Pre-Conditions for Collaborative Port Call Optimization

An Empirical Study and Conceptual Model

Master Thesis

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An Empirical Study and Conceptual Model

by

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TU Delft KOTUG

Preface

In light of the completion of my Master's thesis, I would like to take this opportunity to express my gratitude to the people who have supported me throughout this process. Without their contributions and support, the completion of this thesis would not have been possible. Their help has contributed to overcoming the challenges and paving the way to a successful conclusion.

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With this work a significant part of my life comes to an end, but where there is an end, there is also a beginning. I look forward to what comes next.

Wiebke Buch
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Summary

Ports are pivotal to global trade, handling around 80% of all sea freight. However, ports face numerous challenges, including increased vessel sizes and numbers, unpredictable weather, and congestion, which can lead to increasing waiting times for the arriving vessels. Prolonged waiting times for vessels lead to higher costs for both the ports and the vessels, making the optimization of port call processes paramount for maintaining competitiveness in the market.

The collaboration among different actors inside the port is crucial for Port Call Optimization (PCO). Although existing research, e.g., [60, 59, 81], underscores cooperation, it lacks comprehensive collaboration analysis. Previous work has concentrated on individual stakeholder interactions instead of looking at the ”bigger picture,” leaving room for a deeper exploration of collaboration within the port environment. To fill this gap, first, a review and analysis of the literature was performed to understand the factors that influence a successful port call, as well as the adoption of PCO. Additionally, semi-structured interviews were conducted with industry experts from 20 different ports around the world, which can be considered unique in existing literature. The interviewees, mainly with harbor masters and innovation officers working for the Port Authority, provided insights into the main objectives of the companies for the port call, the influence of existing port governance structures, port size and location, and the most occurring challenges. The interviews were a crucial step in verifying the pre-conditions derived from the literature analysis and to derive additional pre-conditions relevant for the adoption of collaborative PCO. For the interview analysis the interview analysis methods ”Word Frequency Analysis”, ”Concept Mapping”, ”Sentiment Analysis” and ”Concept and Word frequency distribution analysis” to analyze the data. The literature and interview analysis helped not only to identify but also to categorize the pre-conditions into four different types, namely technology, organizational, external environment and interorganizational related conditions, shedding light on the main objectives and means of companies for the port call, insights on the influence of the existing port governance structures, as well as the port size and location. Furthermore, the most occurring challenges could be identified which lead to the definition of the additional pre-conditions. Furthermore, the attitude and efforts of the interviewees toward PCO were analyzed. The investigation of literature and the interviews emphasized centralization, effective communication, and the multifaceted nature of PCO as key elements in enhancing port operations and the port call more specifically. Many factors related to interorganizational arrangements and collaboration among stakeholders were also highlighted. This study also revealed that successful PCO adoption goes beyond technology, emphasizing the need for fostering collaboration and mutual understanding among diverse stakeholders within the port call ecosystem.

Based on the findings of the literature and interview analysis, this study unveiled pre-conditions integral to the adoption of collaborative PCO across diverse contexts. Through a meticulous process, these pre-conditions were discerned and subsequently organized into distinct categories within a novel conceptual model. Recognizing the limitations of the Technology-Organization-Environment (TOE) framework in capturing the intricacies unearthed during interviews, this study introduces a more nuanced TOEI-framework (Technological-Organizational-Environmental-Interorganizational Arrangements). This TOEI-framework, an extension of the seminal TOE-framework by Tornatzky, Fleischer, and Chakrabarti [89], surpasses the organizational boundaries by encompassing interorganizational aspects. Unlike the TOE-framework which focuses on the adoption of technology on an organizational level, the TOEI-framework extends beyond this contexts and allows for interorganizational adoption. During the port call, various actors need to collaborate to ensure the successful and safe vessel navigation. Due to the high level of interdependencies between the process steps and actors involved, PCO can only be achieved if the actors collaborate with each other. The TOEI-framework addresses the complexities of adoption of the pre-conditions when multiple organizations collaborate in the context of PCO. The TOEI-framework recognizes that successful PCO adoption goes beyond technology; it is about fostering collaboration and mutual understanding among diverse stakeholders within the port call ecosystem. The TOEI framework includes four key contexts, each playing a vital role in shaping the adoption of

PCO, addressing must-haves and nice-to-haves essential for collaboration and optimization. For each key context, various preconditions in form of requirements and objectives are presented.

In the validation process of the TOEI-model, feedback from three diverse experts, encompassing academia and industry, reinforced its robustness and practical applicability. The first interviewee, active in the Rotterdam innovation ecosystem for over a decade, is a senior advisor in energy transition at the independent research center Erasmus UPT. The second interviewee, with 1.5 years as the Port Call Optimization Lead at the Port Authority of Rotterdam, brings expertise from previous roles in shipping and logistics. The third interviewee, a Professor at the American University of Sharjah, specializes in Information Systems and Business Analytics, chosen for their extensive TOE framework expertise showcased in prior publications. The validation with experts representing both academia and industry further strengthens its practicality and application in real-world scenarios. Rooted in a solid theoretical foundation, the framework garnered support for addressing both must-haves and nice-to-haves in the realm of collaborative PCO. The experts commended its role in guiding port authorities and stakeholders through the complexities of this multi-organizational environment. Notably, one expert underscored the insufficiency of the TOE-framework alone, expressing agreement with the TOEI framework's necessity. Additionally, the alignment of the TOEI-framework with ongoing research trends was acknowledged, marking it as a valuable contribution to academic discourse. The practicality of the identified pre-conditions was emphasized, with experts foreseeing the framework playing a pivotal role in defining future standards for effective PCO implementation.

Finally, it is important to acknowledge that the developed framework represents the central and significant contribution of the research, offering a novel tool for adopting collaborative PCO measures in different port contexts. It enhances the academic understanding of PCO adoption and has the potential to drive positive changes in the maritime sector by improving port operations. However, more research should expand and refine the TOEI framework, exploring its application in diverse port settings. Future studies should implement and test the framework in a practical problem and customize the pre-conditions identified in the framework if necessary.

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Nomenclature

Abbreviations

Abbreviation	Definition
ATA	Actual Time of Arrival
ETA	Estimated Time of Arrival
ETB	Estimated Time of Berthing
FCFS	First-come-first-serve
HM	Harbor Master
HVCC	Hamburg Vessel Coordination Center
JIT	Just-in-time
PA	Port Authority
PC	Port Coordinator
PCO	Port Call Optimization
PCS	Port Community System
PortCDM	Port Collaborative Decision making
RQ	Research Question
NLP	Natural Language Processing
NSP	Nautical Service Provider
SRQ	Sub-Research Question
TAM	Technology Acceptance Model
TEU	Twenty-Foot Equivalent Unit
TOE	Technology-Organization-Environment framework
TPB	Theory of Planned Behaviour
UTAUT	Unified Theory of Acceptance and Use of Technology
VHF	Very High Frequency
VTS	Vessel Traffic Service

1 Introduction

1.1. Background and Motivation

Background: Ports play a significant role in facilitating global trade [103], with approximately 80% of all freight transported by sea routes [8]. To ensure smooth and timely delivery, it is imperative that not only the vessel voyage itself runs efficiently, but also that the harbor processes are highly efficient and error-free. Due to the increased vessel size which requires a higher operational complexity, as well as the increasing number of ships calling ports [50] among other challenges, the waiting time of ships in the ports is increasing, which indicates that the ports are struggling to cope with this growing demand. These challenges not only impact the overall efficiency of port operations, but also have significant implications for the specific port call process, where delays and congestion can further complicate the timely execution of loading, unloading, and other crucial activities.

A port call refers to the scheduled arrival and departure of a vessel at a specific port for the purpose of loading, unloading cargo, and performing various operational activities. As the duration of a single port call extends to approximately 19 hours [94], a substantial portion of which is spent at anchorage awaiting service, the challenges associated with these prolonged waiting times become apparent. With essential services like pilotage and towage potentially unavailable upon request, the resultant high costs and emissions incurred by vessels underscore the urgent need to address and streamline the operational challenges faced by ports in order to enhance overall efficiency and economic viability. To cope with the growing challenges, it should be in the interest of the ports to optimize the port call process in providing services and be able to accommodate more vessels in a shorter time to ensure a high performance index and good competitive market positions.
Therefore, Port Call Optimization (PCO) has drawn special attention in recent literature such as Jahn and Scheidweiler [38], Nikghadam et al. [60], and Lind et al. [50] as a mean to reduce turn-around times and ultimately costs and emissions. Although there is no standard definition for PCO, it can be defined as a collaborative and strategic initiative designed to improve the overall efficiency and effectiveness of port operations during arrivals (and departures) of vessels. It involves the seamless coordination and integration of various stakeholders, technological solutions, and organizational processes with the goal of minimizing waiting times, reducing operational costs, and improving the predictability of arrivals and departures of ships.

While the challenges associated with prolonged waiting times during port calls are recognized, optimizing this complex process proves intricate, given the involvement of diverse stakeholders with varying incentives. The multifaceted nature of the port call process requires a comprehensive approach to address the intricate interplay of factors that contribute to inefficiencies and costs. Due to the high complexity of the port call process, a description of the process including the involved stakeholders is needed.

Port Call Process Description: The port call itself refers to the entire process of a vessel's arrival at a port, its stay in the port for operations and services (which include activities such as pilotage, towage, berthing, cargo handling, and other services required during the port call), and its departure from the port. It can also be referred to as the scheduled stopover of a ship in a port for cargo operations. Figure 1.1 visualizes the processes that take place and the actors that are generally involved during the port call. Table 1.1 provides the description of the individual steps of Figure 1.1.

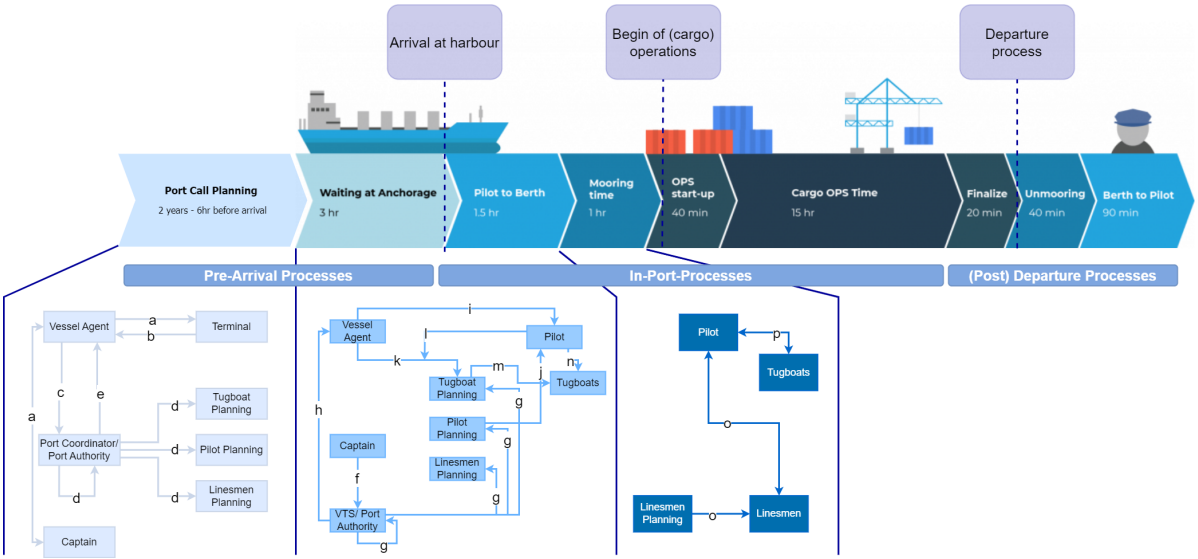


Figure 1.1: Port Call Process (adapted from [32])

Table 1.1: Different Process steps in the Port Call

Process step	Description
a	Announcement of vessel arrival and ETA
b	Confirmation by terminal
c	report confirmation to Port Coordinator (PC)
d	PC checks nautical safety, port health, security, capacity → Port Planning
e	PC approves report and provides clearance
f	operational contact is made
g	checks details of vessel report and makes updates if necessary
h	gives Vessel Agent (VA) go to call pilot to vessel
i	communication about boarding the vessel
j	organize travel of pilot to vessel
k	VA calls for tugboats
l	pilot confirms the number of required tugboats after arrival of vessel
m	orders tugboats to vessel
n	orders tugboats to connect and then to tow vessel to berth
o	organize linesmen at berth and once arrived at berth, the linesmen help moor the vessel
p	while mooring, the pilot and tugboat captain communicate closely to safely get the vessel to the berth

As can be seen in Figure 1.1 the port call process can be divided into different process steps, namely the pre-arrival processes, the in-port processes and the departure processes.

In the pre-arrival processes (process steps a to e in Figure 1.1), the vessel prepares for its arrival at the port by submitting necessary documentation, obtaining clearance, and communicating its ETA to the port authorities and service providers. The vessel agent announces that the vessel wants to call the port. Depending on the type of vessel, this announcement can take place between two years (for cruise ships) to approximately six hours in advance. For container vessels, the first announcement of the port call usually happens a few weeks to one or two day days before the planned arrival. Once the first interaction has taken place the port authority checks if the vessel is eligible for a port call and then gets in touch with the different service providers to check the resource availability and plan the process. As soon as the vessel is close to the destination/the harbor entrance the captain gets in touch with the Vessel Traffic Center (VTS) if existing or otherwise the Port Authority to announce the arrival

of the vessel. Optimally. the the ETA is continuously updated either by the vessel agent or the captain. Once the vessel arrives the pilot should already be available to board the vessel. However, in reality this is not always the case. Therefore, according to Gommans and Zaki [32], the waiting at anchorage usually takes around 3 hours.

Once the vessel arrives at the port, the in-port processes (process steps f to n and o to p in Figure 1.1) come into play. These include activities such as pilotage, berthing, cargo handling, customs clearance, and other services required during the port call. The pilot has boarded the vessel and the tug boats are attached to the vessel the in-port processes can start. The vessel is towed to the berth where the linesman/mooring gang is waiting to moor the vessel to the berth. This process step is visualized via steps o and p. Efficient coordination and collaboration among various service providers, including tugboats, pilots, terminal operators, and customs authorities, are crucial to ensure smooth and timely operations. However, the lack of synchronization and coordination among these stakeholders can result in delays, increased waiting times, and higher costs [29, 59].

After the successful mooring which on average takes about one hour (depending on the port) the port call process of arriving vessels is finalized and the cargo operations start. This thesis focuses on the port call process of arriving vessels which is why the process is not further described in detail in Figure 1.1.
In each step, different stakeholders are involved and different actions including physical movements as well as communication need to be pursued. Overall, this process includes a high complexity level due to the precision that is required to ensure safety throughout the whole process. Therefore, collaboration and communication among the involved parties is required.

Practical Motivation: In recent years, researchers have increasingly explored the concept of port call optimization from various perspectives. One prominent approach focuses on optimizing the estimated time of arrival (ETA) versus the actual time of arrival (ATA), primarily concerning pre-port processes, also often referred to ”voyage-efficiency”. Particularly, the concept of just-in-time (JIT) arrival achieved by route and vessel speed optimization in order to reduce waiting times has gained prominence in several research inquiries such as Johnson and Styhre [39], Jahn and Scheidweiler [38], and Arjona Aroca et al. [8]. However, instead of using a priority system, many ports still adhere to the ”first-come-first-serve” (FCFS) approach, where ships arriving first are admitted first [51]. This motivates shippers to provide overly optimistic ETAs to maintain their favorable position in the queue, which leads to inadequate resource planning and inefficiencies within the port [51].

Furthermore, due to standard ocean shipping agreements, driven by commercial considerations, vessel speed is frequently prioritized over berth or in-port service availability at the destination. This can lead to inefficiencies, externalities such as pollution and greenhouse gas emissions, and adverse economic, safety, and environmental outcomes [51, 6]. Thus, the inefficiency of port calls cannot be fully remedied by optimizing ETAs alone, highlighting the need for research into optimization of port call processes within the port.

Besides JIT-arrivals as one way to optimize the port call, the concept of collaborative port call optimization has gained prominence in recent years. Collaborative PCO covers the collaboration of different stakeholders involved in the port call process such as Port Authorities, Terminal Operators, Tugboat Operators, Pilots, Vessel Agents and many more. Effective collaboration offers several advantages:
Firstly, it promotes the sharing of critical information among stakeholders, thereby reducing uncertainty and improving predictability in the port call process. By sharing real-time data on vessel schedules, cargo availability, and berth utilization, stakeholders can synchronize their activities and make informed decisions that minimize delays and bottlenecks [60].
Secondly, collaborative efforts enable the pooling of resources and expertise. This can lead to optimized resource allocation and utilization, which is particularly important in the context of larger vessels that require significant resources for handling and servicing [20, 60]. By coordinating equipment, labor, and infrastructure, stakeholders can streamline operations and reduce idle times, ultimately enhancing overall efficiency [59].
Thirdly, collaboration fosters a sense of shared responsibility and accountability. When stakeholders

work together towards a common goal of efficient port call processes, they are more likely to align their interests and invest in solutions that benefit the entire ecosystem. This can lead to the implementation of innovative practices and technologies that address challenges holistically [81].
Lastly, collaborative initiatives can facilitate the identification and resolution of challenges that are beyond the scope of individual stakeholders. By engaging in open dialogue and problem-solving, stakeholders can uncover systemic issues that might not be evident in isolation. This proactive approach can lead to the development of comprehensive solutions that address root causes rather than just symptoms.

1.2. Research Gap and Aim

Within the existing body of research, several notable research gaps have emerged [60, 59, 81], collectively emphasizing the imperative for a comprehensive understanding of the pre-conditions for the adoption of collaborative Port Call Optimization (PCO) in different ports. One significant research gap lies in the limited exploration of collaboration within the port environment. While scholars such as Nikghadam et al. [60] have delved into the interactions among individual stakeholders, a holistic view of collaboration remains under-explored. The work of Nikghadam et al. [59] specifically centers on information sharing, omitting many other facets of collaboration. Their simulation model, tailored to a single port structure, does not consider the intricate resource-sharing dynamics among diverse service providers, posing challenges in an industry characterized by competitiveness and contractual complexities.
This research gap highlights the need for a more comprehensive understanding of collaborative dynamics within the port environment. It is crucial to move beyond isolated aspects of collaboration, such as information sharing, and explore the broader spectrum of interactions among stakeholders involved in the port call process. This includes understanding how different service providers collaborate, considering the diverse interests and challenges they face. Addressing this research gap is essential for developing effective strategies and defining pre-conditions that facilitate collaborative PCO adoption across various ports, considering the unique characteristics and operational settings of each port.

This study aims to bridge the previously identified research gap by identifying the pre-conditions required for the successful adoption of collaborative PCO within a port. With the help of a conceptual model, these prerequisites can be presented in an organized and holistic way. The research seeks to shed light on various factors, encompassing both human elements such as decision-making, communication strategies, and training programs, and non-human factors that impact the performance of port calls and the effectiveness of stakeholder collaboration. However, it is important to acknowledge the scope limitations of this research, which primarily focuses on container ships due to their predictable planning, incentives for reducing waiting times, and potential for optimizing port calls.
Container and cruise ships, following predetermined liner routes, differ significantly in planning lead times—cruise ships announce arrivals up to two years in advance, while container vessels provide relatively shorter lead times, typically several weeks. Bulk carriers and liquid bulkers present additional complexities, with infrequent port calls and economic considerations taking precedence over optimization efforts. Given these variations, the decision to primarily explore container ships is driven by their predictable planning, existing incentives for reducing waiting times, and the potential for effective port call optimization.

The ultimate objective of this study is to make a noteworthy contribution to the existing body of research by formulating a conceptual model that visualizes the connection between port structures and port call optimization. Through semi-structured interviews and an in-depth review of relevant literature, this research will unravel the intricate web of relationships among various stakeholders involved in the port call and the multifaceted factors that influence a port's readiness to embrace port call optimization. The findings of this research can serve as a valuable resource for policymakers, port authorities, and potentially nautical service providers, offering concrete insights into identifying specific weaknesses in the port call process and providing recommendations for improvements that ultimately culminate in the optimization of port calls.
Furthermore, by addressing the nuanced collaborative dynamics among stakeholders within the port (call) environment, this thesis aims to contribute actionable insights and guidelines especially for port

authorities, service providers and other stakeholders involved in the port call process, fostering a more holistic approach to collaborative PCO implementation and enhancing the efficiency of port operations.

1.3. Research Questions

Building on the recognition of the need for a more holistic understanding of collaborative dynamics within the port environment, the following main research question was formulated.

> *What are the pre-conditions of adoption of collaborative port call optimization in different ports?*

To answer this main research question, four sub-research questions were determined that need to be answered prior to the main question.

1. What is the potential relationship between port structures and collaborative PCO?
    - Understanding the potential relevance and relationships between port structures and collaborative PCO is directly related to assessing the impact of collaboration in different port contexts, which is the core of the main research question.
    - The research question is addressed through a theoretical analysis of the literature, and then interviews with industry experts are conducted to further illuminate the answer.
2. What are collaborative PCO measures that could enhance the port call?
    - Identifying collaboration measures is a fundamental step in exploring how collaboration can enhance or support PCO. This sub-question addresses the mechanisms through which collaboration can affect PCO.
    - Similar to Sub-RQ 2 this question is answered using literature research and semi-structured interviews.
3. What is the impact of collaborative PCO measures in different ports?
    - Examining the impact of collaboration measures on stakeholders in the PCO process directly addresses the ”effects” aspect of the main research question.
    - This question is answered by analyzing the data collected during the semi-structured interviews and additional expert talks.
4. Based on the determined collaborative PCO measures, what pre-conditions can be conceptionally identified?
    - This sub-research question ties the findings from the previous sub-questions together by synthesizing the measures and their impacts and then drawing conclusions about how these insights can inform the broader port structure. It connects the research findings to practical implications, which is essential for addressing the main research question regarding the effects of collaboration.
    - chapter 5 provides the answer to this research question

Utilizing a blend of qualitative data collection methods, such as semi-structured interviews and literature analysis, the study employs an additional approach—conceptual modeling—to offer a comprehensive and insightful exploration. Once all sub-research questions have been addressed, the study can seamlessly transition to answering the main research question. This process aims to contribute valuable insights into the conditions necessary for effective collaborative port call optimization, thereby bridging the identified research gap on this specific topic.

1.4. Problem Statement

In essence, collaboration among stakeholders transforms the port call process from a series of isolated activities into a cohesive, interconnected endeavor. By leveraging shared information, resources, and expertise, stakeholders can navigate the complexities of modern shipping practices more effectively, ultimately leading to enhanced operational sustainability, resilience, and competitiveness [59]. Another major factor that has an impact on the efficiency of the performance and efficiency of the port is the

environment the port is in - namely the way the port is governed and structured. However, because of the different port settings, incentives of the stakeholders

However, because of the lack of standardized communication protocols and limited data sharing infrastructure among other factors, enabling collaboration among stakeholders is challenging. Additionally, due to the conflicts of interests between the involved parties and the varying levels of digital maturity among key players, the seamless adoption of collaborative port call optimization is further hindered. Therefore, this study aims to first identify the potential relationships between port structures and collaborative PCO and the related challenges hindering collaboration among stakeholders in PCO. Subsequently, the study defines the main prerequisites and pre-conditions that can facilitate the collaboration among different stakeholders, paving the way for a more effective and harmonized adoption of collaborative port call optimization.

