, infrastructure, and port superstructure are found to be more critical in port selection.

Throughout this study, limitations are set as Baltic and Nordic countries with seaports in the Baltic Sea and Norway due to closeness to the region even though there are shores in the Baltic Sea. Thanks to the enormous amount of studies in the literature, the interconnectivity of the port performance measurement with many areas has increased the length of the literature review process. However, specific keyword selection helped to finalise the process within the planned schedule, and challenges were overcome. The nature of the qualitative research method is a time-consuming process. Hence, limited time naturally challenged the number of interviews conducted. However, the accuracy of the interview results helped to overcome this challenge and even with a limited response group, a relevant outcome was ensured.

As a result of this study, it can be said that there are differences between the literature and industry. Meanwhile, the industry uses a more practical approach to measure port performance as partial via berth and crane productivity; academia collaborates it with various perspectives. Also, used indicators and factors or variables that affect indicators are different. It also shows the importance of recording operational disruptions, such as stoppages and idle times, for the ports and shipping lines to measure performance accurately. Additionally, benchmarking practices among industry practices are revealed, showing that competitive benchmarking is not a primary activity for ports; however, internal benchmarking is the main focus.

This paper suggests that future academic studies create a framework according to industry practices and compare it with a common framework within the literature to evaluate the measurement quality with the same data set. Thanks to that, a standard international methodology and understanding can be created, and comparisons might be simplified for future studies. For international organisations in the maritime domain, it is advisable to conduct their studies in parallel or collaborate with academia for the same purpose so that lost time in their data set and measurement can be identified.

7. References

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8. Appendices

8.1 Appendix A: Interview Guideline

Topic

An evaluation of performance measurements and their influence on Benchmarking in Nordic-Baltic container ports

Research Questions

RQ 1: *What are the indicators that affect port performance and what are the factors affecting the indicators that have been used for performance measurement?*

RQ 2: *How do ports especially Nordic Baltic ports measure port productivity?*

RQ 3: *How can port productivity be used for benchmarking and creating a competitive advantage in relatively small-scale ports?*

RQ 4: *How can shipping lines evaluate port performance during port selection if various methods are under usage?*

Sample Group

Industry Professionals from Port and Shipping Line industries located in Baltic Nordic countries.

Research Method

Semi-structured Interviews

Ethical Consideration

The study will prioritise ethical concerns to ensure transparency and confidentiality. Interviewees will remain anonymous, and no personal data will be collected in addition no recording will occur. The focus will be on employees working at ports and shipping lines with relevant positions. Only industry-area information will be shared without any personal details. Interviewees can withdraw their input, and their approval will be sought for data usage. Data will be stored in a cloud account provided by the university and permanently deleted after the study.

Interview Questions

General Questions

1. How is port performance measured in your location?
2. While measuring which indicators are used?
3. Which factors are affecting the performance of selected indicators?
4. If productivity is measured as Berth /Crane, Gross/Net as partial which stoppages waiting times are noted.
5. Do you believe recording stoppages and Idle times can have a positive effect on productivity calculation?
6. Do you believe the quality of productivity measurement is good, and do you know any other methods to calculate?
7. How do you use performance for benchmarking?
8. Do you have any other additional comments?

Additional Question to Port Employees

9. Do you think port performance affects the competitive advantage and attractiveness of the port? In other words, are your customers using the port in your location thanks to its performance?

Additional Question to Shipping Line Employees

10. In the importance scale, is the port performance at the top of the list or are there any other indicators affecting port selection more than port performance?