1.5. Thesis Organization

Table 1.2: Thesis Outline

Chapter	Outline	Research Question
Chapter 1	Introduction	-
Chapter 2	Literature Review and Analysis	SRQ1, SRQ2
Chapter 3	Methodology	-
Chapter 4	Results of the Interview Analysis	SRQ1, SRQ2, SRQ3
Chapter 5	Conceptual Framework	SRQ4, Main RQ
Chapter 6	Discussion and Limitations	-
Chapter 7	Conclusions and future work	-

Table 1.2 shows the structure of the thesis, including where the research questions are addressed. Chapter 1 introduces the research and outlines its purpose. Chapter 2 reviews existing literature on port call optimization and discusses the port call process and its stakeholders. Chapter 3 explains the research methodology, data collection, and analysis. The actual results and of the literature and interview analysis are provided in Chapter 4. Chapter 5 develops and validates a conceptual model based on data analysis and literature. The thesis concludes with Chapters 6 and 7.

2
Literature Review

The following chapter includes an introduction into the existing literature on port call optimization. The different sections provide an overview of the available literature on port call optimization as a whole (section 2.1), the various stakeholders involved in the port call and relevant for port call optimization (section 2.2), the various collaboration measures of port call optimization (section 2.3), the different port governance structures and their impact (section 2.4) and other available adoption frameworks (section 2.5). Finally, the chapter is concluded with an overview of the key findings (section 2.6).
After conducting a thorough literature research, a number of relevant sources could be identified. A total of 35 sources have been considered for this review. A detailed overview of the methods used in each source as well as the main focus of the source can be found in Table B.1 and Table B.2. For the review, various research engines and truncation's were used to gather a broad list of available literature. Furthermore, several search iterations were conducted as synonymous definitions were only identified later on.

2.1. Port Call Optimization

Port call optimization focuses on implementing procedures and technical infrastructure at a specific port to enable efficient and timely ship turnaround through standardized, secure, and real-time communication [86]. This optimization aims to enhance the effectiveness and efficiency of port operations, minimizing waiting times, reducing costs, and improving overall performance. It seeks to promote the concept of JIT-arrival, decrease idle waiting time for both ships and ports, and improve the predictability of ship arrival and departure times. As a result, it enhances the planning process, optimizes capacity and resource utilization, and so on. The literature review emphasizes the significance of two approaches in port call optimization: JIT-vessel-arrival and collaborative port call optimization.

The JIT-arrival approach focuses on optimizing the route and vessel speed to achieve timely arrivals at ports, reducing waiting times for vessels. Alvarez, Longva, and Engebrethsen [6] emphasize the benefits of vessel berthing and speed optimization policies for achieving JIT-arrival. However, Lind et al. [51] highlight that the first-come-first-serve approach followed in many ports undermines the effectiveness of JIT-arrival. This results in inefficiencies, increased pollution, greenhouse gas emissions, and inadequate resource planning within the port. Several other studies have examined the concept of JIT-arrival and its benefits, emphasizing the need for improved coordination and communication among stakeholders to achieve efficient port call processes [59, 56, 70].

In their study, Nikghadam et al. [59] examine the significance of cooperation among vessel service providers and emphasize the advantages of information sharing, coordination, and communication in improving port call performance. Schoneveld [81] explore the identification of key performance attributes that drive innovations in port call management, providing insights into the factors that contribute to optimized port operations. Merkel, Kalantari, and Mubder [56] focus on estimating the feasible potential for CO2 emissions savings through port call optimization, considering factors such as just-in-time arrival and virtual arrival. Poulsen and Sampson [70] discuss the abatement of shipping greenhouse gas emissions through port call optimization, considering energy efficiency, speed reduction, and waiting time.

However, it is important to consider the limitations of the studies and the methodology employed to derive the results. The analysis conducted by Nikghadam et al. [59] does not take into account the

heterogeneity in service demands and the specialization of tugboats and pilots. Discovering the importance of these factors can help improve the visibility of pre-conditions needed for the adoption of port call optimization. Schoneveld [81] includes the practical benefits of cooperation and the benefits of implementing port call innovations in their research by identifying performance attributes for the potential innovations. However, the results are based on a small sample size. Also, Schoneveld [81] identifies different port and governance structures and acknowledges that the structures impact the willingness to collaborate and introduce innovations, however these findings stay on a very general level leaving room for further research. Schoneveld [81] also does not go into detail about how port call optimization can be achieved if this port governance structure is not present in a port.

In addition to the above sources, several other studies contribute to the understanding of port call optimization. Lind et al. [48] highlight the importance of decision support systems and port collaborative decision-making in improving port visits and optimizing port operations. Further research by Lind et al. [49] discuss the implementation of time slot management for port calls to improve a congested maritime supply chain. One of the major challenges of Lind et al. [49] research is that they assume full agreement among stakeholders as well as a full willingness to cooperate. Furthermore, they propose PortCDM as a port call innovation, however, they leave out the different settings in the different ports caused by varying port governance structures which can lead to different motives and incentives of stakeholders, ultimately leading to a reduced willingness to cooperate and potential success of the PCO implementation. Besides Lind et al. [49], other authors like Braidotti et al. [16], Venturini et al. [97], and Suvadarshini and Dandapat [86] suggest PCO through port innovations. However, none of the authors cover the impact of different port governance structures on the implementation of the innovation.

Port Call Optimization can either include an optimization of the voyage efficiency, hence the processes before the actual arrival of the vessel at the harbour, or the processes inside the port such as getting the vessel from the harbor entrance to the berth and the departure of the vessel from the berth. A lot of research has been conducted on the ”pre-port-processes” suggesting various innovations and methods for improvement. However, as vessel arrival is dependent on numerous external factors such as weather conditions or other disruptions [26], it is important to have flexible in-port processes and resource planning to ensure a smooth vessel handling on a short notice. These in-port processes can also be referred to as nautical services.

Understanding and optimizing the nautical chain and nautical services within a port is crucial for efficient port operations. The nautical chain represents the sequence of activities and interactions involved in the movement of vessels within a port. It encompasses the steps of vessel arrival, admission, and departure from the port.

Research on the nautical chain and nautical services is relatively limited compared to studies on voyage efficiency. Most research focuses on one or two stakeholders, such as terminals, [36, 31] pilots or tugboats Kaljouw, Bouman, and Azadeh [40] and Fransen and Davydenko [29]. However, a few studies have considered multiple parties involved in the nautical chain, including Nikghadam et al. [60], Gan [30] and Schoneveld [81].

In an empirical study, Fransen and Davydenko [29] employ an agent-based model simulation to analyze the behavior and interactions of various agents, such as tugboats and pilots, within the nautical services context. The simulation evaluates different operational scenarios, assesses their impacts on performance, efficiency, and safety, and provides insights for potential improvements. This study highlights the importance of considering various actors in the nautical chain for effective port call optimization and their impact on the port performance.

Another study by Gan [30] focuses on simulating the nautical chain of operations in the Port of Rotterdam also using agent-based modeling. Through this approach, they identify bottlenecks in the nautical chain, evaluate operational strategies, and propose enhancements to improve efficiency and safety. The study demonstrates the benefits of simulation models in understanding the dynamics of the nautical chain and identifying areas for improvement in port call optimization.

These studies on the nautical chain and nautical services complement each other by utilizing simulation techniques to simulate and analyze complex port systems. They demonstrate the effectiveness of agent-based modeling in identifying inefficiencies, evaluating alternative scenarios, and proposing improvements for port call optimization. However, it is important to note that the simulations may have limitations in terms of generalizability to other ports with different characteristics and management structures, as a key characteristic of simulations is that they are case specific.

Other studies have also contributed valuable insights to the field of port call optimization. Nikghadam et al. [60] investigate the importance of information sharing to mitigate delays in ports, specifically focusing on the case of the Port of Rotterdam. The study highlights the role of inter-organizational relationships and collaboration in improving port call performance. However, the generalizability of the findings to other ports needs to be further explored. Furthermore, the author assumes that resources are evenly distributed, leaving out the potential competitive or commercial incentives of the individual stakeholders.

Schoneveld [81] adopts the Best-Worst-Method (BWM) approach, a multi-criteria decision tool, to identify the importance of performance attributes for innovations in port call management across multiple ports. While the study provides valuable insights, further research is needed to investigate other evaluation methods or frameworks and assess the importance of performance attributes in different port call contexts.

The findings from these studies on port call optimization complement each other by emphasizing the importance of collaboration, information sharing, and coordination among stakeholders. They highlight the need for integrated approaches that consider multiple stakeholders, operational factors, and the impact on sustainability and greenhouse gas emissions. The studies shed light on different aspects of the nautical chain and nautical services, providing insights into improving port call performance and efficiency. However, further research is needed to address the limitations of these studies, such as generalizability to different port contexts and exploring other evaluation methods or frameworks. This thesis aims to close the research gaps by investigating the changes within the nautical chain based on the underlying port governance structure. Furthermore, the goal is to identify the different stakeholder incentives as well as their importance and other conditions that are relevant for the adoption of port call optimization.

2.2. Stakeholder Relationships and Collaboration

Within a port, multiple stakeholders play distinct roles and possess varying interests. These stakeholders have different responsibilities and objectives. The provided Table 2.1 offers a comprehensive overview of the diverse stakeholders associated with the harbor.
Due to the involvement of numerous stakeholders in various port processes, it is crucial to distinguish between those directly involved in the port call and those indirectly involved. It needs to be noted that many more stakeholders can be involved in the port call or more generalized in a harbor. However, due to the limited scope of the arriving (container) vessels into the harbor, stakeholders that are not directly or indirectly involved will not be considered.

Table 2.1: Stakeholders involved in the port call process per sector [64]

Commercial (Traffic and Operations)	**Institutional** (Policy and regulations)	**Community** (Public relations)
Directly Involved		
- Terminals - Pilotage - Tug companies - Mooring service providers - Vessel Traffic Services (VTS) - Ship Master / Captain - Carriers/ Shipping companies	- Port Authority - Customs	
Indirectly Involved		
- Logistics facilities, industrial sites, commercial real estate,... - Road, rail, and barge operators - Inland ports - other port service providers (bunkering, water companies)	- Governmental institutions - Trade and investment agencies - Financial institutions - Municipal governments - Regional and provincial governments - Non-governmental organizations - Environmental organizations etc.	- Labor unions - Special interest groups - port-related economic activities (trade, manufacturing, tourism) - Foundations - Tourists and Passengers

Knowing who the main stakeholders are, and what their responsibilities and incentives include is relevant to improve the port call [85]. In literature, many different stakeholders relevant for the port are mentioned (Nikghadam et al. [60], Schoneveld [81], and Andersen et al. [7] to name a few).

Based on how relevant the literature identified the different stakeholders for the port call, the following power-interest grid is presented in Figure 2.1. Mendelow's Stakeholder Power-Interest Grid is a tool used in stakeholder analysis to categorize stakeholders based on their level of power and their level of interest in a project or organization. The grid helps in determining the most appropriate strategies for engaging with different stakeholder groups. Mendelow's grid consists of four quadrants: Keep Satisfied, Keep Informed, Monitor/Minimum Effort, and Key Players [71]:

- **Low Priority (Low Power, Low Interest):** Stakeholders with the lowest ability to impact the port call, and are also not interested in doing so. There is less of a need to inform or engage with this group but it should be monitored in case circumstances change.
- **Keep Informed (Low Power, High Interest):** Stakeholders with relatively low power but high interest in the port call or certain organizations involved in the port call. They should be kept informed about the port call and any changes that may affect them.
- **Keep Satisfied (High Power, Low Interest):** Stakeholders with high power but relatively low interest in the port call or organizations involved in the port call. They should be kept satisfied by addressing their concerns proactively and engaging them when necessary.
- **Key Players (High Power, High Interest):** Stakeholders with significant influence over the port call and a high level of interest. They should be engaged closely, collaborated with, and their expectations actively managed.

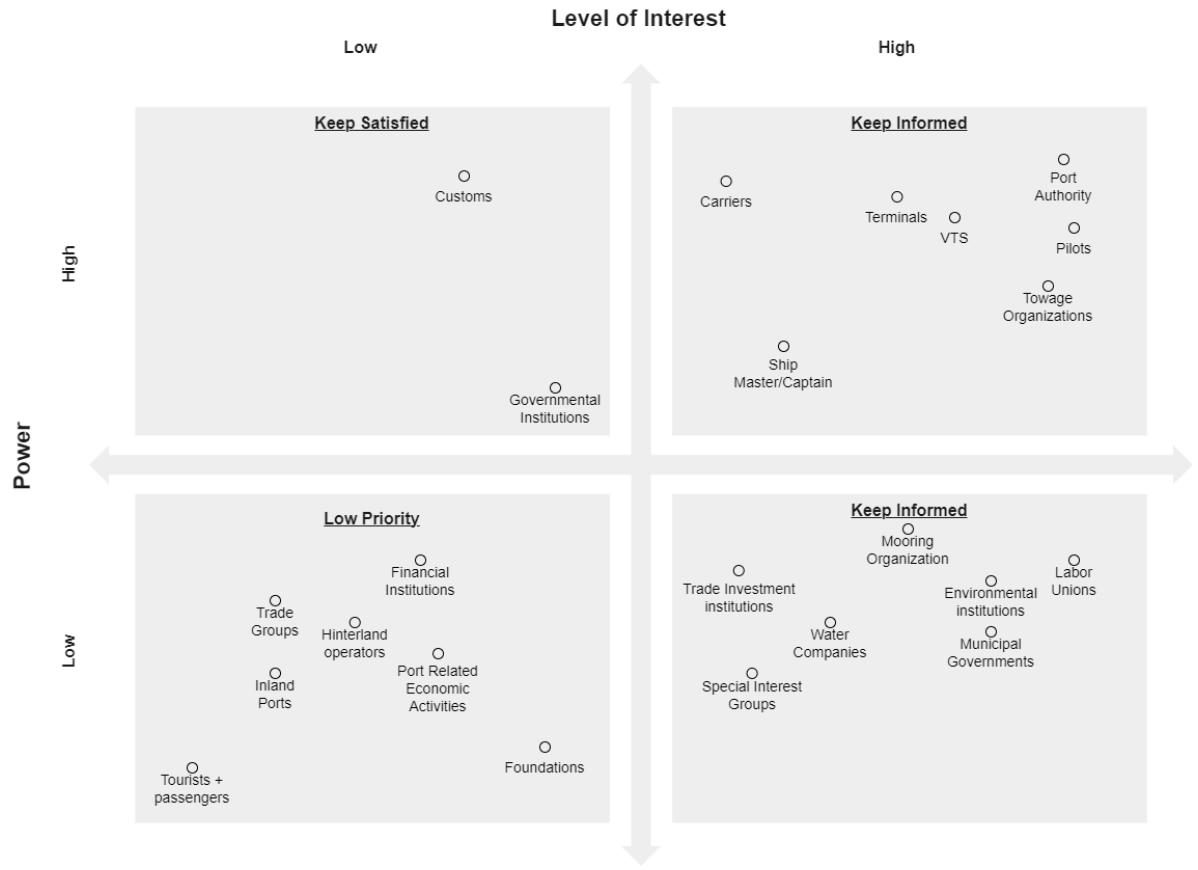


Figure 2.1: Medelow's Stakeholder Power Grid

The power order is based on the level of control and influence each stakeholder has over port operations and decision-making. The Port Authority has the highest authority, followed by terminals and carriers, which play significant roles in cargo handling and transportation. Pilot Organizations, Towage Organizations, the Vessel Traffic Center and the Captain of the vessel all have more specific roles that support the overall functioning of the port. Due to their high level of interest and power, they are all considered key stakeholders. A characteristic all these stakeholders have in common is that they are all directly involved in the port call process. The mooring organizations are also directly involved in the port call. However, as their activity only starts at the end of the port call of arriving vessels, their power in the port call is considered lower but their level of interest high, leaving them in the "Keep informed" quadrant. Due to the limited scope of this thesis, only the key stakeholders of the port call process are considered. A detailed overview of the responsibilities and incentives of these players can be found in Appendix A.

Terminals are of high significance as they provide the space where the vessel will be loaded and unloaded. If no berthing space can be provided, the vessel cannot enter the port and the port call can therefore not take place. Besides the provision of space the terminal also provides provisional storage space and is the connector between sea and hinterland transport [104].
Besides the terminal, the tugboat operators and pilots determine the success of the port call. Without tugs, a vessel is often not strong enough to maneuver themselves to the berth. Furthermore, the tug masters are familiar with the local infrastructure and the local waters, often providing guidance to pilots when maneuvering the ship. A functioning towage service is therefore crucial[27]. In a private port structure the importance of one individual towage provider might be less relevant due to competition with other (towage) service providers. But in a port where only one operator is available, their cooperation should always be ensured. Pilots board the vessel once she has entered the harbor. Even though the captain remains responsible of the ship, the pilot takes over the navigation of the vessel until the berth [27]. As the captain optimally does not interfere in the navigation of the vessel during

the port call, they will not further be considered for this research. The captain is assumed to align with the decisions made that affect them. Besides the captain, also the VTS is not considered as an individual key stakeholder. For this research the stakeholders are not particularly considered on an intra-organizational level as this would exceed the complexity of this thesis. As the VTS are most often a department or sub-division of the Port Authority, responsible for the planning processes but not an individual organization, they will not further be considered individually.

Effective stakeholder relationships and collaboration are essential for optimizing port operations and achieving port call efficiency. The literature highlights the importance of collaboration, information sharing, and communication among various stakeholders involved in port operations.

Nikghadam et al. [60] explores the role of information sharing and inter-organizational relationships in port operations. The study emphasizes the significance of efficient information exchange among port stakeholders to enhance operational efficiency and reduce waiting times. It highlights the importance of trust and collaboration among organizations involved in port operations. However, the assumption of evenly distributed resources in their analysis may not reflect the competitive or commercial incentives of individual stakeholders. Future research could investigate the impact of different incentives on stakeholder collaboration.

In their paper, Lind et al. [51] address the critical issue of port call optimization in the maritime sector. Their study highlights the challenges faced by this industry, which operates within a self-organizing ecosystem, resulting in sub-optimal operations. The primary findings of this research indicate that the maritime sector struggles to optimize its operations due to the disjointed and independent actions of its stakeholders. The conventional ”first come - first served” practice in ports leads to inefficiencies, externalities like pollution, and greenhouse gas emissions. The paper emphasizes that global harmonization and digitization are essential for enhancing sector efficiency. The authors argue for the establishment of a global governance structure for PortCDM and collaboration among stakeholders in the sea transport value chain as a means to promote international harmonization and improved port operations. They also stress the importance of a cooperative ecosystem environment and increased data sharing to support data analytics for optimization. However, a limitation of the paper is the absence of an in-depth exploration of potential barriers and challenges related to data sharing and collaboration among maritime sector stakeholders, which could provide valuable insights for achieving increased efficiency in the field.

Poulsen and Sampson [70] delve into the potential for greenhouse gas (GHG) emissions reduction through the optimization of port call procedures in international shipping. Their qualitative research approach, involving non-participant ethnographic observations and semi-structured interviews, provides valuable insights into this topic. The main findings of their study reveal that reducing turn-around-time in ports can be a key strategy for GHG abatement, but it is a complex challenge due to the involvement of multiple stakeholders and the limited room for maneuver for crews and shipping companies. The research documents why waiting times occur during port calls and highlights the impact of various port stakeholders on crew stress and delays. The authors recommend that the International Maritime Organization (IMO) facilitate the sharing of real-time traffic data among port stakeholders to improve efficiency. However, the paper also has limitations. It calls for further investigation into successful cases of swift turn-around in ports and the identification of best practices in coordination among stakeholders, infrastructure investment, and traffic management. Additionally, comparative studies across different transport modes are suggested to identify transferable lessons and practices, and the behavior of port officials and measures to minimize delays caused by them should also be examined to address remaining gaps in the research.

These studies on stakeholder relationships and collaboration complement each other by emphasizing the importance of collaboration, information sharing, and communication in port call optimization. They highlight the potential benefits of stakeholder engagement and efficient information exchange in achieving efficient decision-making and synchronized port operations. However, more research is needed to further investigate the dynamics of stakeholder relationships, incentives for collaboration, and the integration of social and sustainability aspects into collaborative port call optimization. Fur-

thermore, it is important to address the challenges that arise due to the self-organizing nature of the maritime sector, where multiple independent players may act in their self-interest. Lind et al. [48] highlight the risk of suboptimization when individual stakeholders prioritize their own operations without considering the overall optimization of the port ecosystem. To ensure optimal port operations, it is necessary to reach an agreement where some actors may occasionally have less than optimal operations for the greater good of the port ecosystem. Future research could explore strategies for promoting collaborative decision-making and coordination among stakeholders to achieve overall port optimization.

In conclusion, stakeholder relationships and collaboration play a crucial role in optimizing port operations and achieving port call efficiency. The literature emphasizes the significance of collaboration, information sharing, and communication among various stakeholders involved in port operations. However, research on the different stakeholder relations in different port structures and their influence and impact on port call optimization is lacking. Besides this research gap which this thesis partially aims to close, future research should further investigate the dynamics of stakeholder relationships, incentives for collaboration, and the integration of social and sustainability aspects into collaborative port call optimization. Additionally, strategies for promoting collaborative decision-making and coordination among stakeholders can contribute to overall port optimization and efficiency.

2.3. Collaboration Measures to Improve the Port Call

When discussing the enhancement of specific processes, the discourse frequently extends to the subject of collaboration (for reference, see Lind et al. [51]). Nevertheless, prior to delving into the specifics of collaborative measures at an individual level, it is imperative to establish a comprehensive definition of collaboration, both in a general sense and within the framework of port calls and nautical services.

General definition of Collaboration:
According to [19] collaboration can be defined as follows: *Collaboration is a particularly intensive form of cooperation in which social units (teams, companies, etc.) use resources in joint work and decision-making processes in order to achieve a result that cannot be easily achieved through division of labor.*

Collaboration in the maritime context:
For the maritime context, this definition can be adapted slightly:
Collaboration in the maritime context refers to a cooperative working practice where individuals join forces with a shared objective, aiming to attain mutual advantages within the framework of port call processes (involving arriving vessels). This collaborative approach empowers individuals to effectively combine their efforts and expertise, working collectively to fulfill a distinct and shared maritime objective. Collaborative measures vary from simple improved communication throughout the process and between the different parties over complex applications to jointly plan resources. Besides the ”simple” measures, collaboration also often thrives on innovation, a crucial path to sustained competitiveness, well-established in business studies. In maritime logistics, innovation’s growing significance fuels success. However, the maritime business realm largely overlooks innovation’s role, aside from naval architecture discussions. Despite rising innovation endeavors, the mechanisms for successful innovation remain unclear. As a result, initiatives tend to lack coordination, direction, management, and expected outcomes. To enhance innovation processes, a deeper understanding of motivational factors along maritime supply chains is vital. This holds particularly true for ocean carriers, terminal operators, port managers, and hinterland transport operators [2].

In literature, many different kinds of collaboration measures can be found. In general, these measures vary from big implementations such as specifically designed port collaboration applications to small and ”simple” adjustments such as customer satisfaction (The port conducts regular surveys to gather feedback from customers, addressing their concerns and suggestions to enhance collaboration and improve overall satisfaction during the port call). The differentiation between measures that require radical vs. ones that require only incremental change is important to understand what pre-conditions are required for the adoption of this specific measure. To the researchers knowledge, literature on this differentiation is missing. Only Nikghadam et al. [59] dives into some general pre-conditions that are needed for information-sharing, another PCO measure.

PortCDM:
One measure that has been discussed extensively is the one of PortCDM, short for Port Collaborative Decision Making [51, 50]. PortCDM aims to enhance efficiency and coordination in port operations. It is used to facilitate real-time data sharing and communication among various stakeholders in a port, enabling better planning, reducing delays, and improving overall port performance. Limitations of the literature discussing this measure include practical implementation challenges and strategies for achieving interoperability and standardization [50].

Port Community Systems:
Literature reveals that in a majority of ports, a Port Community System (PCS) is actively employed with the primary aim of streamlining administrative processes and reducing paperwork associated with port calls. The PCS can be described as a centralized hub for port information and data, serving to integrate and disseminate data from various stakeholders as outlined in Tijan et al. [88]. The specific functions of the PCS can vary between ports and are contingent on the willingness of stakeholders to both utilize and share data.Keceli [42] categorizes these functions into three main categories: port management, customs-related operations, and serving as an online platform for electronic commerce among port users.

2.4. Port (Governance) Structures

Besides the stakeholder relations, the port governance also plays a pivotal role in shaping the rules, authority, and management strategies that underpin port operations, benefiting both society and the economy [62]. This multifaceted concept extends its reach across both public and private sectors, although its application varies depending on the predominant interests at stake [88]. The dynamic landscape of port governance is profoundly influenced by global trade trends, transportation dynamics, technological advancements, and the integration of information and communication technology (ICT) and e-governance mechanisms [88].

Governments and decision-makers lead port governance structures, driven by distinct policy objectives such as optimizing traffic capacity or maximizing profitability [62]. Many countries faced difficulties in establishing suitable port administrations to adapt to the changing environment following a series of port reforms in the 1980s and 1990s. The World Bank offered a port reform toolkit in 2003, which served as a guide for policymakers by presenting best practices and conducting an extensive literature review [65]. In this toolkit, the World Bank categorized ports into four categories - service, tool, landlord, or private ports [88]. Each type entails varying degrees of public and private involvement, ownership, and control over port assets and operations, demonstrating the adaptability of port governance structures in response to market dynamics, institutional reforms, environmental regulations, and societal pressures [88]. Figure 2.2 provides an overview of the different port governance structures and their influencing factors and responsibilities.

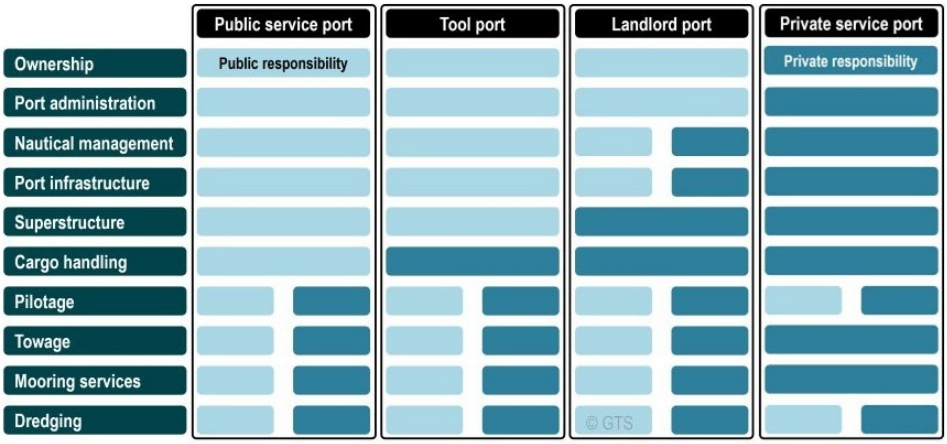


Figure 2.2: Overview Port Governance Structures [73]

Public port:
A public port, in the traditional sense, places the ownership, management, and infrastructure provision squarely in the hands of the public sector (as can be seen in Figure 2.2 shown by the ”public responsibity”-assignment). This means that all nautical services, including towage and pilotage, can be managed either by the government or a private organization. To help simplify the differentiation between public and other ports, for the purposes of this research, it is assumed that public ports are exclusively operated by a governmental organization. The Port of Chittagong in Bangladesh serves as a prime example of a public port.

Tool Port:
A tool port closely resembles a public port, but with a distinction: cargo handling at the terminal is often outsourced to private companies. When looking at Figure 2.2 the only distinction between the two ports is the private responsibility of cargo handling in a tool port vs. the public responsibility in the public port. These terminals are frequently leased out to carriers, who then oversee their operations. In this research, it is presumed that the resources for nautical services, such as tugs, are owned by the government, while the actual operations can be leased to private companies through concession agreements or tender processes. The Port of Kokkola in Finland is a notable example of a tool port.

Landlord Port:
Landlord ports represent the most prevalent governance structure, where public ownership exists, but the provision of nautical services can be either public or private. Figure 2.2 shows that more private responsibility can be assigned in different areas relevant for the port compared to the two previously described ports. In landlord ports, typically, pilots are public servants, while other services are entrusted to private organizations, which often own the requisite resources. The Port of Rotterdam in the Netherlands exemplifies the concept of a landlord port.

Private Ports:
Private ports, in contrast, are characterized by the complete ownership and operation of infrastructure by private organizations. Such ports are also managed privately, and services can be provided either by the port's owning organization or by external service providers. In Figure 2.2 all responsibility is assigned to the private sector with the exceptions of pilotage and dredging which can still remain public. For the purposes of this research, a private port is defined as one that is entirely owned and operated by private entities. This adoption of the original definition helps to distinguish easier between a private and a landlord port. The Port of London in England stands as an example of a private port.

In summary, these distinct governance structures in the world of ports provide a spectrum of public and private involvement, shaping how these essential gateways function and who oversees their operations.

Over time, the landlord port model emerged as the most prevalent form of public administration because it effectively balances the public interest of society with the private interests of shareholders. Fully private ports, on the other hand, primarily serve the interests of shareholders and gain limited adoption worldwide [92]. Public service ports and tool ports occupy the opposite end of the spectrum. In the landlord port model, the port operator owns the land and maintains the port infrastructure, while the private operators are responsible for constructing the superstructure. Port labor is predominantly private, although some ports receive (partial) public funding for training. The port operator obtains the land through concession agreements and assumes full responsibility for terminal operations and the associated economic risks [92]. The distinctions among these models stem from various factors, including the nature of service providers (whether they are public, private, or a combination thereof), their scope (whether they operate locally, regionally, or globally), the ownership of infrastructure, superstructure, and assets, as well as the conditions of dock labor and management, as noted in the source by Andersen et al. [7].

Extensive research in the field of port economics has examined how port governance models can undergo significant transformations due to comprehensive port reform and devolution initiatives (see Cullinane, Yap, and Lam [20] and Zhang et al. [102] among others). After investigating the different

port structures and trying to categorize the major ports into the four provided categories, it becomes clear that a categorization is not always as simple or obvious as thought. Examples of Ports that do not fit in any of the traditional categories include the Port of Haifa whose infrastructure is owned by a private company, namely Adani Ports SEZ but the port is still operated and managed by a governmental organization - the Israel Port Authority. Often the responsibility division between the port authority and the operating services are not as transparent. Literature suggests a reform of the conventional governance structures into more fitting models. However, to this date, this reform has not taken place. Several sources including Notteboom* and Rodrigue [64] have come up with new governance structures. However, these structures often only identify the objectives and responsibilities of Port Authorities, and ignoring the other operating service providers involved in the port (call). Therefore, revised definitions of the port structures is still lacking.

For this research it has been discovered that not only the port governance structure but also the port governance itself as well as the port structures are influential for the successful adoption of port call optimization. While conducting literature research it has been discovered that the definitions of the different terms are fluid and not uniformly used. Figure 2.3 provides an overview of the definitions used in this research.

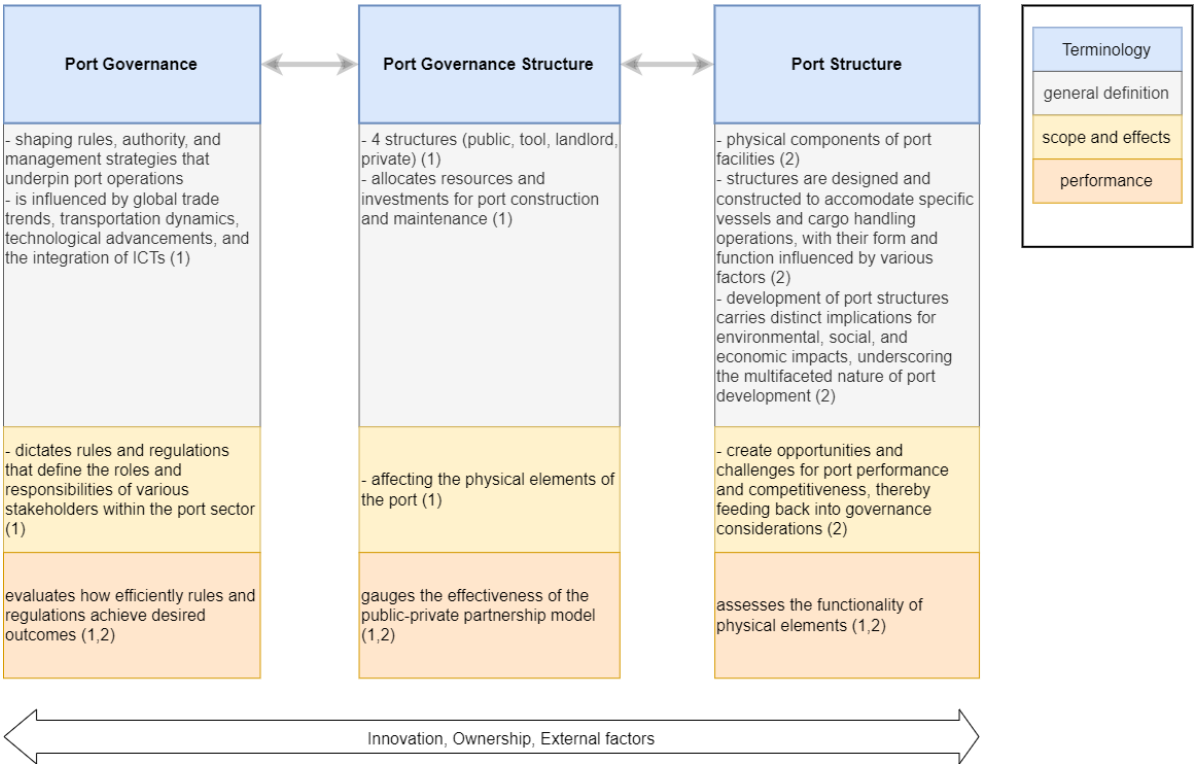


Figure 2.3: Port governance vs. Port Governance Structures vs. Port Structures (Source: (1 - [88]; 2- [62])

Port governance, port governance structures, and port structures are interrelated and mutually influential concepts, demonstrating their profound impact on port development and management. Port governance dictates the rules and regulations that define the roles and responsibilities of various stakeholders within the port sector [88]. Port governance structures allocate resources and investments for port construction and maintenance, thereby affecting the physical elements of a port [88]. Port structures, in turn, create opportunities and challenges for port performance and competitiveness, thereby feeding back into governance considerations [62].

Furthermore, these three concepts share common themes related to performance, ownership, external factors, and innovations. Performance is a critical measure of all three dimensions. Port governance performance evaluates how effectively rules and regulations achieve desired outcomes. Port governance structure performance gauges the effectiveness of the public-private partnership model. Port

structure performance assesses the functionality of physical elements [88, 62]. Ownership patterns vary across different types of port governance structures, ranging from full public ownership in public service ports to full private ownership in private service ports, with various combinations in between [88]. External factors, such as global trade trends, environmental regulations, and natural disasters, can significantly impact port governance, governance structures, and port structures, necessitating adaptation and resilience [88, 62]. In summary, the intricate interplay between port governance, governance structures, and port structures underscores the complexity of managing and developing port facilities in an ever-evolving global landscape. These concepts collectively shape the dynamics of the maritime industry, facilitating adaptability and innovation in response to emerging challenges and opportunities.

The literature on port governance structures identifies different models that influence port operations, decision-making processes, and port development strategies. Understanding these governance structures is crucial for effective port management and optimization.
Among other things, the suggested literature focuses on port governance and its implications for port call optimization. Cullinane, Yap, and Lam [20] provide insights into the governance structures of port authorities in the Port of Singapore and their influence on port operations. They acknowledge that conventional governance models cannot capture the current changes the port is undergoing. However, the study focuses only on a single port, making it difficult to generalize the results to other harbours. Furthermore, the study is only conducted on a general level, leaving out other relevant stakeholders involved in the port call including for example pilot or towage organizations. Similar to Cullinane, Yap, and Lam [20], Song and Lee [84] discuss port governance and points out the changes happening in the port governance structures globally. Instead of only focusing on literature analysis, they use comparative analysis to investigate the role of governance mechanisms in port performance improvement in Korean Ports. Again, the research lacks the investigation of the individual stakeholders included in the port call, only focusing on the general port structure. Brooks and Pallis [18] examines the governance structure of ports and its impact on port efficiency and competitiveness. They highlight that standardization is missing and that user perspectives and satisfaction are among the most neglected issues in current port performance measurement practices. This suggests a challenge in incorporating user feedback and ensuring user-centric port governance.

The reviewed sources provide insights into the characteristics and implications of different governance structures. For example, the Port of Singapore is recognized for its successful governance structure, which serves as a reference for other ports [20]. Concession agreements are identified as essential tools for port governance, and their role and effectiveness have been discussed [61]. The studies shed light on the actors involved in port governance and the aspects that are governed [102]. Comparative analyses reveal differences and similarities in port governance practices between different countries and regions, emphasizing the need for tailored governance approaches [33, 47]. The evolving nature of port governance, including adaptation processes, smart port development strategies, and internationalization of port management practices, has also been explored [33, 47].

These findings on port governance structures complement each other by providing insights into the role of governance in shaping port operations, decision-making processes, and port performance. They highlight the importance of tailored governance approaches, concession agreements, and adaptation processes in port management. However, there are research gaps that need to be addressed. More in-depth analyses of specific governance models are required, along with an examination of the implications of emerging technologies on governance structures and the changing objectives of stakeholders based on the existing governance structure. Additionally, integrating sustainability and social aspects into port governance frameworks should be a focus of future research. This thesis aims to close one of the research gaps by investigating the different port structures and the roles and objectives of stakeholders within those different structures by conducting semi-structured interviews with representatives of the different ports.

2.5. Application of Conceptual Models on Adoption

The goal of this thesis is to identify the pre-conditions of adoption of collaborative Port Call Optimization in different ports. There are several conceptual models and frameworks that have been developed to explain and predict the adoption of technology in different settings. The goal or potential of the models in the maritime context is to explain the factors and challenges related to PCO.

Conceptual Models for PCO:
Conceptual modeling is a prominent and recurrent method frequently encountered in the literature addressing the intricacies of PCO. This approach is instrumental in unveiling the underlying factors and prerequisites that govern the successful adoption and implementation of PCO within the maritime domain. A fundamental underpinning of this methodology is the development of conceptual models, which serve as tools for representing complex systems and phenomena. These models use concepts and ideas to describe the characteristics, behavior, and interrelationships of PCO.

An investigation into the relevant literature reveals notable contributions. Brooks and Pallis [18] offers a comprehensive port evaluation framework that intertwines critical port performance components. The study highlights the challenge in establishing uniform performance measurement practices across ports, asserting that strategic intent, governance models, and performance measurement activities often lack consistent patterns. This limitation underscores the need for standardized and cohesive performance measurement practices. Additionally, the study underscores the often-neglected perspective of users and their levels of satisfaction in the realm of port performance measurement, implying a challenge in engendering user-centric port governance.

Nikghadam, Rezaei, and Tavasszy [58] ventures into the partnership model by Lambert, applying it to the unique context of the Port of Rotterdam. The study delves into the relationship potentials and information-sharing prospects among diverse port actors, ultimately unveiling significant variations in the potential for inter-organizational relationships. This leads to a disparity in the potential for information sharing among these stakeholders.

Notably, the concept of PortCDM, as introduced by Lind et al. [52] and elaborated upon in subsequent works (see Lind et al. [51, 48, 50] for further reference), emerges as a pivotal conceptual model. PortCDM acts as a compass, guiding the description of processes and elements involved in enhancing the coordination and synchronization of multifaceted activities and stakeholders inherent to a port call. It seeks to mitigate the challenges associated with port calls, such as excessive waiting times, elevated costs, increased emissions, and uncertainties. In doing so, PortCDM aims to amplify the efficiency, safety, and dependability of maritime transport. This model pivots on the principles of Collaborative Decision Making, which have previously demonstrated their effectiveness in the aviation sector. PortCDM successfully adapts the collaborative decision making concept to the maritime domain and offers a set of operational and technical guidelines. These guidelines empower port call actors to pursue more predictable operations based on a shared understanding of timings and plans, involving diverse entities like ship operators, terminal operators, pilots, tugs, agents, authorities, and hinterland transporters.

Conceptual Models for Adoption:
While these contributions discuss various factors relevant to PCO, they stop short of providing a comprehensive overview of the pre-conditions for PCO adoption. To address this gap, a literature research on available adoption frameworks was conducted. The most fitting frameworks include the Technology Acceptance Model (TAM) by Davis et al. [22], the Theory of Planned Behavior (TPB) crafted by Ajzen [5], the Unified Theory of Acceptance and Use of Technology (UTAUT) proposed by Venkatesh, Thong, and Xu [96], and the Technology-Organization-Environment (TOE) framework introduced by Tornatzky, Fleischer, and Chakrabarti [89].

TAM: The TAM is a model that aims to explain and predict the acceptance of information systems and technology by individuals. It explores the factors that influence users' attitudes and intentions regarding technology adoption. The model primarily focuses on two key factors—perceived ease of use and perceived usefulness. It helps answer questions related to how user perceptions of technology's ease

of use and utility affect their acceptance and intention to use it [22]. Limitations of the model include that it simplifies the complex nature of technology adoption by primarily concentrating on individual-level factors. It may not fully account for external influences, organizational dynamics, or the broader context of technology adoption.

TPB: The TPB is a model designed to understand and predict human behavior, particularly in the context of decision-making and intention formation. It extends the Theory of Reasoned Action by adding the element of perceived behavioral control. TPB considers three key factors: attitude (user's evaluation of the behavior), subjective norm (social pressures related to the behavior), and perceived behavioral control (the ease or difficulty of performing the behavior). It can be used to answer questions about how these elements influence individuals' intentions and behavior, particularly in the context of technology adoption [5]. Limitations of this model are that it TPB assumes a rational decision-making process, which may not always reflect real-world complexities. It may not fully account for external influences, and it might be less suitable for predicting behaviors influenced by habit or external constraints.

UTAUT: The UTAUT is a comprehensive model that integrates multiple earlier models, including TAM and TPB, to predict and explain technology acceptance and usage. It takes into account a wider range of factors and contexts. The model identifies four key constructs—performance expectancy, effort expectancy, social influence, and facilitating conditions. It also considers four moderators—gender, age, experience, and voluntariness. UTAUT can be applied to answer questions about how these factors and moderators influence user intentions and behaviors in diverse technology adoption scenarios [96]. While more comprehensive than earlier models, UTAUT may still not encompass all possible influences on technology adoption. It assumes that these factors and moderators have a universal impact, which might not hold in all contexts.

TOE: Lastly, the TOE-framework was discovered. The TOE framework focuses on technology adoption in organizational settings and aims to provide a holistic view of the factors influencing the adoption decision. It takes into account technological, organizational, and environmental factors. TOE encompasses technological factors (characteristics and availability of technology), organizational factors (organizational size, structure, culture, and resources), and environmental factors (external pressures and opportunities). It can help answer questions about how these multifaceted factors affect the adoption of technology within organizations [11]. While comprehensive, TOE does not offer specific guidance on which factors are most influential in a given context. It may require tailoring to the specific circumstances of each technology adoption case. Furthermore, the framework works on an organizational level, not accounting for situations where technology needs to be adopted by multiple organizations. However, the TOE-framework covers a wide range of factors relevant for the port call and was therefore chosen as the base for this research.

It is noteworthy that none of these frameworks were originally developed with PCO in mind as they were developed before PCO became a prominent topic discussed in literature. Moreover, while the TOE framework has found applications in the adoption of Blockchain technology within the maritime sector (including Li, Zhou, and Yuen [46] and Shin et al. [82]), no known instances exist where these or any other adoption frameworks have been employed to identify the pre-conditions essential for the effective adoption of PCO within the maritime industry. An adoption framework generalizable for any collaborative PCO measure in any port is still missing. This reflects a significant gap in the current body of research that warrants further exploration and investigation. This thesis aims to close the research gap by providing such a framework which provides the pre-conditions for adoption of collaborative PCO in different ports.

2.6. Key Insights from the Literature Review

The literature review provides critical insights into the field of PCO in the maritime industry. The focus of PCO on achieving JIT-vessel arrivals and promoting collaboration among stakeholders stands out as a key objective, aiming to minimize waiting times, reduce costs, and enhance the predictability of ship arrivals and departures [86].

Collaboration, information sharing, and coordination among stakeholders have emerged as central drivers for optimizing port call processes. The significance of integrating collaboration and information sharing into PCO is underscored, particularly in the context of considering the nautical chain and in-port processes [59, 81]. Although research on the nautical chain and nautical services lags behind pre-port processes, valuable insights from simulations and agent-based modeling highlight the complexity of port call optimization [29, 30]. Still, the generalizability of these findings to various port contexts remains a topic requiring further exploration.

The literature also emphasizes the critical roles played by various stakeholders in port operations, including terminals, tugboat operators, pilots, the Port Authority, customs, and carriers [85]. Effective collaboration, information sharing, and communication among these stakeholders are deemed essential for achieving port call efficiency [51, 70]. While stakeholder engagement's importance is highlighted [51], further research is needed to delve into stakeholder relationships within different port structures and their influence on port call optimization. Investigating the dynamics of stakeholder relationships, incentives for collaboration, and the integration of social and sustainability aspects into collaborative PCO emerge as significant research gaps.

The review recognizes the profound impact of port governance structures on port operations. Ranging from fully public ports to entirely private ones, with intermediary models like tool ports and landlord ports, the adaptability of governance structures is evident, driven by market dynamics, institutional reforms, and societal pressures. The need for tailored governance approaches and the pivotal role of concession agreements in port management are highlighted [88]. However, research gaps exist, necessitating in-depth analyses of specific governance models, exploring the implications of emerging technologies on governance structures, and integrating sustainability and social aspects into port governance frameworks.

In the context of PCO adoption, the literature review identifies various conceptual models and frameworks for technology adoption in different contexts (see Brooks and Pallis [18], Nikghadam, Rezaei, and Tavasszy [58], Lind et al. [52], Davis et al. [22], Ajzen [5], Venkatesh, Thong, and Xu [96], and Baker [11]). These models provide different perspectives on the factors influencing adoption, user behavior, and organizational adoption processes. The research gap lies in the absence of a generalizable adoption framework specifically designed for collaborative PCO measures in various port settings. This research aims to address this gap by providing a comprehensive adoption framework tailored to the unique challenges and opportunities presented by collaborative PCO in different ports.

The literature review has laid a strong foundation for the research, underscoring the importance of collaboration, stakeholder engagement, governance structures, and the need for a specific adoption framework to drive effective PCO implementation. The subsequent chapters of this thesis will delve into the identified research gaps, explore the impact of port governance structures, and provide a comprehensive adoption framework for collaborative PCO in diverse port settings.

3 Methodology

For this research, an empirical and exploratory study attempts to capture the pre-conditions that influence the successful adoption of collaborative PCO measures in different ports. The research method is qualitative. The methodology can be summarized in seven main steps, namely:

1. *Literature Analysis to identify challenges and pre-conditions relevant for the PC*
2. *Interview Design and Data Collection*
3. *Interview Analysis Method*
4. *Interview Analysis*
5. *Prototype Framework*
6. *Feedback Discussions with academia and industry experts*
7. *Finalization of TOEI-Framework*

Step 1 considers the analysis of relevant references of collaborative PCO implementation and related studies in the literature, with the aim of determining a set of conditions that facilitate the implementation of collaborative PCO measures in different ports. This step allows to already determine a set of pre-conditions used in the later step of framework development as well as to help guide the interview questions which validate those factors in Step 2 and 4. The second step considers the design of an interview guide for semi-structured interviews based on Kallio et al. [41] followed by the conduction of the actual interviews with industry experts of different ports. This data collection step allows to identify the current situation of the different ports and to validate the list of facilitating conditions defined by the literature review. Additionally, it helps to identify new challenges the ports are facing and to determine more conditions relevant for the adoption of collaborative PCO. Furthermore, two experts (one from the Erasmus Center of Urban, Planning and Transport Economics Rotterdam, Netherlands and one from the Smart Ports Alliance) in the field were also interviewed to validate the facilitating conditions preliminary defined. Additional conditions were determined and summarized according to their occurrence during the interviews with stakeholders of the participating ports.
Step 3 consists of the description of the interview analysis methods and coding process used. In this case, various interview analysis methods including word frequency analysis, concept, concept map, sentiment and content and frequency distribution analysis were considered. To draw further conclusions, the interviewed ports were categorized into port size, port governance structure and port location to be able to identify relationships between those factors and other influences experienced during the port call process. In the following step 4, the previously described interview methods are applied and the results analyzed. The goal of this step was to identify the current situation within the ports regarding the port call and port call planning as well as the identification of faced challenges and opinion on PCO. Furthermore, this process step also aims to identify relationships between different processes and identify the importance of different stakeholders or process steps during the port call and planning phase which would ultimately lead to the formulation of more relevant pre-conditions. In step 5, a conceptual framework is developed, visualizing the pre-conditions identified in literature and interviews. The goal is to show all the factors relevant for the adoption of collaborative PCO. Step 6 includes an iteration process of feedback discussions with academia and industry experts and the modification of the prototype framework leading to step 7, the finalization of the final framework, namely the TOEI Framework. The implementation of the first three steps is further described in the following subsections, while chapter 4 presents the results obtained in step 4 and chapter 5 the development and validation of the conceptual framework (Step 5 to 7).

3.1. Literature Analysis

In addition to the interview analysis, a comprehensive literature review was conducted, which is a central component of the study. This literature review included a careful examination of existing scientific papers, focusing on the conditions and factors associated with PCO. The analysis aimed to identify the positive and negative influences of these factors and, equally important, their relevance in the context of PCO adoption. A detailed discussion of the relevant literature and its main findings as well as potential limitations can be found in chapter 2. The following Table 3.1 is a summary of the most relevant factors important for collaborative Port Call Optimization identified in literature. During the conceptual model validation more literature useful for the identification of especially organizational and interorganizational factors was recommended. As the literature review chapter was already finalized before receiving that feedback some of the literature referred to in the following Table 3.1 is not represented in the literature review. Some general definitions of the conditions are already provided. A more in-depth description is provided in section 5.2 and the following subsections.

Table 3.1: Pre-Conditions identified in literature

Pre-Condition	Definition	Source
Technology Readiness	State of preparedness and suitability of the solutions that are required for the adoption	[34], [100], [60]
Data Sharing Standards	Established protocols and formats for exchanging information and data among different stakeholders	[34], [60], [70]
Multi-User	Ability of the technology to be adopted and integrated by multiple users	[95]
Financial Resources	Availability of sufficient funds and capital within the organizations involved in the process to support the adoption and ongoing implementation of the technology	[95]
PCO necessity awareness	Knowledge and understanding of the technology among the various stakeholders involved in the process	[72], [60]
Perceived benefits	Anticipated advantages and positive outcomes that stakeholders expect to achieve from the adoption of the technology	[95], [23], [60]
Organization/Firm size	Size of the organization or firm involved in the (port) operations	[34]
Stakeholder pressure	Force exerted by various entities, such as government agencies, shipping companies, and local communities, prompting ports to optimize operations to meet diverse expectations	[34], [100]
Legal Structure / Regulatory Environment	Encompasses the framework of laws and regulations governing the (port) operations, including ownership models, property rights, and the legal rights and responsibilities of (port) operators and stakeholders	[95], [23]
Perceived Industry Pressure	Influence of market trends and industry standards shaping the motivation for port call optimization initiatives	[72], [100]
Management Risk Position	Extent of organizational, management, and financial risk acceptable by top management	[34], [60]
Level of Competition	Degree of rivalry among ports or terminal operators vying for the same business, influencing port call optimization strategies	[23], [29]

Continued on next page

Table 3.1 – *Continued from previous page*

Pre-Condition	Definition	Source
Collaboration Agreements	Formal contracts or arrangements established among different stakeholders and organizations involved in the (port) operations	[95], [23], [60], [59]
Information Sharing Protocols	Rules, methods, and standards for exchanging data and information among stakeholders	[95], [60]
Cultural Awareness	Recognition and understanding of the diverse cultural backgrounds, values, norms, and practices of the various stakeholders and organizations involved in the (port) operations	[23]
Incentive Structures	Frameworks of rewards and penalties that drive behavior and decision-making in port operations, impacting optimization efforts	[23], [60]
Top Management Support	Endorsement and active involvement of senior leadership in a port organization, crucial for the successful implementation of port call optimization strategies	[72], [34], [100], [60]

The specific assumptions that emerge from this comprehensive literature review are explained in detail in chapter 5. This systematic discussion of the literature provides a solid foundation for understanding the PCO landscape and ensures that the results of the study are based on sound knowledge.

3.2. Interview Design and Data Collection

Semi-structured interviews can be a valuable research method when investigating the pre-conditions of adoption of collaborative port call optimization in different ports. Unlike quantitative methods such as simulations or case studies, semi-structured interviews allow for a nuanced exploration of the subject matter. The complexity of port operations and the diverse array of stakeholders involved can make it difficult to capture the rich, context-specific insights that are crucial to understanding adoption pre-conditions. Through semi-structured interviews with key informants and stakeholders, researchers can gather in-depth information, ask about tacit knowledge, and adapt their questions in real time to follow up on promising leads. This flexibility is particularly important when studying a multifaceted and evolving phenomenon like PCO, which requires an understanding of the unique challenges and opportunities in each port. Semi-structured interviews are suited to reveal the social, political, and economic factors that underpin adoption decisions, offering a more holistic and comprehensive view of the research question compared to purely quantitative methods.

The followed step-by-step approach visualized in Figure 3.1 is based on the interview guide developed by Kallio et al. [41].

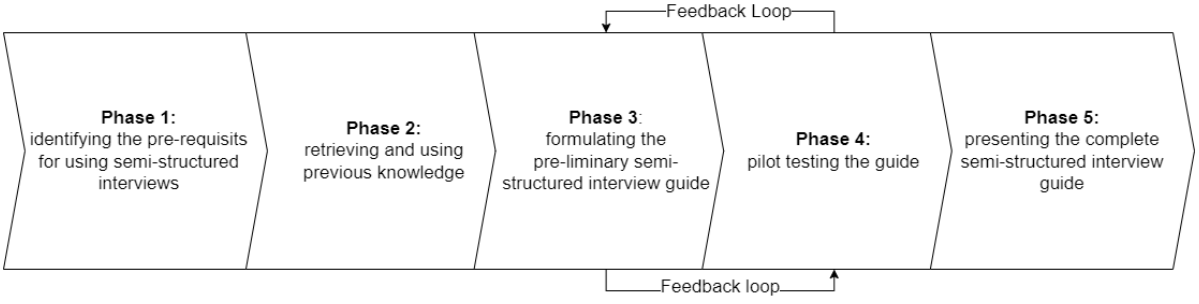


Figure 3.1: Step-by-step interview process

Semi-structured interviews are commonly utilized in case-research and conceptual modeling due to their ability to identify critical factors and collect information on a port's current practices related to port governance and port call efficiency enhancement. Moreover, these interviews are considered versatile

and flexible, making them popular in academic research [41, 17]. Notably, semi-structured interviews facilitate reciprocal interactions between interviewers and participants, allowing for spontaneous follow-up questions and the exploration of participants' verbal expressions [3, 17].

The interview questions are based on prior knowledge obtained during the literature review, emphasizing the significance of this preparatory step. After conducting a literature search, an interview guide is developed to outline the main topics of the study, offering a structured framework for both the interviewer and the participants, though it allows for flexibility and adaptation [3]. The interview objective is to delve into the port environment, exploring the importance of various factors such as the port's location and common practices and standards. The interview guide provides guidance on the topics to be covered [41].

Phase 1 and 2:
Kallio et al. [41] interview method guide comprises five phases, with the first two phases, aimed at evaluating the appropriateness of semi-structured interviews as a data collection method for the main research question (Phase 1) and gaining a comprehensive understanding of the subject (Phase 2), having been covered in previous chapters, primarily relying on extensive literature review.

Phase 3:
Following the literature review, a preliminary semi-structured interview (Phase 3) is formulated with the goal of creating a tool for interview data collection using logical and coherent structures based on previous knowledge. This phase also aims to get spontaneous, in-depth, and vivid responses from participants. In this research, an interview template consisting of four topic blocks and a total of 21 questions was developed, with several feedback iterations involving the daily supervisor and the company supervisor to ensure question relevance.

Phase 4:
During Phase 4, a pilot interview is conducted with the Port of Copenhagen/Malmö, revealing that the questions are too generic and do not lead to highly relevant results. Consequently, a return to Phase 3 is necessary to renew the interview guide. After a more thorough literature review, including the examination of interview questions used by other researchers (such as [81]), a new guide is created, comprising eight topic blocks and a total of 39 questions. The structure aims to initiate interviews with introductory and general questions, followed by follow-up questions to explore relevant topics in greater depth. The questions become more generic toward the end of the interview for a smoother conclusion. The complete interview guide can be found in Appendix C.
The final interview guide is subjected to further feedback and refinement through discussions with the daily and company supervisors, resulting in a final guide used for subsequent interviews. A pilot interview is conducted to ensure the desired outcomes.

Phase 5:
For the final stage (Phase 5 - Presenting the complete semi-structured interview guide), a total of 20 interviews are conducted with industry experts from ports around the world. A geographical overview of the interviewed ports can be seen in Figure 3.2 with a more detailed overview of the individual interviews in Table C.1 in Appendix C. The decision to conduct 20 interviews was guided by several factors including the diversity of the participants and richness of data among others. Furthermore, the sample size was deemed sufficient to achieve a level of data saturation where additional interviews were unlikely to yield substantially new insights. Throughout the following sections the aspect of tractability, traceability, and reproducibility will be discussed in more detail.
The interview structure is designed to initiate with light questions, encompassing introductory inquiries about the participant's role, the company they are associated with, and the company's position in the port call process. These aspects are addressed in both the "Introductory questions" section and the "General questions on the port call process" section. These questions are complemented by follow-up questions aimed at revealing additional stakeholders involved in the port call, revealing relationships and overarching structures among these stakeholders, and exploring the diverse processes relevant to the port call. The extent of follow-up questions depends on the level of detail provided by participants

Figure 3.2: Interviewed Ports

regarding the core topic.

Following this initial ”warming-up” phase, the interview delves into more in-depth questions concerning the current efforts of the organization or the harbor in terms of port call optimization. Participants are asked to identify any recurring issues or challenges they perceive. Once again, a set of primary topic questions is presented, followed by additional follow-up questions designed to steer the conversation in specific directions.

In addition to investigating port call optimization, the researcher also aimed to gather information on the prevailing port governance structures within various harbors. Consequently, a dedicated question block is allocated to this area of research.

As the interview nears its conclusion, the questions revert to a more general nature, offering a lighter conclusion to the discussion.

On average, the interviews lasted approximately 60 minutes and were recorded to facilitate the review of results. The interviews were primarily conducted in English, with two exceptions where the interviews were conducted in German. However, the researcher later translated these interviews to ensure comparability.

3.3. Interview Analysis Method

After conducting 20 semi-structured interviews, as well as having two expert talks, the interviews were transcribed, coded/labeled and a sorrow data analysis using the following interview-analysis methods was performed:

- Word Frequency
- Concept Analysis
- Sentiment Analysis
- Content and frequency distribution analysis

The chosen combination of word frequency analysis, concept analysis, sentiment analysis, and content with frequency distribution analysis in the analysis of semi-structured interviews aligns well with princi-

ples of tractability, traceability, and reproducibility in qualitative research. Following Yin [99]'s approach to case study research can provide a guiding framework for these aspects. Tractability is addressed by systematically applying these varied analyses, allowing for a structured and manageable approach to handling the complexity of qualitative data.

In order to be able to do the various analyses, the data needs to be prepared. Therefore, each interview recording is first transcribed and then anonymized. The functions of the interviewees as well as the organization they work in can be found in Table C.1.

The interview conduction phase lasted two months from the 14th of August, 2023 until the 5th of October, 2023. While the interviews were still going on, the already held interviews were transcribed. After transcribing all the interviews each transcription is summarized and sent to the interviewees for validation. In case of misunderstandings, the necessary changes were implemented in the interview summaries.

After the data preparation the actual data analysis starts. For that, the computer-assisted qualitative data analysis software *Atlas.ti* is used. Atlas.ti is a tool which offers the analysis of unstructured and non-numerical data. It offers organized, transparent and integrated analysis as well as both qualitative and quantitative analysis [9].

3.3.1. Word Frequency Analysis

Word frequency analysis is a quantitative textual analysis method employed to identify and quantify the occurrence of specific words or terms within a body of text. This technique offers several benefits, including the ability to gain insights into the most prevalent terms in a text, identify recurring themes or keywords, and discern patterns and trends within the data. To conduct word frequency analysis, the interview transcripts or interview summaries are collected and the most frequent words are identified using Atlas.ti. To get a better representation, high frequency, non-relevant words such as ”the”, ”and” and other words are excluded beforehand using a so-called ”Stop-list”.

3.3.2. Concept Analysis

Concept analysis is a systematic research method utilized to clarify and dissect the meaning and characteristics of abstract concepts or terms. This approach is commonly employed in fields such as nursing, psychology, and the social sciences to gain a deeper understanding of complex and multidimensional concepts [83]. Concept analysis aims to elucidate the defining attributes, consequences, and variations associated with a particular concept. The benefits of concept analysis include the ability to establish a common understanding of a concept within a specific context, leading to improved communication, research, and theory development. To conduct concept analysis, a structured process identifying key attributes and sub-concepts, and the development of a concept map or model that visually represents the relationships and dimensions of the concept is followed.

3.3.3. Sentiment Analysis

Sentiment analysis is a natural language processing technique used to assess and quantify the emotional tone, attitude, or subjective opinions expressed in text data. Sentiment analysis is a machine learning and NLP-based feature that sifts through documents, extrapolating tone, and language nuance to give the subtext within seconds. It finds extensive applications in various domains, including market research, social media monitoring, customer feedback analysis, and academic research. The primary goal of sentiment analysis is to classify the sentiment of a piece of text as positive, negative, or neutral, and sometimes into more fine-grained categories like joy, anger, or sadness [57]. By conducting sentiment analysis, valuable insights into public perception, customer satisfaction, or trends in user-generated content can be gained. The benefits of sentiment analysis include the ability to quickly process large volumes of text data, automate the evaluation of sentiment, and identify sentiments that might otherwise be challenging to capture manually.

3.3.4. Content and Frequency Distribution Analysis

Content and frequency distribution analysis is a research method used to explore and understand the distribution and patterns of content within a dataset, often based on concepts or words. It relies on the groundwork laid by word frequency and concept (map) analysis. Concept analysis helps in the identification and clarification of key terms and their interrelationships within the dataset, providing a conceptual framework for subsequent analysis [24]. Word frequency analysis assists in recognizing the prevalence of specific words, aiding in the initial understanding of the dataset's content. To enhance reproducibility, the data is categorized into themes, topics, or codes with the frequency of elements quantified, and sentiment considered. This method enables the researcher to gain deeper insights into both the discussed content and the associated sentiments. This comprehensive approach aids in revealing patterns, assessing the significance of particular ideas, and understanding the distribution of content within the dataset, ultimately contributing to a more holistic and contextually rich understanding of the subject under investigation.

3.3.5. Coding of the Interviews

In the process of coding the interview transcripts, several systematic steps were undertaken to ensure transparency and replicability. Initially, the recorded interviews were transcribed. This process step was done manually, as due to the companies policy it was not possible to download the recordings to insert them into professional software.
Subsequently, a comprehensive familiarization process involved multiple readings as well as the summarization of the transcripts to develop an overarching understanding of the content. The summaries were sent back to the interviewees for validation.

After conducting the word frequency analysis, the coding process began with an open coding approach, allowing for the identification and labeling of initial concepts and themes. This was executed using an inductive approach, avoiding preconceived categories to ensure a more organic emergence of codes. To streamline the coding process and enhance organization, the dedicated coding software Atlas.ti was employed. The application of codes to specific segments of text within the software's interface facilitated a more structured approach to the analysis.
The coding process was not a one-time affair; it was an iterative process characterized by ongoing refinement of the codes based on emerging patterns and insights. Saturation, a key consideration in qualitative research, was assessed by comparing newly coded data with existing codes to identify redundancy and repetition.

As the coding progressed, higher-level themes and patterns were identified through axial coding. This involved exploring connections between codes to derive more meaningful and nuanced interpretations of the data. This process step took place simultaneously to the concept and content and frequency distribution analysis as those methods include similar procedures. This allowed for the identification of first relationships and reoccurring topics.
Throughout the coding process, a detailed audit trail was maintained, including memos and memo groups, as well as developing coding groups, reflections, and decisions made at each stage. This served as a transparent record for future reference and verification. In the reporting phase, the final coded data, along with representative quotes, were incorporated into the results section of the thesis.
This careful and systematic approach to coding the interview transcripts not only ensures the transparency of the research process, but also provides a basis for the reproducibility of the study by future researchers.

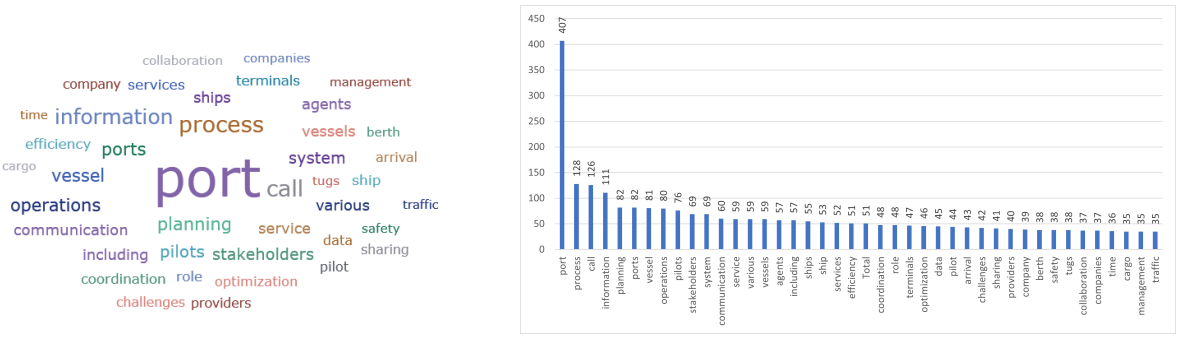
4

Results of the Interview Analysis

The following chapter includes the results and analysis of the various interview analysis methods described in the previous chapter 3 as well as the identification of relationships.
First results of the word frequency analysis are provided in section 4.1 followed by the Concept Analysis (section 4.2), Sentiment Analysis (section 4.3) and Content and Frequency Distribution analysis (section 4.4). Afterwards, the interviewed ports are divided into three major categories, namely Port size, Port Governance Structure and Port location and from that relationships are drawn with regard to identified company objectives and means to fulfill those objectives, challenges perceived during the port call and the port call planning phase, PCO, Centralization and the collaboration between the stakeholders involved in the port call in section 4.5.

4.1. Word Frequency Analysis

As already identified, Word frequency analysis is a quantitative textual analysis method employed to identify and quantify the occurrence of specific words or terms within a body of text. Figure 4.1 visualizes the most frequent words said in the interviews combined. The larger the word is presented, the more often the word was mentioned in the interviews. To limit the search and receive only context-relevant words, the search was limited to only nouns, adjectives and verbs.



(a) Word Cloud - Word Frequency Analysis

(b) Word Frequency - Bar Chart

Figure 4.1: Word Frequency Analysis

As can be seen is ”port” the word with the highest frequency (n=407), followed by ”process” (n=128) and ”call” (n=126). If all of the words belonging to port (e.g. ports) are added, the total count is n=489. For process (including ”processes”, ”processing” and ”processed”) the total count then becomes n=158 and for call (including also ”calls”, ”called” and ”calling”) the number increases to n=156. This result was expected as most of the questions asked circled around the port call process inside the port. Therefore, the interview respondents explained certain processes inside their responsible port, challenges they face during the port call process and other topics concerning the port call process. The interviewed ports with the highest frequency of the word ”port” or ”ports” are Port of Hadera with 52, Port of Barcelona with 39 and Port of Bremen/Bremerhaven with 38 occurrences. In total, those three ports count for 26% of the overall occurrence. For the word ”process/processes/processing”, the Port of Bremen/Bremerhaven with n=19 with the highest frequency, Port of Algeciras with n=15 with the second highest and Port of Haifa with n=14 with the third highest frequency make a total of 30% of the overall

word frequency. Lastly, for the word ”call/calls or calling”, again the Port of Bremen has the highest frequency with a total of 19, followed by the Port of Sohar with n=14 and finally the Port of Barcelona, Port of Gothenburg, Port of Hadera and Port of Haifa on the third place with n=12 with an overall total of 52%.

Word Frequency Analysis is a good tool to get a first understanding of the data. It allows for the interpretation of these findings to understand the core themes and trends in the data, enabling a more structured and data-driven approach to analysis and interpretation. Word frequency analysis is particularly useful in uncovering the key concepts or terms within a data set, aiding in summarizing, content exploration, and the identification of critical information in a text [80].

However, a limitation of the word frequency analysis conducted in atlas.ti is that often common topics can not be fully grasped as it is not possible to connect words. Furthermore, words (e.g. ship and ships) are not identified as the same word just singular or plural, making the significance of the results unreliable. A manual validation including the same word groups (singular, plural or verb) was performed to get more precise results. Additionally, a concept analysis was conducted.

4.2. Concept Analysis

Using the concept analysis tool provided by atlas.ti, the following word cloud presented in Figure 4.2 was extracted.

Figure 4.2: Concept Analyses

Only using the automatically generated concepts did not provide very valuable insights as the concepts are still very similar to the ones identified in the word frequency analysis. Combined words like ”information sharing” or ”stakeholder collaboration” could not be identified only using Atlas.ti. Therefore, a manual concept analysis resulting in concept maps for each performed interview was conducted. First, the central themes, main concepts, and significant insights gathered during the interviews were identified. Nodes were then used to represent the key elements and to connect them with red, green or black lines or arrows to illustrate relationships and dependencies. Red represents a negative relationship, green a positive one and black a neutral one. The concept maps and additional concept analysis serve as a valuable tool for synthesizing information, identifying patterns, and gaining a holistic understanding of the interview findings. Furthermore, they enhance conceptual clarity and promote a comprehensive grasp of the concept, which can be invaluable for theory building, research design, and practice development within various academic and professional domains. When the same concepts consistently appear across multiple interviews, it indicates that the data is reaching a point of saturation. This visual

representation provides a comprehensive overview of the interview findings, making it easier to recognize when new interviews yield diminishing returns or redundant information. Concept maps also thus serve as dynamic tools for not only organizing and understanding interview data but also for discerning patterns that signify saturation, ultimately aiding in the decision-making process about the need for further interviews or data collection methods.

After developing concept maps, the following reoccurring schemes and concepts could be identified:

- Challenge
- Stakeholder
- Improving efficiency
- Management
- Coordination
- Technology
- Information systems
- Information sharing
- Collaboration
- Port Authority
- Communication
- Port optimization
- Governmental
- Digitalization
- Private
- Port Call Optimization
- Sustainability
- Prioritization / Priority System
- Infrastructure
- Transparency
- Resource coordination
- Innovation
- Planning
- Incentive
- Ownership
- Regulations
- Safety
- External restrictions
- Centralization
- Providing services
- Resistance to change
- Competition
- Delays
- Collaboration with other ports

Some of the concepts are very general and match the word count and concept analysis (i.e. Challenge, Technology or Safety). However, looking at the different concepts almost all of the concepts fit into a few parent categories namely,

- Technology and Digitization i.e. innovation and Information systems
- Infrastructure and external influences i.e. weather, delays, safety and external restrictions
- Regulatory influences including ownership and management both on an organizational as well as a port level
- interorganizational relationships or arrangements including collaboration, (resource) coordination and competition

These main categories are important later on in the research when the conceptual model is designed (chapter 5).

4.3. Sentiment Analysis

Atlas.ti has an integrated feature which allows for sentiment analysis either per paragraph or per sentence. For this analysis, the sentiment per paragraph was chosen, as most paragraphs already only consisted of one sentence and covered one topic which was meant to be analyzed. The automatically generated sentiment codes were validated by going through each code and comparing if the assigned code matches what has been said. Several times, the sentiment had to be adjusted as the automatically generated code did not match the actual sentiment. Figure 4.3 shows the distribution of positive, negative and neutral sentiments per interview document.

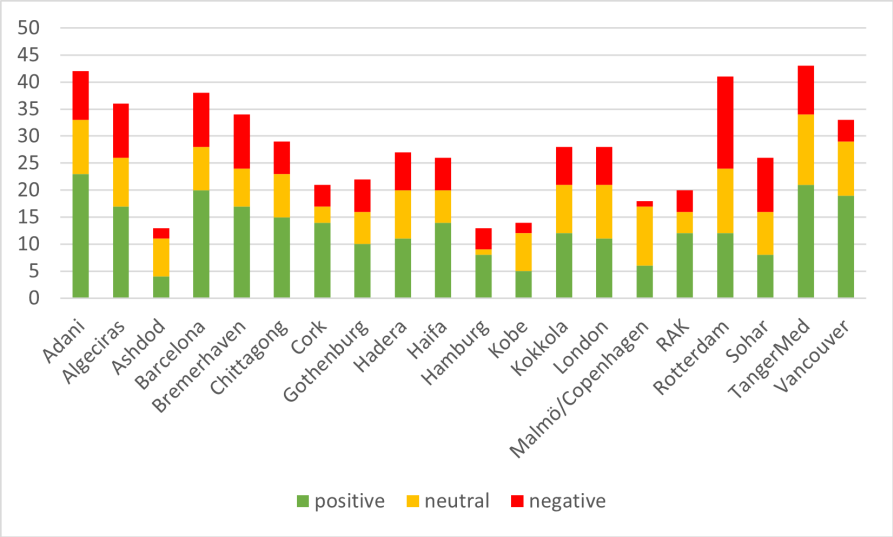


Figure 4.3: Sentiment Analysis - Distribution per interview

The deviating coding number can be explained by the fact that some interview respondents went into more detail about the individual topics and gave more detailed answers that went beyond general descriptions. Furthermore can also be assumed that the function of the interview partner plays a major role for the sentiment analysis. Interviewees who have experience in port call optimization (such as in Rotterdam or TangerMed among others) were more willing to talk about their experiences and possibly point out deficits or problems. Additionally these interviews had an overall longer duration as for example the interview with the port of Malmö/Copenhagen. The interview with the Port of Kobe was conducted partially via e-mail and partially in an in-person meeting. However, the language barrier and the answering of the questions via email led to the interview partners often giving short answers not leaving a lot of room for in-detail follow up questions.

Besides the general findings, the researcher decided not to use the sentiment analysis for further data analysis as it was perceived that this form of analysis is too much based on personal bias and will not result in statistically relevant or concrete results.

4.4. Content and Frequency Distribution Analysis

Content and frequency distribution analysis is a research method used to explore and understand the distribution and patterns of content within a dataset, often based on concepts or words. It relies on the groundwork laid by word frequency and concept (map) analysis. Concept analysis helps in the identification and clarification of key terms and their interrelationships within the dataset, providing a conceptual framework for subsequent analysis [24]. The following categories were identified based on the previous word frequency and concept analysis:

- Important attributes/features for the Port Call
- Perceived Challenges during the Port Call
- Definition of the Port Call Optimization
- Implementation phase of PCO Measures
- Objectives or goals of the interview respondents/their organization
- Type of platform implemented or planned for the Port call/PCO
- Key Stakeholders and Relationships between them
- Communication and Information sharing channels
- Centralization

Each main category led to the identification of several subcategories, enriching the analysis. For instance, perceived challenges during the port call were meticulously subdivided into 64 individual challenges faced by at least one of the interviewed ports. This detailed categorization not only enhances

transparency but also facilitates the reproduction of the analysis by other researchers, enabling a more granular understanding of the dataset. In section 4.5, the results of the more in-depth analysis are provided, shedding light into the different relations and giving overall more detailed results.

4.5. Results

In the following sub-sections, the different results from the data analysis are presented and analyzed. To be able to draw conclusions and find relationships, the various ports were assigned into the categories ”Port size”, ”Port Location” and ”Port Governance Structure”. Using those categories in the data analysis is a sensible approach because these factors play crucial roles in shaping the dynamics of ports and can significantly influence various aspects of port operations. ”Port Size” is a fundamental categorization as the scale of a port, measured by its capacity and throughput, often correlates with the complexity of its operations, infrastructure, and economic impact on the surrounding region. ”Port Location” is essential because the geographical positioning of a port affects accessibility, transportation networks, and potential economic partnerships, contributing to its overall significance. ”Port Governance Structure” is a critical category as it reflects the administrative and decision-making framework governing a port, influencing its efficiency, adaptability, and responsiveness to challenges. Considering ”Port Location” is crucial because the geographical positioning of a port significantly impacts accessibility, transportation networks, and potential economic partnerships, as well as potential economic advantages, thereby playing a pivotal role in shaping the overall significance of a port. By categorizing the various ports based on these factors, the analysis can uncover patterns, relationships, and trends, allowing for more nuanced and context-specific conclusions about the factors influencing port-related phenomena. The following Figure 4.4 shows the chapter division. First, the results of the categorization are provided, then an analysis based on those categories on the topics objectives and means, challenges, PCO, centralization and stakeholder relations is conducted, followed by the identification of relationships, unexpected findings of the interviews. Those categories were identified as main topics during the previously described content and frequency distribution analysis. The definition of requirements for the Port Call based on the interview findings which will lead to the development of the conceptual model in chapter 5.

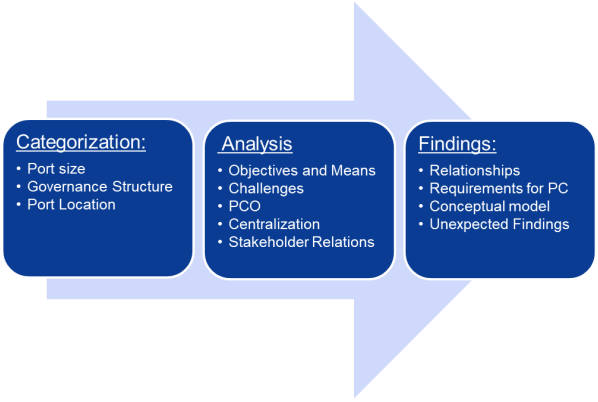


Figure 4.4: Process diagram

4.5.1. Results of Categorization

Port size:

The port size relates so the annual throughput of TEU (Twenty-Foot Equivalent Unit) in a harbor per year. The identification of the annual container volumes was done via online research beforehand. Adani Ports SEZ owns and operates multiple harbors in India and across the world. The Port of Mundra was selected as a representative Port for Adani Ports SEZ due to its status as a key asset in the company’s portfolio.

After identifying the annual TEU per harbor the ports are categorized into ”large”, ”medium” and ”small ports”. A large port is a port that has a volume higher than 4 million TEU per year. A medium sized port has an annual throughput of one to four million TEU and a small port has volumes lower than one

million TEU per year. Besides choosing this division to create an even distribution, the division of ports also allows for a meaningful classification of ports according to their scale of operations. This categorization enables a clear distinction between ports with high, moderate, and low throughput, providing a convenient framework for analysis. ”Large” ports like Rotterdam, Hamburg, and TangerMed, with annual throughputs exceeding 6 million TEUs, represent major hubs with substantial container traffic. ”Medium” ports such as Vancouver, Barcelona, and Chittagong fall within an intermediate range, while ”Small” ports like Gothenburg, Sohar, and RAK have comparatively lower throughput. This classification facilitates a comprehensive understanding of the diverse capacities and roles played by different ports in the global maritime landscape. Figure 4.5 and Table 4.1 show the distribution annual container volumes over the different interviewed ports.

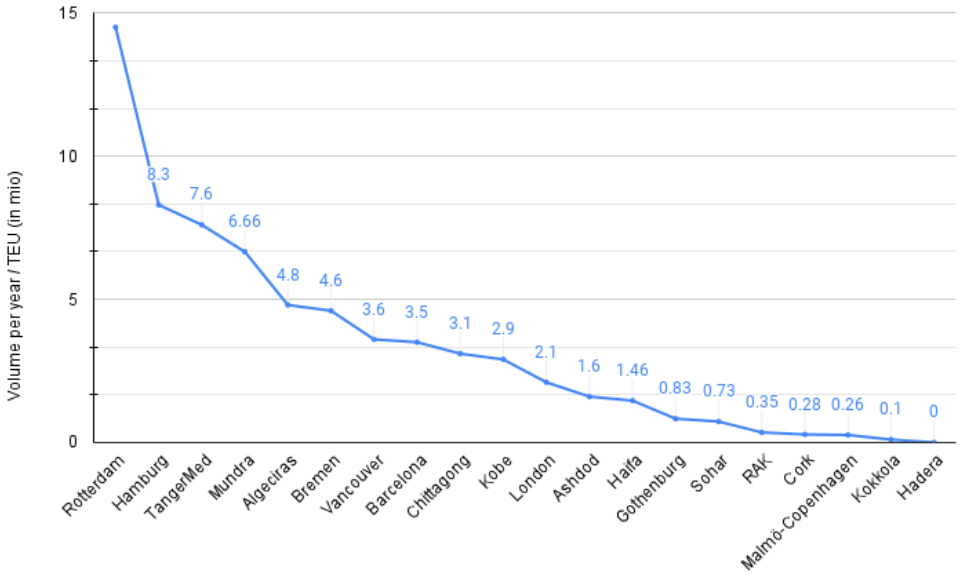


Figure 4.5: Annual throughput of TEU per year per harbor (in million)

When looking at the Figure 4.5, two things need to be mentioned:

1. The annual volume of TEU was chosen as the scope of this research is limited to container shipping. It needs to be noted that if the total number of movements or the overall total throughput of the ports would have been considered, the categorization into small, medium and large ports might look different.
2. The volumes of several ports do not represent the actual volume of the port. In this research, the Port of Hadera has an annual volume of zero which is due to the fact that they are an energy port that does not focus on container shipping. For the Port of Kokkola, a similar phenomenon exists. Some ports have lower volumes than shown here as their main business lies in other industries rather than container shipping. However, when limiting the scope to only container shipping, their importance in the industry is representing reality.

Figure 4.6 geographically visualizes the interviewed ports and gives an understanding of the dimensions of a larve vs. medium vs. small port.

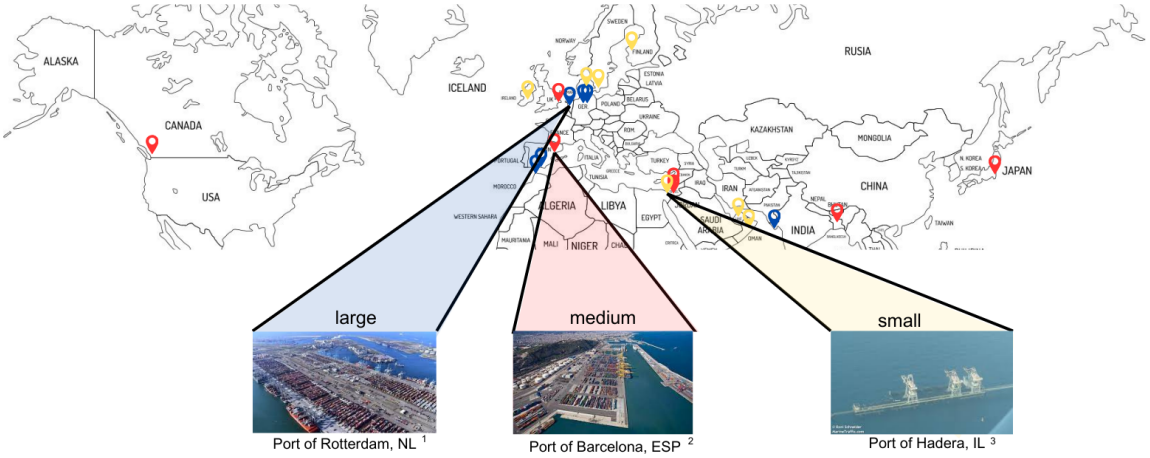


Figure 4.6: Port size of interviewed Ports - Map (image source: 1 - [77], 2 - [53], 3 - [54])

Table 4.1: Annual throughout of TEU per year per harbor (in million) including categorization

Port	Volume per year / TEU (in mio)	Category	Source
Rotterdam	14.5	Large	[45]
Hamburg	8.3	Large	[45]
TangerMed	7.6	Large	[45]
Mundra	6.66	Large	[45]
Algeciras	4.8	Large	[45]
Bremen	4.6	Large	[45]
Vancouver	3.6	Medium	[45]
Barcelona	3.5	Medium	[45]
Chittagong	3.1	Medium	[45]
Kobe	2.9	Medium	[45]
London	2.1	Medium	[45]
Ashdod	1.6	Medium	[87]
Haifa	1.46	Medium	[25]
Gothenburg	0.83	Small	[21]
Sohar	0.73	Small	[67]
RAK	0.35	Small	[69]
Cork	0.28	Small	[14]
Malmö-Copenhagen	0.26	Small	[66]
Kokkola	0.1	Small	[28]
Hadera	0	Small	[13]

Port Location:
The port location identifies if a port is an inland or a sea port. An inland port is a port on a navigable lake, river (fluvial port), or canal with access to a sea or ocean, which therefore allows a ship to sail from the ocean inland to the port to load or unload its cargo [78]. A seaport on the other hand is a port located on the shore of a sea or ocean [62]. Depending on the location of the port, the services and business inside the port can differ meaning that a sea port is more often associated with container or other types of cargo while inland ports often focus more on private usage [78]. However, this is not always the case. For this research, the distribution of sea vs. inland ports can be seen in Figure 4.7.

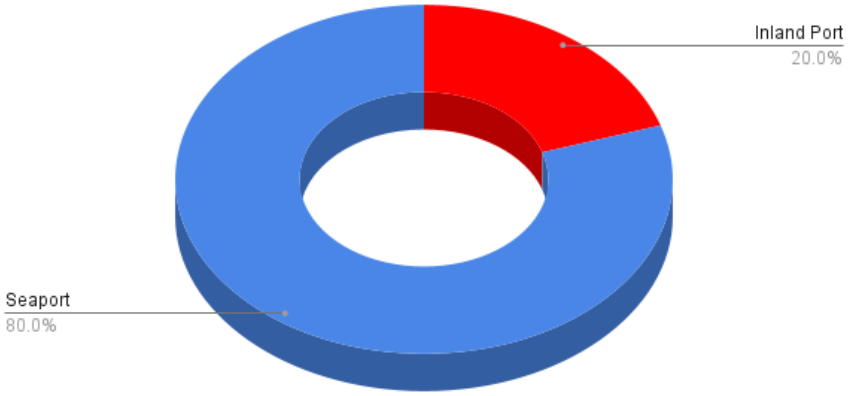


Figure 4.7: Distribution Sea vs. Inland Port (n=20)

Only four out of 20 ports were identified as inland ports including:

- Bremen/Bremerhaven - Germany
- Hamburg - Germany
- Kokkola - Finland
- Copenhagen/Malmö - Denmark/Sweden

Bremen/Bremerhaven and Hamburg in Germany and Kokkola in Finland are designated as inland ports despite their coastal location. This classification results from their strategic location on navigable inland waterways, which facilitate access to important trade routes. In the case of Bremen/Bremerhaven, the Weser serves as an important waterway that provides access from the North Sea to the inland. Hamburg is also considered an inland port due to its connection to the Elbe, which routes maritime traffic inland despite its direct access to the North Sea. Kokkola, located on the Gulf of Bothnia, is considered an inland port because it is located inland away from the more extensive waters of the Gulf and access is facilitated by regional waterways. The Port of Copenhagen/Malmö is classified as an inland port due to its distinctive position along the Øresund Strait, strategically connecting the North Sea to the Baltic Sea. Anchored by the Øresund Bridge, which integrates road and rail infrastructure, the port serves as a crucial link between Denmark and Sweden. Despite its inland location, the port plays a pivotal role in regional and international trade by leveraging its connectivity and multimodal transportation options. This designation underscores its unique geographical features and its significance as a central hub facilitating the efficient movement of goods between major waterways. The remaining 16 ports can be categorized as sea ports. Figure 4.8 provides a geographical distribution of the inland vs. sea ports.

For more equally distributed and therefore potentially more statistically relevant results, further research should be conducted including an equal amount of sea and inland ports. However, as external factors and other factors might be more or less relevant depending on the location of the port, the researcher decided to still include this categorization under reservation.

Figure 4.8: Port Location of interviewed Ports - Map

Port Governance Structure:
Even though it was identified in chapter 2 that the traditional categorization of ports into public, tool, landlord or private ports does not always reflect the reality it has been decided to keep using these definitions for the following research. The decision to retain these traditional governance structures is based on the need for consistency and comparability to ensure a standardized framework for analysis across the scope of the study. By retaining these familiar categories, the research aims to utilize the existing literature and enable meaningful comparisons, while acknowledging the limitations and nuances associated with these classifications.

Based on the infrastructure, ownership and operation handling identified in the different interviews, the ports could be categorized into the four different structures ”public port”, ”landlord port”, ”tool port” and ”private port”. A port that did not fit any of the structures is the Port of Haifa as they are owned by a private company but operated by the government. However, during the interview it was identified that even though the government does not own the infrastructure, they are still in charge of it. Therefore, it was decided to categorize the Port of Haifa as a public port. Several other ports including the Port of RAK and the Port of London did not fully match the conventional definitions. However, the infrastructure, ownership and operation handling mostly remained within the governance structure's definition which is why it has been decided to assign them to the categories public port (Port of RAK) and private port (Port of London). The following Figure 4.9 shows the distribution of the different categories. Table 4.2 shows how the assignment of the categories took place. Figure 4.10 visualizes the different ports geographically.

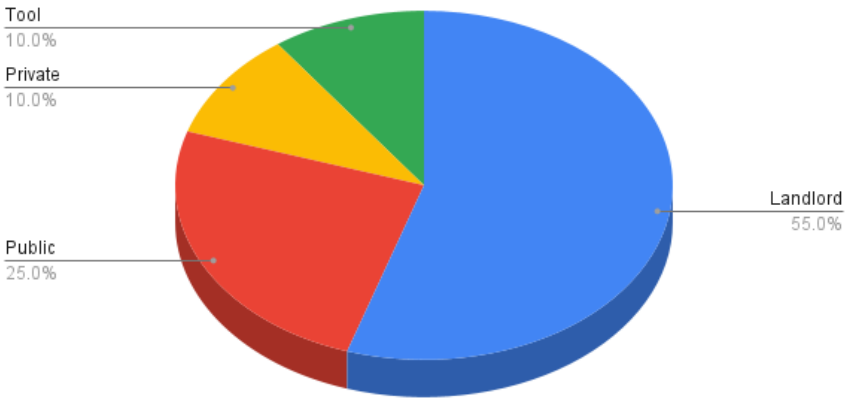


Figure 4.9: Port Governance Structures of interviewed ports

Figure 4.10: Port Governance Structure of Interviewed Ports - Map

Table 4.2: Port Governance Structures - Categorization

Port	Ownership	Infrastructure	Operations
Algeciras	governmental	private	Landlord
Barcelona	governmental	private	Landlord
Bremen	governmental	private	Landlord
Gothenburg	governmental	private	Landlord
Hamburg	governmental	private	Landlord
Kobe	governmental	private	Landlord
Malmö-Copenhagen	governmental	private	Landlord
Rotterdam	governmental	private	Landlord
Sohar	governmental	private	Landlord
TangerMed	governmental	private	Landlord
Vancouver	governmental	private	Landlord
London	private	private	Private
Mundra	private	private	Private
Ashdod	governmental	public	Public
Chittagong	governmental	public	Public
Hadera	governmental	public	Public
Haifa	private	public	Public
RAK	governmental	public	Public
Cork	governmental	public/private	Tool
Kokkola	governmental	public/private	Tool

Just like with the port location, it can be seen that the interviewed ports are not equally distributed over the four port governance categories. A majority of ports was identified as landlord ports. However this result verifies what has already been identified in literature. Namely, that the landlord port structure has become the most dominant port structure across the industry. For further research, it is recommended to consult more private, public and tool port operators to make sure the arguments made during the interviews are generalizable for the whole port governance structure and were not made specifically by that port.

4.5.2. Objectives and Means Relevant for the Port Call

After analyzing and coding the interview transcripts, the following company objectives or goals with regard to the port call could be identified (Figure 4.11 visualized by the blue bars). Additionally to the objectives, the means to achieve those objectives were identified as well (visualized in Figure 4.11 by the red bars). When asking the interview respondents about their objectives and means they were allowed to state multiple objectives and means which explains why the overall frequency count (y-axis) does not equal the total number of conducted interviews.

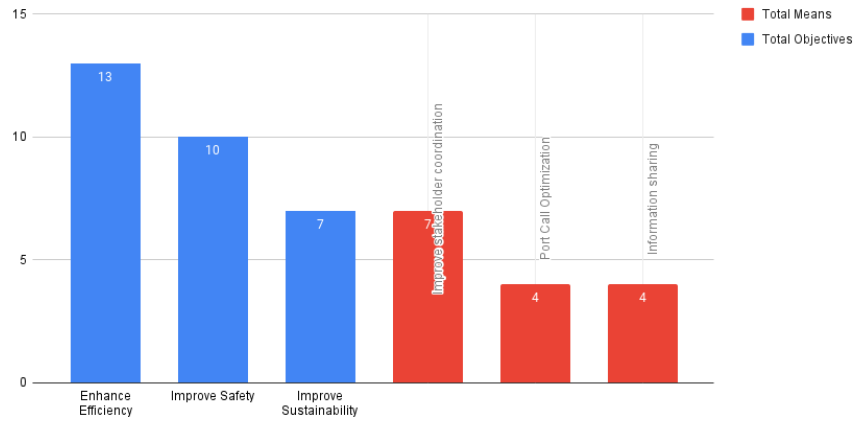


Figure 4.11: Objectives or goals of the interviewed companies within the port

Objectives:
The following three objectives mentioned by the interviewees with regard to the port call could be identified:

- Improving efficiency
- Improving safety
- Improving Sustainability

More general objectives like ”improving hinterland” or ”collaboration with other ports” were also mentioned by interviewees like the Port of Vancouver or the Port of London. However, as those objectives are not directly related to the immediate port call process and on a different operational level, it has been decided to not consider those objectives for this analysis.

Improving efficiency:
Anticipating a common focus on enhancing efficiency, as it emerges as the most frequently cited objective by 13 distinct ports, is reasonable. Prolonged and inefficient port calls can lead to escalated overall costs and potentially weaken a port’s competitive position, diminishing its appeal due to inefficient operational practices. Improving efficiency can be approached through various methods. According to the interviewee from the port of Algeciras, eliminating waste and idle time is key to enhancing efficiency. Similarly, the Port of Gothenburg and Port of Rotterdam highlight the improvement of efficiency by reducing waiting times and optimizing the movement of incoming and outgoing vessels, among other measures. The port of TangerMed emphasizes that efficiency can be heightened through adherence to rules and the seamless functioning of processes, ensuring smooth operations. This perspective on smooth operations as a means to achieve efficiency is also echoed by the Port of Bremerhaven and the Port of Kokkola.

Improving Safety:
Given that it falls within the purview of port authorities to guarantee secure navigation and overall port security, it comes as no surprise that the objective of *”improving safety”* ranks as the second most frequently cited goal among various interviewees. Safety emerged as a priority for 10 interviewees, encompassing all Israeli Ports (Ashdod, Hadera, Haifa), Barcelona, and Sohar, among others. Notably, all Israeli ports identified safety as their primary objective, with the Port of Hadera underscoring the paramount importance of ”Safety of Navigation” in safeguarding the projection of the port’s jetties. Emphasizing the significance of pilots as stakeholders, the interviewee of Hadera Port highlighted that ensuring perfect pilotage is crucial for navigation safety, aligning with the stakeholder power grid elucidated in literature and depicted in Figure 2.1. When discussing safety as a corporate objective, the majority of interviewees stressed the importance of enhancing safety in navigation and the imperative to minimize or prevent accidents. The Port of Sohar also prioritized safety but noted that, given their operational constraints of handling only one movement at a time, safety during such movements is already predominantly assured. They state:

"[Safety] is already almost guaranteed because you can only do one movement at the time which makes it fairly difficult for two ships to hit each other."

The interviewee asserted that commonly most accidents occur when multiple ships are involved, a factor they are able to mitigate.

Sustainability/emission reduction:
In addition, the topic of sustainability has become increasingly important in the shipping industry in recent years and was mentioned as a declared goal during port calls in seven different ports surveyed. Noteworthy among these ports are the Port of Copenhagen-Malmö, the Port of Gothenburg, the Port of Kobe, and the Port of Vancouver. The Port of Kobe, in particular, highlighted its ongoing initiatives aimed at substituting conventional fossil fuels with alternative options like Liquefied Natural Gas (LNG). The heightened emphasis on sustainability as a corporate objective reflects an increasing awareness of its importance in the corporate mindset. This trend is further driven by the imposition of legal and regulatory mandates compelling companies and ports to proactively adopt measures for carbon footprint mitigation, as indicated in the International Maritime Organization's 2020 report [1].

Means to Achieve the Objective:
Additionally to the three discovered objectives, the interviewees mentioned several means to achieve those objectives, including the following:

- Improve Stakeholder coordination
- Port Call Optimization
- Information Sharing

Stakeholder coordination:
Given that port calls involve complex processes with many interdependent stakeholders, the high frequency of *stakeholder coordination* as an objective was expected as well. The improvement of process efficiency is contingent, in part, on effective coordination among the various stakeholders, and it follows logically that stakeholder coordination closely aligns with the top-ranked objective of efficiency improvement. Furthermore, this mean as the highest stated mean validates the importance of this condition for the port call as already mentioned several times in literature (see [59, 48]).

Port Call Optimization:
The interviewees who speak of *PCO* as a mean to improve efficiency include the ports of Algeciras, Haifa, Kokkola, and TangerMed. These ports differ in size and governance structure. Nevertheless, all of these ports stand out for their recognition as pioneers that are or have been involved in various PCO projects [79, 91, 10]. In addition, it is noticeable that the interviewees from TangerMed and Algeciras hold innovative positions that are particularly involved with "new" concepts such as PCO. Algeciras' interviewee is the Chief Information and Innovation Officer, while TangerMed's interviewee holds the position of Port Call Optimization and Invoicing Manager.

Information sharing:
Information sharing can also be seen as a mean to improve efficiency as well as improving safety as sharing more information often leads to enhanced efficiency [60]. This argument can be supported by the fact that the ports that indicated information sharing as a mean, including the Port of TangerMed and Port of Kokkola also mention enhancing efficiency as an objective.

The collaborative nature of the identified means and objectives extends their impact to all stakeholders engaged in the port call process. As these means converge to achieve overarching objectives, a collective synergy emerges, transforming these objectives from organizational goals to systemic imperatives. This shift is vital for establishing a comprehensive foundation that fosters a shared commitment to optimizing port call processes.
However, it is crucial to acknowledge that the conducted interviews primarily involved Port Authority employees, providing a specific perspective that may not fully represent the diverse landscape of service providers integral to the port call ecosystem. In exploring the viewpoints of other key participants, such as towage organizations, potential variations in objectives and means are anticipated, possibly emphasizing profit-driven and organizational measures over collaborative efforts. Consequently, further

research is recommended to uncover these nuances, providing a more holistic understanding and laying the groundwork for the necessary pre-conditions for the effective adoption of port call optimization measures.

Objectives/Means vs. Port Size:
After identifying the objectives and means of the companies representatives for the port call, in order to draw conclusions, they need to be compared. Figure 4.12 shows the relations between the size of the port and the objectives or means the interviewees representative for the company have stated.

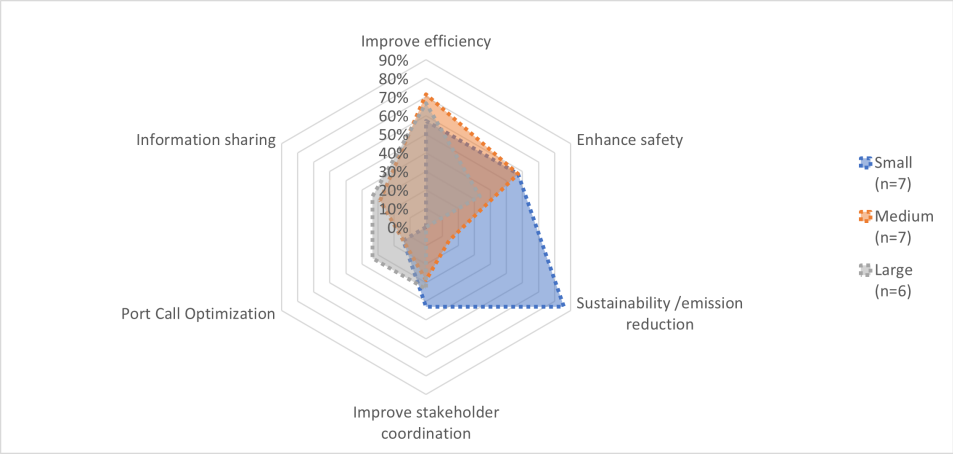


Figure 4.12: Port size vs. frequency of occurring mentioned objectives/means

Sustainability: One striking observation is the zero occurrence of sustainability as a prominent objective among larger ports while six out of seven small ports (all ports excluding Hadera) stated sustainability as one of their objectives. One reason for this result could be that larger ports are often subject to more extensive and stringent regulations due to their scale of operations [90]. Therefore, they may perceive that they are already addressing sustainability through compliance with these regulations. Smaller ports may not face the same level of regulatory scrutiny and may voluntarily adopt sustainability goals as a proactive approach to improve their competitiveness. Furthermore, smaller ports may be more directly influenced by local communities, environmental groups, or governmental bodies that emphasize sustainability. In contrast, larger ports including the Port of Rotterdam may have a more diverse set of stakeholders, some of whom may prioritize other aspects of port operations over sustainability. Some of the medium sized ports such as the Port of Kobe mentioned sustainability but it is not one of the major objectives overall. They state that ”improving efficiency is a mean to improve sustainability”.

Information sharing: Another result to be highlighted is that information sharing was not mentioned as an objective for any of the small ports. When looking at the individual interviews, it becomes clear that communication often consists of telephone calls and in-person meetings. In addition, the harbor master of Hadera Port in particular emphasized that all service providers know each other and everyone ”knows exactly what to do”. It can therefore be concluded that information sharing is often already in place and less complex due to the size of the port and is therefore not listed as a separate objective. Even though information sharing was not mentioned a lot by any of the ports, all ports talked about the importance of communication and information sharing in some sense. The ports acknowledge the importance of that factor for the port call (and port call optimization) but barely state it as an objective or mean of the company relevant for the port call.

Improve efficiency: Improving efficiency is the most frequently stated objective. When looking at the size of the port, no major difference can be seen between the occurrence of the objective and the port size.

Objectives/Means vs. Port Governance Structure:
Besides the port size, comparing the port governance structure is also relevant to identify potential relationships and to identify new pre-conditions for the adoption of collaborative PCO. Figure 4.13 shows the relation between the objectives/means and the Governance Structure in the different ports. It is evident that the distribution of public, tool, landlord, and private ports is highly uneven, which raises concerns about the representativeness of the results. This uneven distribution necessitates careful consideration when interpreting the findings.
The results from the analysis of the relationships between port governance structures and company objectives during the port call process yield several noteworthy insights:

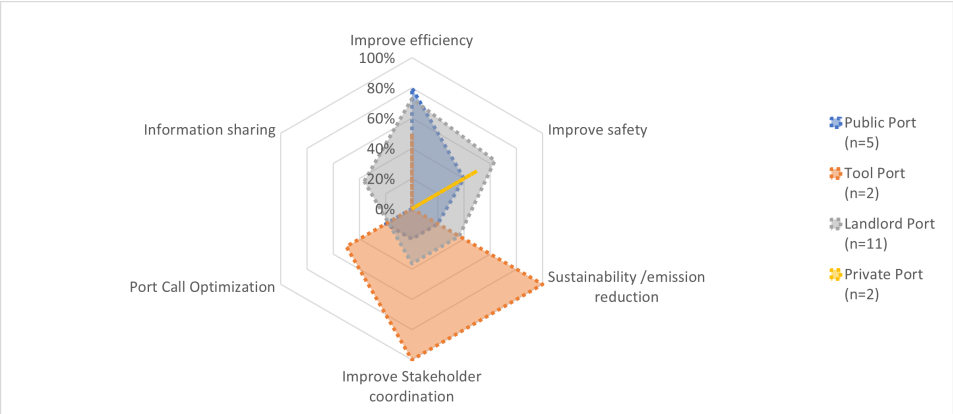


Figure 4.13: Port Governance Structure vs. Company objectives/means mentioned

Tool Ports: Sustainability and improving stakeholder coordination emerge as a significant objective and mean, particularly for small ports. Interestingly, all the interviewed tool ports fall within the small port category. However, this raises questions about the true connection between the importance of sustainability and the governance structure. Therefore, the need for additional research to explore this relationship further is highlighted.

Private ports: Private ports, also represented by just two interviewees (the Port of London and the Port of Mundra/Adani Ports SEZ), show a shortage of stated objectives, only mentioning ”improving safety” by the Port of London. This suggests a weak or potentially inconsequential connection between company objectives and private ports.
Notably, despite ”improving efficiency” being the most frequently cited objective overall, no private ports mentioned it as their company objective, prompting questions about the priorities of private ports in relation to efficiency. It needs to be mentioned that when going through the interview transcripts, the question about the companies objective (”When performing activities for the port call, what are your company’s objectives?”) was only directed towards the CEO of Adani Ports who then answered in a more general way:

> *” Improve growth with goodness - We try to support the economies we work in, we work with the local people. We try to see how the humanity can benefit.”*

The interviewee of the Port of London answered the question of the companies objective indirectly by already giving detailed answers regarding the importance of certain features or conditions for other questions.

Public ports: In the case of public ports, ”improve efficiency” emerges as the predominant objective, while objectives such as ”information sharing”, and ”Port call optimization” were notably absent from their responses.
Public ports, on the whole, do not emphasize other objectives to a significant degree, indicating a concentrated focus on efficiency enhancement.

Landlord ports: Conversely, landlord ports repeatedly highlight ”improving efficiency” and ”enhancing

sustainability" as core objectives, ranking as the second most frequently mentioned objectives in this category. Landlord ports consistently mention each objective at least twice, with "Port call optimization" being mentioned only twice but still relatively frequently compared to other governance structures. The two ports stating PCO as a mean to fulfill the objectives were the Port of TangerMed and the Port of Algeciras whose interviewees both hold an innovative or Port Call Optimization related job position.

4.5.3. Challenges

As can be seen in Figure 4.14 compared to the objectives are the challenges more evenly distributed with a maximum of ten and a minimum of four times mentioning the challenges. However, while the objectives and means are limited in number, there are way more challenges mentioned overall. The various challenges identified during the interviews can be categorized into different types of challenges, namely:

- **External challenges (that cannot be influenced):**
  weather, regulatory restrictions, tidal restrictions
- **Stakeholder (higher level) related challenges:**
  information sharing among stakeholders, having many stakeholders
- **Process challenges:**
  complexity, having many stakeholders and coordination vessel entrance and exit
- **People (lower level) related challenges:**
  willingness to use, resistance to change, resistance of different stakeholders and traditional way of working

Only challenges that were mentioned by more than 20% of the interviewees are considered for this analysis.

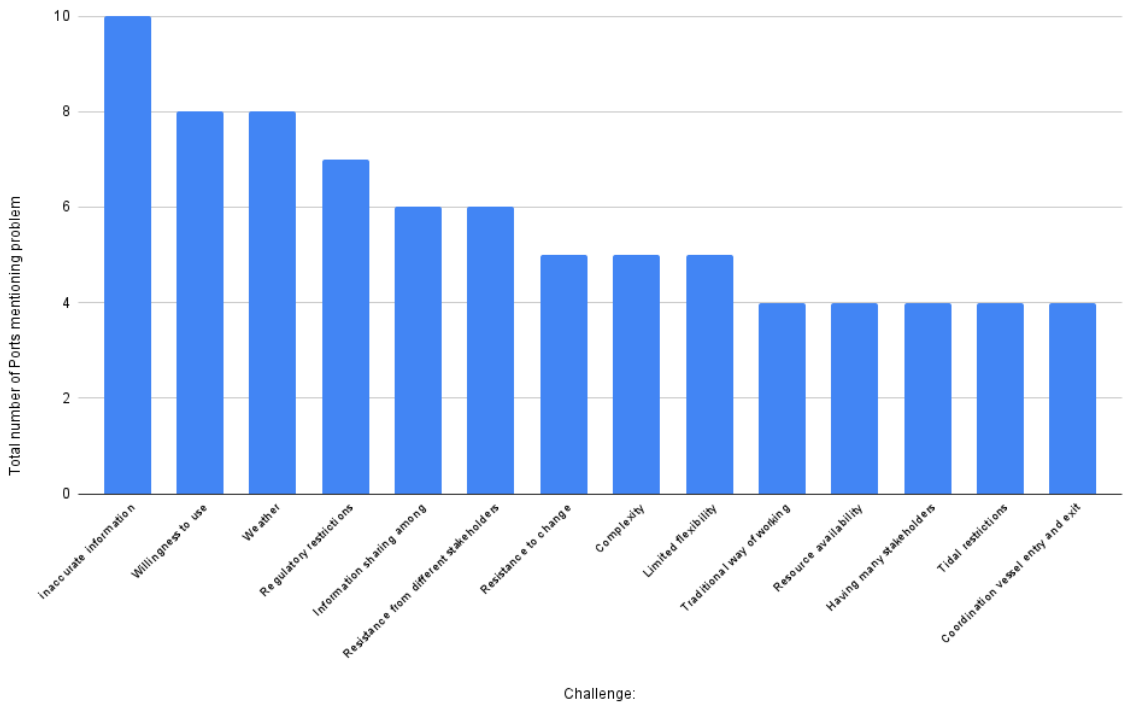


Figure 4.14: Frequency distribution of challenges identified in different ports

The most frequently stated challenges include "inaccurate information", "willingness to use", "weather" and "regulatory restrictions". A brief description is required to understand what is meant by those challenges.

Inaccurate information: During the planning of the port call and the physical process, a lot of information needs to be shared between the different involved parties to ensure a successful and smooth port call. This information is shared by and with different people and can include information like the ETA, resource availability, type of cargo to be handled, Estimated-time-of-berthing (ETB) just to name a few. During the interviews especially information related to arrival, departure, berthing and other timings was mentioned as a reoccurring problem. Especially the ETA and ATA are often shared by the vessel agent and need to be communicated hours to days before the actual arrival of the vessel and updated continuously.
Even though ”inaccurate information” is the most mentioned challenge faced by the interviewed ports during the port call with 10 out of 20 interviewees mentioning it, barely any port states ”information sharing” as a mean to improve efficiency. One could argue that the sharing of the information by itself is not a challenge but rather the type of information or time stamp when the information is being shared that is challenging.

Willingness to use: The willingness to use was often mentioned in relation to platforms or systems that make the process more advanced in any way. Especially when talking about digital solutions this challenge seemed to occur very frequently. The interviewee of the Port of Haifa states that ”experienced employees want other stuff (like a small computer to minimize the difficulties in the port) but not the optimization tools that the port authority provides”. The only solution the interviewed harbor master sees is to wait until new employees, or more specifically pilots will come and join the team because regarding to his words: ”Only the new pilots will use the technologies”.

Weather: The challenge ”weather” includes all kinds of weather related challenges like wind, waves, light restrictions and in general, everything that restricts the port but that they cannot really change. In Northern ports like the Port of Kokkola or Port of Vancouver, ice was also mentioned as one of the major weather related challenges while Ports like the Port of Hadera faces more challenges with high waves due to heavy winds and storms.

Regulatory restrictions: Regulatory restrictions were mostly mentioned in combination with bureaucracy difficulties and decisions taking very long as they need to go through several entities before they can actually be enforced. Closely related to the regulatory restrictions is the limited flexibility which results from the regulatory restrictions. The Port of Barcelona highly criticized the regulatory restrictions when talking about the planning of the port call as they are legally required to welcome all arriving vessels calling for the port, even though they might be out of capacity already. The interviewee stated that the regulations for that regard are highly affecting the efficiency of the port call and that they wish to change the regulatory ground.
An intriguing discovery emerged when comparing the two Spanish ports Port of Barcelona and the Port of Algeciras. Despite the Port of Barcelona claiming significant issues with governmental regulations, the Port of Algeciras, also subject to the same regulations, did not identify regulatory restrictions as a major challenge.

The four most common challenges all belong to a different problem category. Inaccurate information is often shared among different organizations. Therefore, this problem belongs to the higher level stakeholder related challenges and can be categorized as a challenge on an interorganizational level. Besides inaccurate information, information sharing among stakeholders in general and having too many stakeholders, which are also both challenges faced on an interorganizational level, are also assigned to this category. All these problems have in common that they require the cooperation of different stakeholders, hence are interorganizational, which seems to be a general problem in the port. It is important to investigate whether these problems are more common in small or large ports or whether the governance structure has an influence.

Challenges that can be traced back to the behavior of individual employees and are therefore on an organizational, rather than interorganizational level include, in addition to ”willingness to change”, the ”resistance from different stakeholders”, ”resistance to change” and ”traditional way of working”. In connection with these challenges, the age of the employees was frequently mentioned and the older

the employees are, the more difficult it is to convince them of new work processes or the use of new platforms. However, this statement should not be generalized and considered with care.

Port Size vs. Challenges:
Figure 4.15 presents the previously described challenges in relation to the port size of the interviewed ports.

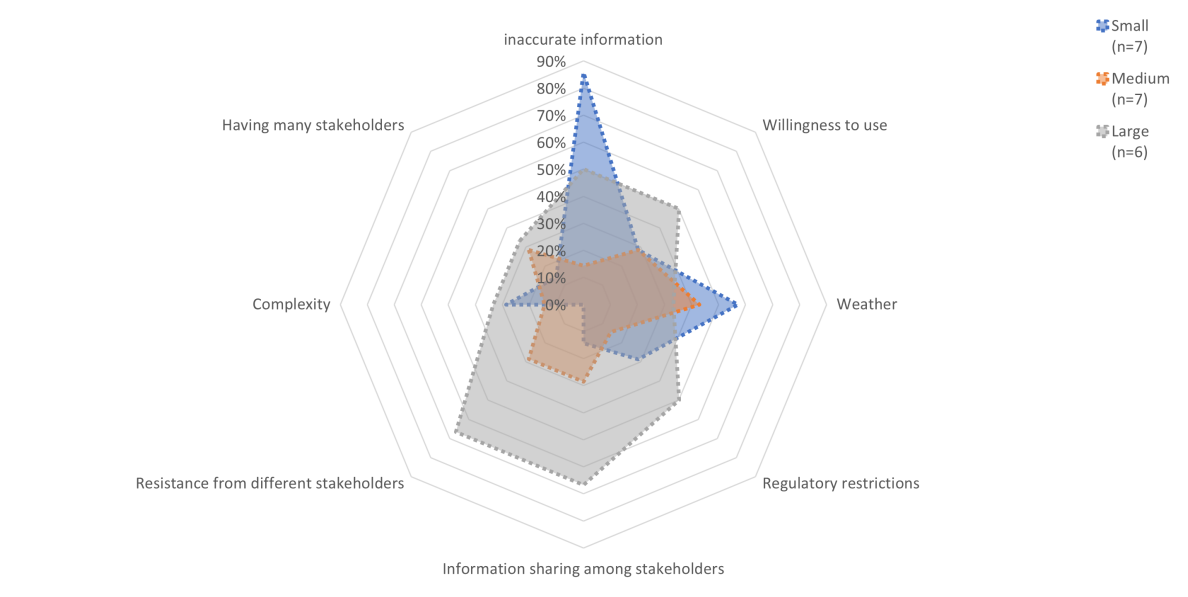


Figure 4.15: Port size vs. Frequency of occurring challenges mentioned

Large ports: In the analysis of port challenges, it becomes evident that large ports face a multitude of challenges across various domains, with a notably higher frequency of encountering resistance from different stakeholders and difficulties in sharing information among stakeholders. The interviewee of the Port of TangerMed stated, that it took them (the Port Authority of TangerMed Port) four years to get the actors to share information required to optimize the port call and that they are still not resistance free. According to the interviewee information sharing was only possible due to a gradual process in the first place where they did not ask the actors to share all of their information at once but rather asked for specific information, why they need it and how they will gain from this information. To this day there are sometimes complains by the involved operating stakeholders about different things like priorities or the current conditions. Once a complain appears the Port authority will have meetings and workshops with the actors to find out what information needs to be shared to make the current situation better. The interviewee stated that information sharing is about negotiation and transparency. They stated: ”You need to share this [piece of information] so I can grant you access to this [piece of information]”.
The analysis of information sharing among stakeholders indicates that larger ports, involving more stakeholders in their processes, face increased complexity. However, it’s crucial to note that while complexity and a multitude of stakeholders are challenges common in larger ports, they are not as frequent as ”resistance from different stakeholders” and ”information sharing among stakeholders.”
In contrast, larger ports confront every challenge at least twice, while small and medium-sized ports exhibit variations, with certain challenges such as resistance from different stakeholders or complexity either not appearing at all or occurring only once.
Overall, large ports appear to contend with more challenges than their smaller or medium-sized counterparts. The challenges listed were mentioned by a total of 23 ports (some ports counted multiple times due to the mention of multiple challenges), compared to 14 for medium-sized ports and 18 for small ports.

Medium ports: Medium-sized ports, on the other hand, face problems without any one challenge standing out prominently. Regulations, inaccurate information, and complexity do not seem to pose significant issues for this category of ports. This raises questions about whether these observations

are a consequence of the limited size of the port or if they are influenced by the specific governance structures in place at these ports.

Small Ports: Small ports, interestingly, do not identify information sharing as one of their primary means to achieve their objectives. However, six out of seven small ports including the Port of Gothenburg mention that the information they receive is often inaccurate. In the Port of Gothenburg the Port Control which is part of the Port Authority has a helicopter view and plans the resources, however dialog still takes place between the individual involved actors. According to the interviewee, all the information between the service providers should go through the traffic central (a communication system provided by the Port Authority) but in reality the information sharing process is a lot more informal. Even though the traffic central division they are actively searching for information to make sure the information is accurate and complete, it does not always happen leading to inaccurate or missing information. Furthermore, resistance from different stakeholders is not reported as a challenge in small ports. In cases such as the Port of Hadera and the Port of Kokkola (both classified as small ports), interviewees note that the relationships among the involved parties are very personal, with everyone well-informed throughout the process. These two ports involve only a limited number of stakeholders, which potentially reduces overall complexity and results in lower resistance from different stakeholders. It's worth noting that out of the seven small ports, five are exposed to challenging weather and sea conditions. For instance, the Port of Hadera has open water terminals directly influenced by sea conditions like waves and wind. Similarly, the ports of Kokkola, Malmö, and Gothenburg are situated in Northern Europe, where ice and heavy storms occur more frequently, particularly in winter. Therefore, it is open for discussion whether the frequency of weather-related challenges is influenced by the size of the port or its geographical location.

4.5.4. Port Call Optimization

The interviewed ports exhibit a wide array of interpretations regarding what constitutes to PCO. Notably, there is a significant divergence in their definitions, reflecting the multifaceted nature of this concept in the maritime industry. For some, PCO entails physical infrastructure enhancements, such as the construction of additional berths and the augmentation of tugboat resources to expedite the port call process (e.g. the Port of Ashdod and the Port of Haifa). Others focus on pre-port call optimization strategies, including the implementation of JIT-arrivals to ensure that vessels arrive precisely when needed (i.e. the Port of Kobe). Furthermore, PCO encompasses a broad spectrum of technology and digital platforms that can streamline port operations. Surprisingly, there are those who believe that achieving PCO can be as straightforward as holding regular meetings to enhance communication among the various stakeholders involved (e.g. Port of Barcelona and Port of Bremen/Bremerhaven). This diversity of perspectives underscores the complexity of PCO.
Figure 4.16 categorizes the mentioned measures into five category groups.

PCO measure categories (based on interviews)				
				
Digital Solution/ Technology	**Interaction Measures**	**Infrastructure improvement**	**Inter-Systematic**	**Pre-Port Call (Planning) Strategies**
Platform Port Community System (PCS) Technology	Information Sharing Coordination Collaboration Knowledge Sharing Regular meetings	Additional Resources (e.g. tugs, terminals) Augmented Resources (e.g. tugs)	Competition between ports Knowledge Sharing	JIT-arrival

Figure 4.16: PCO measure categories (identified during the interviews)

Those categories combine measures on different levels, namely a technological level (Digital solution/Technology). The ports mentioning those measures stated that PCO includes the introduction of a system or any kind of digital solution that will somehow improve the port call. The second category, ”interaction measures” includes interorganizational measures like information sharing or coordination among the various involved actors to optimize the port call. The category ”Infrastructure Improvements” includes measures both on an organizational as well as external environment level. Organizational level measures include additional resources which not only includes adding more terminals or tug boats but also employing more pilots. External environment measures involves updating of the current infrastructure by introducing the latest models of tugboats or automation. Fourthly, the inter-systematic measures include measures beyond the individual port. Sharing knowledge with other ports or looking at their way of operating to improve the own port call falls into that category. Lastly, Pre-Port Call (Planning) Strategies were identified as a fifth category. Similar to the interaction measures this categories is on an interorganizational level as the planning of JIT-arrivals necessitates the collaboration of multiple stakeholders involved in the port call. Throughout the remainder of this section, the individual identified measures are explained and analyzed in more detail.

The following Figure 4.17 visualizes what ports consider as port call optimization measures and which interviewees talked about which measure as a measure of PCO.

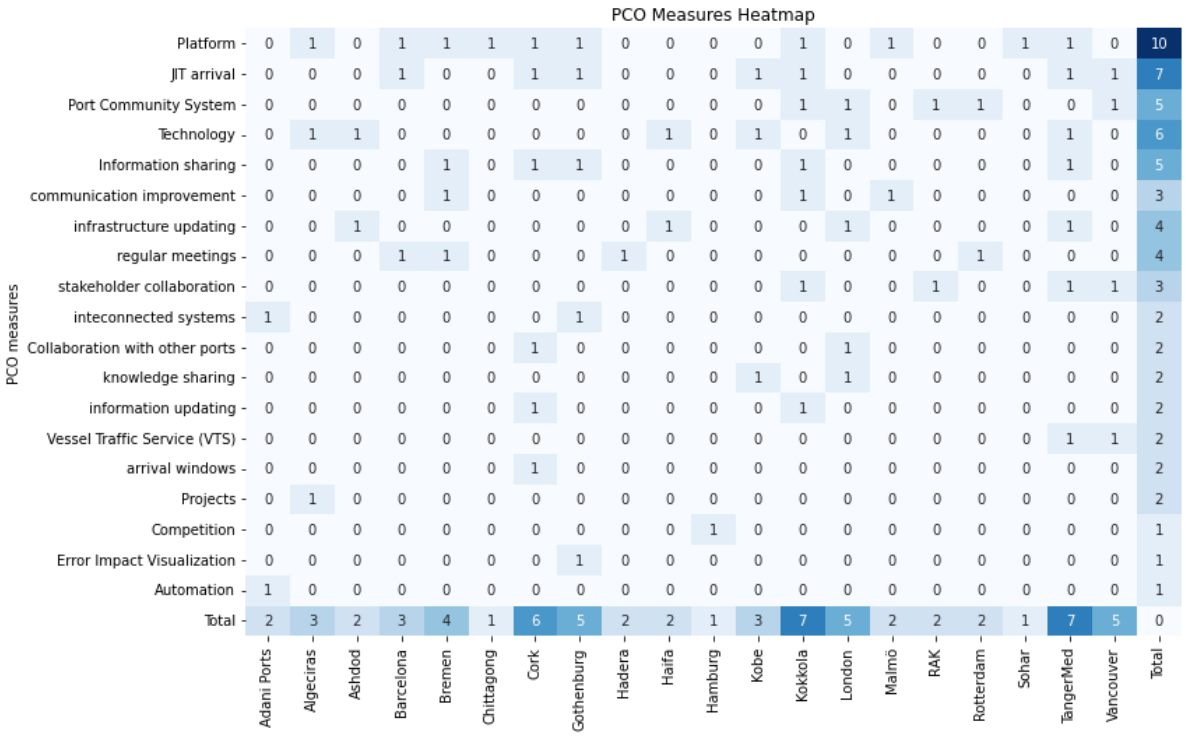


Figure 4.17: PCO measures in the different port

Many of the measures considered as PCO include some sort of digital solution or technology. Out of the four most frequently named measures, three can be considered of technological origin. Those include platform, PCS and Technology. Technology, even though it is very general is considered it’s own measure as many of the interviewees stated that without technology (not specifying what exactly is meant by technology) Port Call Optimization cannot take place. Besides technologies, non-physical processes have also been mentioned several times as PCO-measures. Information sharing, coordination, collaboration, and knowledge sharing are all non-physical processes that involve the exchange, management, and dissemination of information and ideas among individuals or entities. These processes primarily belong to communication and interaction among people, organizations, or systems, and they are essential for effective teamwork, decision-making, and problem-solving. All of these measures are of interorganizational nature and have previously already been identified as important for

Port Call Optimization in literature (see chapter 2). Another category of measures resolves around the physical infrastructure needed during the port call. Various ports stated that infrastructure updating like modernizing or expending the resources like tugs or terminals will improve the port call. Another measure that was identified as a PCO measure by the interviewee from the HVCC (Hamburg, Germany) was competition for the port. If a port faces competition from surrounding ports, like it is the case for the Port of Hamburg, they are forced to take action to improve the port call in order to maintain their market position.

Importance of PCO:
Many different measures for PCO were stated. Some occurred more frequently then others. However, besides discovering what the interviewees consider as PCO measure it is also relevant to identify how important the different interviewees think PCO actually is by looking into how far the implementation process already is. Figure 4.17 visualizes which PCO measure was mentioned by which interviewee. Figure 4.18 brings the previous figure in relation with the importance of PCO in general, PCO as an objective of the company and the implementation phase of the previously mentioned PCO measure by the interviewee. As the interviewee from the Smart Port Alliances takes over a consulting role and is not related to a specific port, no measure implementations take place and all values equal 0.

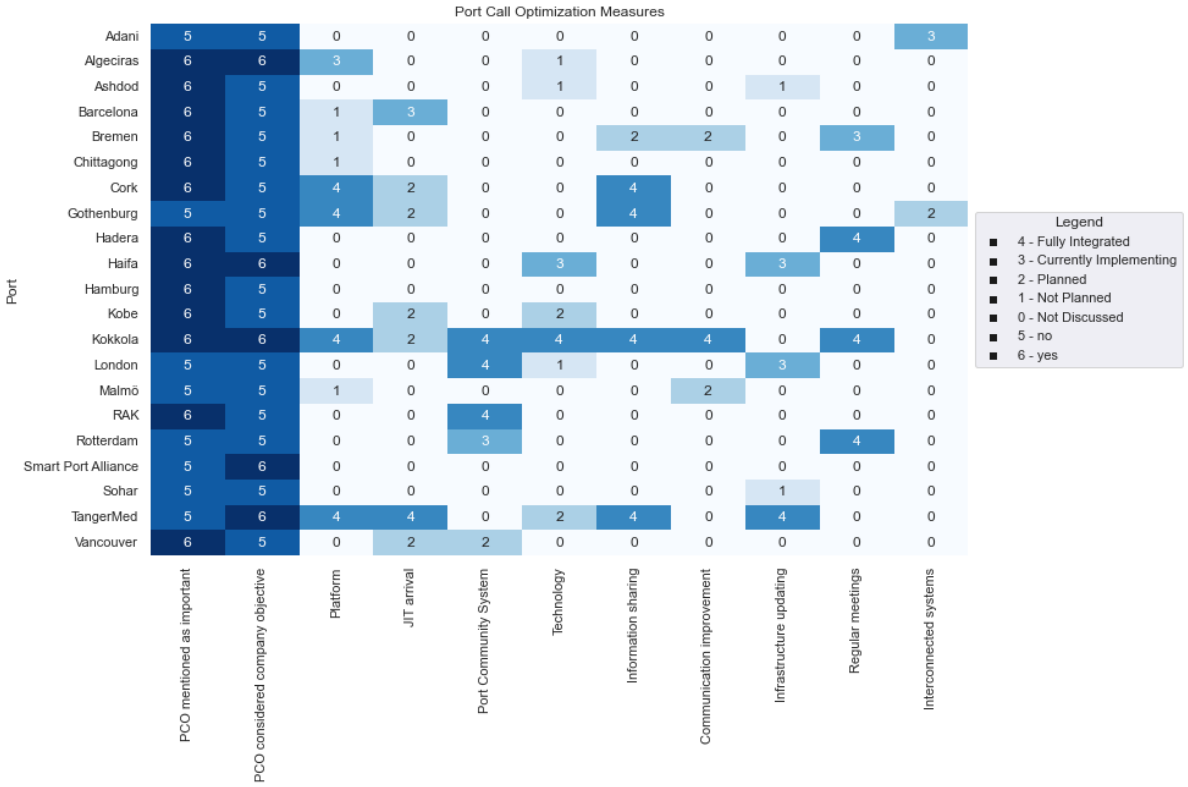


Figure 4.18: Importance of PCO vs. PCO measure vs. Implementation stage

While conducting the interviews, two respondents clearly stated that they do not see the relevance in port call optimization. Those two ports include the Port of Hadera and the CEO of Adani Ports SEZ. However, the reasoning between the two interviews differed significantly.
The port of Hadera is a small energy port that solely provides energy related services. During the interview the Harbor Master stated that the Israeli government is planning on converting the countries energy supply from coal to electricity, erasing the purpose of the port. Efforts are made to convert the port into a differently functioning port, however, as the future of the port is still uncertain, Port Call Optimization is simply not a topic that is relevant.

The CEO of Adani Ports on the other hand sees a high significance of optimization. However they stated the following:

> *"Port optimization is becoming less relevant, and the focus is shifting towards controlling the entire supply chain, including owning the customer and logistics, as the carrier's influence grows, making AI-driven port call management less significant."*

Adani Ports owns and operates several ports. And although the efficiency of individual ports is important to the company, the profitability of the entire company is more relevant than that of individual ports. Adani Port's view of the individual port call is therefore much more abstract than that of a "traditional" Port Authority, which is "only" concerned with its own port. Furthermore, Adani Ports is not only involved in the maritime industry, but also does business in many other areas such as energy, aviation and many more. The company therefore has a different perspective on the relevance of the entire supply chain due to its broad positioning. This explains why the optimization of the port call is not considered as relevant.

It is evident from the interviews that all other interviewees share a unanimous perspective on the relevance of PCO and the need for measures to enhance and optimize the port call process. Their collective viewpoint emphasizes the significance of PCO as an essential approach to improving the efficiency and effectiveness of port operations. This consensus underscores the shared commitment among industry professionals to take proactive measures, whether in terms of physical infrastructure enhancements, technology integration, communication improvements, or other strategies, to ensure that port calls are executed in the most streamlined and effective manner possible, thus benefiting both the ports and their stakeholders.

Efforts to Implement PCO Measures:
In the analysis of the interviewee's views on Port call optimization for the port call process, it's noteworthy that 13 out of 21 respondents consider PCO to be important (indicated in the first column in Figure 4.18). Four of these 13 individuals have gone further by explicitly including PCO as one of their company means to fulfil the companies objectives (highlighted in the second column in Figure 4.18). To validate whether the ports have already taken actions to improve the port call or if they are only talking about it, the answers given by the interviewees were summarized into five categories as can be seen in Figure 4.19. Those categories align with the categories 1 to 4 in Figure 4.18. The numbers behind each of the stated measures represent the port mentioning this measure. The overview of the numbers assigned to each port can be found in Table C.1. According to the interviewee of the Port of TangerMed, the HVCC and the Smart Ports Alliance the full implementation of a PCO measure such as for example a cross-organizational platform is a long lasting process which takes at least 4-5 years [Source: interview 11, 18] but can take up to 10-15 years [Source: interview 21].

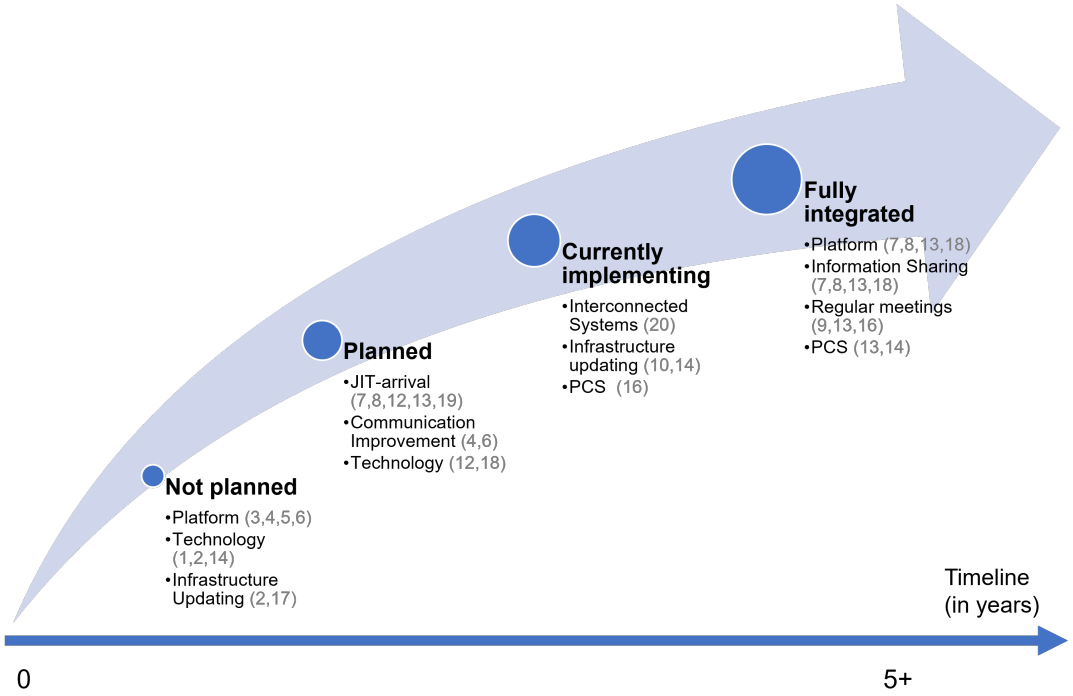


Figure 4.19: PCO measure implementation timeline

It is evident that the implementation of PCO measures varies significantly among different ports, reflecting diverse levels of advancement. The specific types of measures also show considerable variation, with some ports having fully implemented certain strategies and actively pursuing further enhancements to boost efficiency. On the other hand, there are ports that acknowledge the importance of PCO but currently lack plans for the comprehensive implementation of these measures.
Notably, the Port of Algeciras is currently in the implementation stage, emphasizing a proactive approach toward optimizing port call processes. In contrast, several other ports either have no plans for implementing PCO platforms or have already completed the full implementation. This disparity underscores the diverse strategies employed by different ports in response to the efficiency-enhancing potential of PCO measures.
When inquiring about the adoption of Just-In-Time (JIT) arrival, responses from interviewees across various ports reveal that while the concept is acknowledged and planned, only a few have actually implemented the measure. The Port of Algeciras is actively in the process of implementation (stage 3), and the Port of TangerMed stands out as having fully implemented JIT arrival (stage 4), showcasing a notable commitment to time-sensitive optimization measures.
Furthermore, discussions about Port Community systems as a PCO measure highlight that some ports, such as the Port of London and Port of RAK, have already fully implemented this system. Meanwhile, others, like the Port of Rotterdam, are in the active stage of implementation. This diversity in the adoption and progress of PCO measures underscores the need for tailored research and strategies to address the unique challenges and opportunities within each port, laying the groundwork for a more cohesive and universally beneficial optimization framework.

All ports have implemented some PCO measures (as can be seen in Figure 4.18). The interviewee of the Port of Hamburg belongs to the HVCC, which is a centralized planning organization whose task it is to plan and optimize the port call and ultimately improve efficiency. Therefore, the organization can be seen as a PCO measure in itself.
In many cases, a platform is integrated, however, it is often only accessible internally within the company and does not allow for any information sharing or planning. The Port of London for example has had their PCS for over 12 years (the interviewee stated, the system already existed when he started working at the PA, which was 12 years ago), however the system is not able to implement information automatically. All port call relevant information from the different actors needs to be manually added by

the responsible of the Port authority. Furthermore, not all the relevant information goes into the PCS but into another system. This can lead to inaccurate or missing information. The interviewee stated the following:

> *"We have [several] external companies coming in. I start my job at 8 in the morning, and I get information from my colleague. Sometimes I can't remember everything. There are important things to check, like whether the ship has tugs arranged, but that's separate from this system. I check that on [the other platform] because external parties input the information, and they may not update it. If I don't catch it, the first I know is when the pilot calls, and it's only 20 minutes from the berth. I need a better safety net for such important things. I need to check the external website to ensure the information is correct."*

Based on this statement and other statements made by other ports, the assumption can be made that having a platform integrated does not automatically mean that Port Call Optimization takes place.

It is interesting to note that, apart from the Port of Hadera, which initially expressed disinterest in PCO, the other ports without any highly advanced measures planned still emphasize the importance of PCO. This raises the question of whether they genuinely aim to adopt PCO but require inspiration or if they merely pay lip service to the concept without genuine intent for implementation. Further exploration is recommended to understand their actual motivations and commitment. Moreover, the current modes of communication among the ports vary, indicating differing levels of advancement in this aspect.
In considering the ports that emphasize the importance of PCO but have not planned any measures (stage 1) as well as the ports that have planned measures but have not implemented them (stage 2), a careful examination of the relevant conditions for PCO adoption is imperative before undertaking any projects. This proactive approach prevents potential failures by ensuring that crucial conditions are accounted for. Evaluating the current situation within these ports is essential to identify existing conditions and gauge the overall level of port advancement. Subsequently, a tailored PCO measure can be determined and seamlessly integrated, aligning with the port's infrastructure and capabilities.
A practical implementation strategy for ports without planned measures could involve approaching each port individually to assess their readiness for specific PCO measures. This assessment should be based on the port's level of advancement and the pre-existing availability of conditions necessary for successful PCO adoption. By tailoring the approach to each port's unique circumstances, stakeholders can gauge receptiveness and effectively design and implement PCO measures that not only align with the port's current capabilities but also set the stage for continuous optimization in the future.

When asking to further elaborate on the currently implemented or planned platforms, the following functions of the various platforms were revealed as can be seen in Figure 4.20:

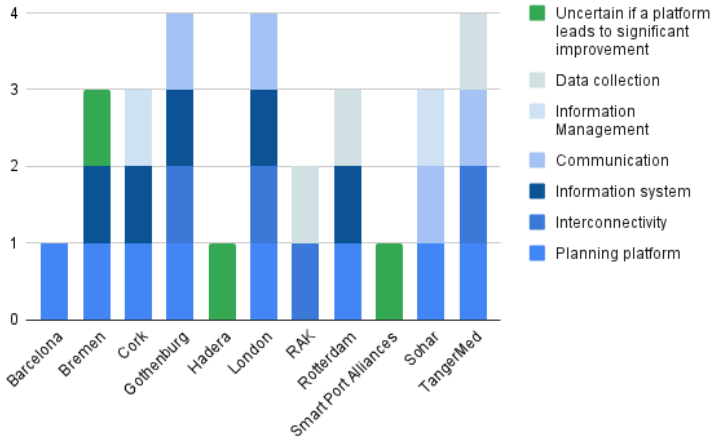


Figure 4.20: Types of Platforms used or planned in different ports

A result that stands out is that three interviewees could not say with precision whether a platform would really provide for a major change in processes or an improvement in efficiency. Those interviewees

include the Harbor Master (HM) of the Port of Hadera, the Port of Bremen/Bremerhaven and the representative of the Smart Port Alliances. The HM of Hadera has stated several times that even though Port Call Optimization might be useful, it is not in the interest of the port to implement it. Therefore, a negative attitude towards the effectiveness of a platform is not surprising. Besides the Port of Hadera, the Port of Bremen and the Smart Port Alliances also announced their uncertainty regarding the improvement of the Port Call through a platform. The interview respondent from the PA Bremen stated the following:

> *"Platforms themselves are not a panacea, but they could enhance awareness and data transparency; for instance, Optiport might improve some port calls, although the significant improvement of processes and workflows remains uncertain."*

Similar to the interviewee from the Port of Bremen, the interviewee from Smart Port Alliances also sees only a conditional success rate through the implementation of platforms or digital solutions in general. They state:

> *"Technology offers solutions to about 85% of the problems, but the willingness to adopt and use these technological solutions can be a major challenge. Another barrier is that companies are reluctant to invest in change due to financial concerns, and digital projects are often difficult to demonstrate immediate benefits, which can discourage companies from investing in them."*

To sum it up, an effective change can only be achieved if the mindset of the people and the interpersonal relations including trust in the process are given.

Communication Channel vs. PCO

During a typical port call, the primary mode of communication is through the use of VHF (Very High Frequency) communication. VHF is a reliable method for ship-to-shore and shore-to-ship communication, provided that the planning and coordination before the vessel's arrival are effective. In cases where the pre-arrival planning has been thorough and there are no significant disruptions during the port call, VHF communication serves its purpose smoothly.

However, communication during the planning phase of a port call can be more diverse. Various communication channels are employed during this stage, depending on the specific requirements and circumstances. These channels include email correspondence, telephone conversations, in-person meetings, centralized communication facilitated by the port authority, and communication through dedicated platforms or systems. Figure 4.21 shows the preferred communication channel of the different ports before and during the port call.

The choice of the communication method during the planning phase often depends on the nature of the port call, the preferences of involved parties, and the level of technological infrastructure available at the port. Each of the communication methods has its advantages and may be employed as needed to ensure the successful planning and execution of the port call. Depending on the perceived challenges communication improvements potentially via a platform or other means should be considered.

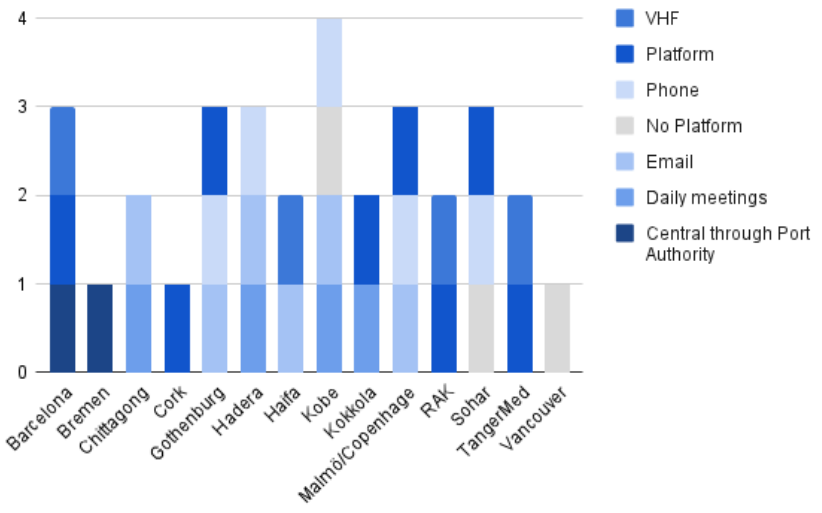


Figure 4.21: Communication Channels

4.5.5. Ideal Level of Centralization:

Most interviewees highlighted the significance of centralization in one form or another when it comes to the port call process. This consensus among the interviewees underscores the widely acknowledged importance of centralization in streamlining and optimizing port call operations already discovered in literature like Schoneveld [81].

Forms of Centralization:

Centralization can take various forms within port governance structures, such as the consolidation of decision-making processes, unified communication channels, or the establishment of a centralized authority to oversee and coordinate port activities. Figure 4.22 shows which ports already fulfil a centralized planning role (i.e. the interviewed organization functions as centralized leading role), think a centralized entity (unrelated of who or what that entity should look like) or even further a centralized planning platform is beneficial for the port call process, which ports also have some kind of centralized planning and in which ports the communication takes place central via the Port Authority.

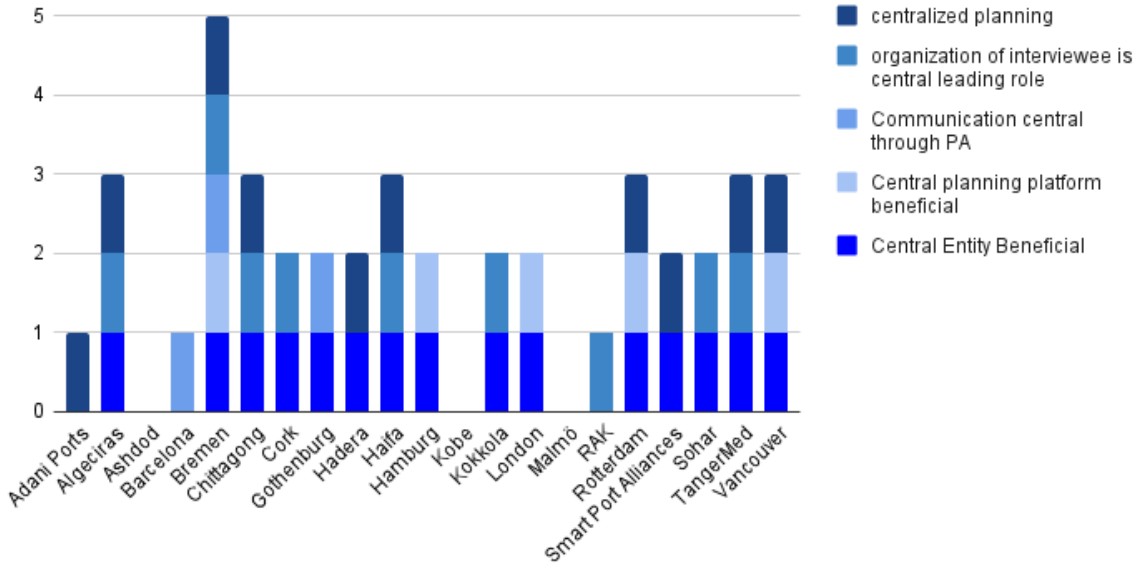


Figure 4.22: Centralization discovered in interviews

Centralization was not discussed in the interviews with Ashdod port, Malmö-Copenhagen as well as the Port of Kobe which is why they do not have any bars assigned in that figure.
8 out of 17 interviewees (excluding the interview with the Smart Port Alliances) mentioned that their organization takes over a central leading role in both the planning of the port call as well as the physical process. The interviewees of these ports are all employed by the Port Authorities of the responsible port.

Out of the eight ports stating they take over a central leading role, four operate as landlord ports, like the Port of Bremen, which have licensing agreements with nautical service providers. In contrast, two ports are categorized as tool ports, while the remaining two are public ports.
Public and tool ports naturally exhibit a more centralized nature, as they typically own and partly operate the land. This involvement in the processes facilitates their ability to maintain a comprehensive overview of port activities and to navigate when necessary. On the other hand, landlord ports, although owning the infrastructure, often outsource operations to private operators and service providers. An interview with the Port of Rotterdam, a landlord port, revealed that the decentralized nature of such ports poses challenges when optimizing the port call process. Interestingly, certain landlord ports have taken on a unique, central leadership role. For instance, the Port of TangerMed places significant emphasis on optimizing not only the port in general but also the port call process itself. They have made it their mission to support service providers lacking the digital infrastructure or maturity to implement port call optimization measures. In return for collaboration and information sharing, these landlord ports assume a special central role in the port's operations.

What should the centralization look like?
In the discussions with the 21 interviewees, a notable consensus emerged regarding the benefits of centralizing some aspect of port call optimization. 15 of these interviewees emphasized the advantages of having a centralized entity, which could manifest as a platform or an organization, to enhance the port call process. Among these 15, four interviewees specifically advocated for the establishment of a centralized planning platform. However, opinions diverged on who should maintain or take responsibility for this platform.

The Port of Bremen, for instance, referred to the HVCC as a successful model, highlighting the benefit of a neutral party managing port call planning in the Port of Hamburg. Conversely, other ports suggested that the Port Authority, already overseeing the port's general operations, should assume the central role due to their comprehensive overview.

Notably, the interviewee from the Port of Rotterdam voiced the need to grant more authority to the Port Authority to enforce decisions effectively. This, in their view, could promote streamlined decision-making. In contrast, the HVCC and the representative from the Smart Port Alliances emphasized the effectiveness of entrusting a neutral party with the responsibility. They argued that this approach enhances data security, fosters trust, and reduces conflicts associated with resistance or the willingness to share information, thereby mitigating potential competitive disadvantages.

Furthermore, some interviewees including the Managing Director of the HVCC recognized the potential drawbacks of central or military-style structures for PCO and digitalization. They highlighted the risk of compromising sustainability without intrinsic motivation and the potential for resistance from process participants when implementing top-down decisions. This underscores the importance of cultural awareness and the acknowledgment that different ports, each with unique cultural backgrounds, may respond differently to similar decisions.

Additionally, in three ports, communication among different stakeholders related to planning is facilitated through the Port Authority. The Port of Barcelona, for example, employs this approach to ensure safety and secure navigation both within the port and during the port call process.

The interview findings also revealed an industry-wide trend toward centralized planning. 9 out of 17 interviewees either have existing centralized planning or aim to establish it in their ports. Interestingly, this trend spans across various port sizes, including five large ports, three medium-sized ports, and one

small port. Furthermore, among these ports, three out of five public ports have already implemented centralized planning, as have five out of eleven landlord ports. The data demonstrates that centralization is not limited to a specific type of port, indicating that diverse ports share a collective drive for increased efficiency and optimization. Before implementing a PCO measure it is important to consider if the port has a more centralized or decentralized structure and if the potential to change this structure exists. Depending on the structure in place, different PCO measures promise to be more successful than others. Furthermore, other related relevant pre-conditions need to be adjusted according to the level of centralization in the port in order to ensure the successful implementation.

What if centralization cannot take place?

In cases where centralization poses challenges or is not feasible within a port context, achieving PCO necessitates alternative approaches that capitalize on existing structures and foster collaboration among stakeholders.

Without centralization, a key strategy is to emphasize enhanced collaboration among stakeholders involved in the port call process. Interview findings underscore the importance of establishing effective communication channels and information-sharing mechanisms. Ports that cannot adopt a centralized model may benefit from facilitating dialogue and coordination among various entities, such as shipping lines, terminal operators, and service providers.

Ports facing challenges in achieving centralization can benefit from industry collaboration and the sharing of best practices. Establishing forums or alliances where ports exchange insights and successful strategies can provide valuable guidance. Learning from the experiences of other ports, especially those with similar structures, can inform the development of effective optimization measures.

In cases where regulatory barriers impede centralization, advocating for or participating in regulatory and policy adjustments becomes crucial. Ports can engage with relevant authorities to address obstacles and create an environment conducive to collaborative optimization efforts. In the Port of Rotterdam for example Tug operators with contracts with carriers often prioritize vessels from those carriers, potentially leading to delays for other vessels. This can result in a perception that tug companies are frequently late. To counteract this phenomenon, the Port Authority addresses this by regulating minimum pricing for tug services and working towards cross-structuring rules that would require operators to be able to serve all customers at different times of the day, allowing hiring from other providers if necessary [Source: interview 16].

Understanding the unique cultural aspects of a port and implementing effective change management strategies become paramount. Without centralization, achieving buy-in from diverse stakeholders requires addressing cultural nuances and fostering a shared vision for Port Call Optimization. Building a culture of collaboration and openness becomes a foundational element for success.

Additionally, compensation measures like performance based contracts or information sharing and transparency initiatives, can also lead to the achievement of PCO without centralization being in place. Introducing performance-based contracts provides a mechanism to link compensation directly to operational outcomes. Stakeholders, such as service providers or shipping lines, can be rewarded based on their contribution to overall port call efficiency. This approach aligns individual interests with the collective goal of optimization, fostering a sense of shared responsibility. To overcome concerns about data security and transparency, ports can implement initiatives that prioritize secure information sharing. Developing robust data-sharing protocols, encryption measures, and transparent governance structures can alleviate apprehensions and build trust among stakeholders.

In summary, while centralization is favored for PCO, ports facing challenges in adopting this model can still achieve significant improvements through other measures like stakeholder collaboration, technology integration, flexible decision-making, industry collaboration, regulatory adjustments, incremental improvements, cultural awareness and/or compensation incentives. Tailoring strategies to the specific characteristics and constraints of each port ensures a more sustainable and effective approach to optimization. It is important to recognize the existing structures and possible measures in the port before port call optimization can be undertaken. Being able to offer an alternative to the centralized port structure is important and should therefore be recognized as a precondition for the implementation of PCO measures.

When is a decentralized organization prefered over a centralized one?

While centralization is widely favored by most interviewees, there are concerns regarding its effects in certain port contexts. The Port of Chittagong, for instance, maintains a centralized structure where

it manages all nautical services, simplifying resource planning and providing a comprehensive port overview. However, this centralization has been hindered by government regulations that have frozen tug tariffs for two decades, resulting in decreased profitability. The interviewee suggests that introducing competition among tug service providers could lead to more competitive tariff rates. Furthermore, the interviewee emphasizes the advantages of centralization while acknowledging that a certain degree of decentralization could stimulate profitability, innovation, and the drive for change in the port industry.

4.5.6. Stakeholder Collaboration

Key Stakeholders:

The conducted interviews reinforced the findings from the literature review, revealing a consistent identification of key stakeholders in the context of this thesis. Notably, the stakeholders identified most relevant for the port call process, including the Port Authority, pilots, tugs, and shipping agents, align with the central focus of this study. Figure 4.23 gives an overview of the most frequently stated key stakeholders by the interviewees.

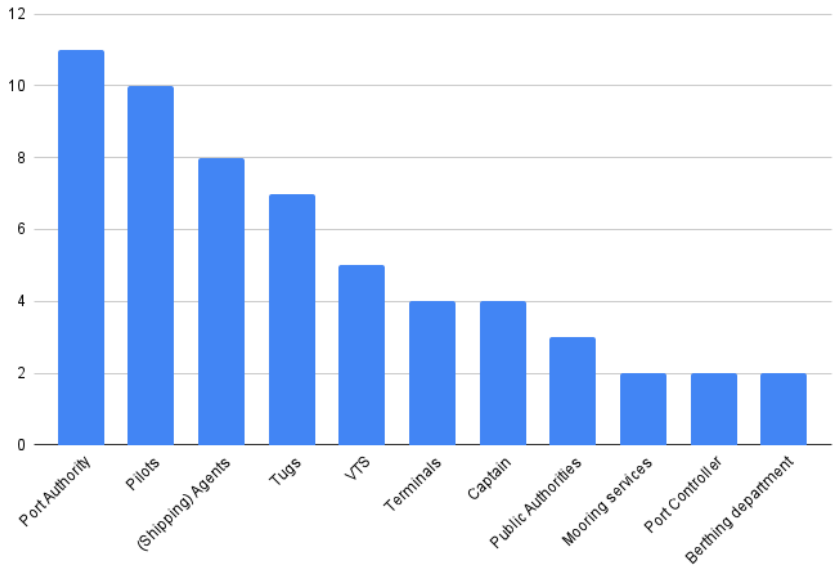


Figure 4.23: Key stakeholders identified in interviews

In many instances, stakeholders earned the status of ”Key stakeholder” either due to their direct involvement in the operational aspects of port call execution, such as pilots and tugs, or because they play a pivotal role in the planning stages. Among these central stakeholders are captains or vessel agents and terminals, consistently acknowledged for their crucial functions. They are primarily responsible for disseminating essential information regarding ETA, ETB, berth availability, and other pertinent factors, making their contributions indispensable to the success of a port call.

Public or other Authorities were mentioned as main stakeholders by the Port of Barcelona, the Port of Vancouver as well as the Port of Hadera. The interviewees of all three Port Authorities mentioned that other governmental organizations like the Israeli government for the Port of Hadera, the Ministry of Public (OPPE) and European Maritime Safety Agency (EMSA) for the Port of Barcelona and Transport Canada, a government department of Canada have a high influence on the decision making process. The three ports have high volumes of non-containerized cargo with Hadera mostly shipping coal, Barcelona being the forth biggest cruise harbor in the world and Vancouver shipping bulk including special commodities like fertilizer, soy beans and grains. An assumption could be that the stakeholder interest and power grid shifts depending on the cargo that is mainly being handled resulting in public authorities having a higher power and interest. However, this aspect is out of the scope of this research and needs further verification.

Relationships between stakeholders and relevance of competition:
Figure 4.24 visualizes the opinions and perceived importance of competition by the different interviewees for their port. The attributes marked in green display a positive relationship, while the attributes marked red are perceived as negative. The blue bars are neutral as the interviewees were stating facts rather than sharing their opinion on the influence on competition.

The interviews shed light on the multi-faceted role of competition within the port call process and illustrate its importance from different perspectives. Competition emerged as a critical factor used as a means to achieve PCO and a catalyst for the success of the port call process. In addition, the interviews revealed an intricate dynamic among nautical service providers that revealed the complex relationships among them in the competitive landscape.

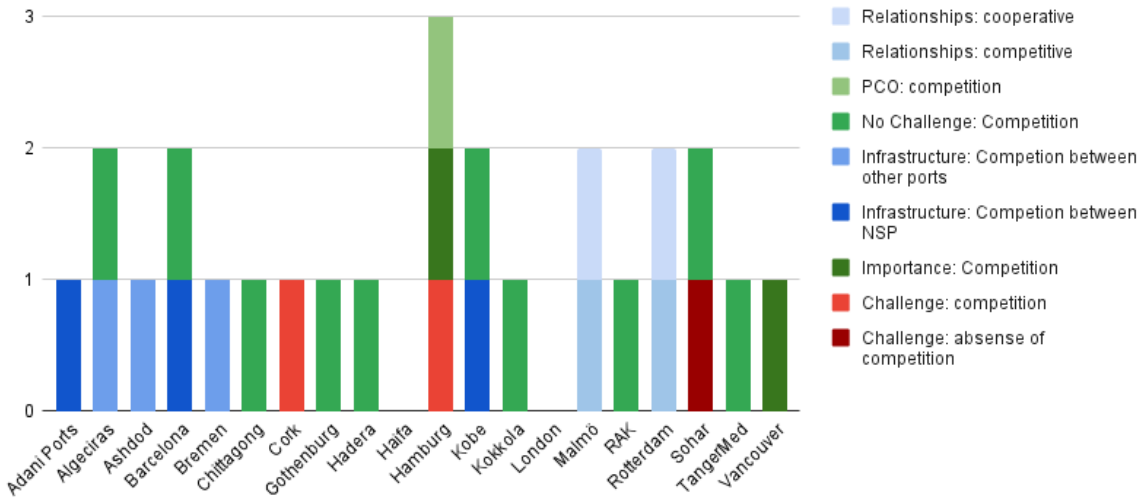


Figure 4.24: Opinion towards Competition

The impact of competition wasn't uniform across all ports. In two cases, competition among service providers was perceived as a challenge. Notably, these two ports, one being a tool port and the other a landlord port, expressed concerns about the absence of competition, emphasizing that its presence could enhance the efficiency of the port call process.

Interestingly, for ten ports, competition, although potentially present, was not considered a significant challenge. This perspective was reflected in the data, with the "No challenge: competition" category often appearing as a dominant theme.

Moreover, competition in the ports took two different forms. On the one hand, it manifested itself within the port boundaries and fostered competition between the various nautical service providers (NSP), which is referred to as "Infrastructure: Competition between NSP" denoted and highlighted in dark blue. On the other hand, competition extended beyond the boundaries of the port and led to competition between different ports (marked in light blue as "Infrastructure: Competition between other ports". However, it can be assumed that even though competition might not be a challenge perceived by PA in terms of resource availability, referring back to the challenges mentioned in subsection 4.5.3, inaccurate information, information sharing among stakeholders as well as the resistance from different stakeholders seems to be a challenge. A relation between these challenges and competition can be assumed as many stakeholders fear to show their weaknesses and flaws when they share (accurate) information. Exposing their weaknesses can be disadvantageous for the competitiveness of the service. Resistance from different stakeholders and information sharing among stakeholders in general also has a relation with competition as organizations generally are more hesitant to share sensitive information with their competition. Even if the information might not intentionally be shared with other service providers, organizations often resist to share if it cannot be fully ensured that no information

influencing their competitiveness (both positively and negatively) will be published.

Compensation and Incentives in PCO:
The Port of Kokkola and TangerMed stand out for their efforts with regard to PCO, having fully integrated technologically advanced PCO measures — a remarkable feat compared to many other ports still in the early planning or initial implementation stages. This achievement was not without its share of challenges, as noted by the interviewee of the Port of TangerMed+.

One notable challenge the port faced was the resistance of stakeholders to share their information. Introducing changes or new measures often leaves the individual benefits unclear to each party involved. Therefore, transparent communication becomes paramount in addressing these concerns. TangerMed's approach spanned four years, favoring a gradual transition over immediate, radical change. Rather than requesting all information at once, the PA initially sought specific data, along with explanations of why it was needed and how stakeholders would benefit from sharing it. Over time, stakeholders began to recognize the advantages and developed trust in the process and managing organization, thus becoming more willing to share information. Nevertheless, occasional complaints still arise regarding priorities, conditions, and related matters. In response, the PA regularly conducts meetings and workshops to identify where additional information sharing is necessary. In the end, the interviewee emphasized that it's always a matter of negotiation — sharing information in exchange for access to other crucial data.

The implementation of new solutions within the context of port operations, including gaining acceptance from all relevant stakeholders, is a process that demands a significant investment of time, typically spanning around five years or even longer. This argument was not only brought by the interviewee from TangerMed but also by the general director of the HVCC, the CEO of Adani Ports, the representative of the Smart Port Alliance and the interviewee from Algeciras port. This extended timeline is largely attributed to the considerable negotiation and collaboration required with the various parties involved.

Initiating change in the port industry depends on the willingness of decision-makers to embrace innovative and novel solutions. If these leaders are resistant to change and refuse to alter established practices within the port, even the most promising solutions may not sway their decisions. To foster a successful transformation, decision-makers must exhibit trust in the proposed changes and be willing to take calculated risks, acknowledging that the full benefits of a solution may only become evident after it has been implemented and used over a period of time.

In addition to decision-makers, the front-line workers responsible for operating these systems must also be open to change. Conducting training sessions and workshops can significantly contribute to their understanding and acceptance of new systems. It is essential to emphasize how the transition from current work processes to a new system ultimately benefits these workers, ensuring their buy-in.

Surprisingly, technology itself is rarely the primary obstacle during implementation (also mentioned by Adani Ports and the Port of Algeciras among others). Technical issues or bugs can often be resolved relatively easily. Instead, the critical factor for successful implementation is the mindset of the individuals involved. Influencing the mindset of stakeholders positively is a fundamental aspect of a smooth transition, building trust and demonstrating that the process is mutually beneficial.

While monetary compensation or hierarchical enforcement may drive initial compliance, these methods are seldom sustainable in the long term. When financial incentives or force are removed, parties are prone to reverting to their old work habits. Therefore, building a genuine commitment to change through collaboration, trust, and mutual benefit is far more effective in achieving lasting transformation in the port industry (HVCC).

The use of regulatory or legal support as an enforcement tool presents a dual-edged impact. When these legal measures are current and in alignment with evolving needs, they can facilitate the widespread adoption of PCO among various stakeholders, even though they might not want to collaborate in the first place. However, legal mandates tend to evolve slowly and may not always guarantee benefits

for every party involved. Consequently, they can pose obstacles when attempting to introduce new innovations or changes. Hence, the strategy of persuading stakeholders to collaborate through legal enforcement should be approached with caution and careful consideration.

4.6. Key Findings of the Interview Analysis

To conclude this chapter a concise overview of the key findings and insights drawn from the interviews and the followed analysis is given.

Port Size and Categorization: The study categorizes ports into large, medium, and small based on their annual TEU throughput, emphasizing the unique challenges faced by each category. This classification, however, primarily considers container shipping, sometimes overlooking the diverse activities some low-TEU ports are involved in.
Inland and Seaport Classification: The distinction between inland and seaports reveals an imbalance in research representation. Although valuable, this classification requires caution due to location-specific influences on port activities.
Port Governance Structures: The categorization of ports into public, tool, landlord, and private showcases the dominance of landlord ports. Broadening the sample pool is advised for comprehensive insights.
Company Objectives in Port Calls: Port companies exhibit a spectrum of objectives, including efficiency, safety, sustainability, collaboration, and port call optimization. These objectives underscore the multifaceted priorities of port stakeholders, from efficiency to sustainability and collaboration.
Variations in Objectives: Smaller ports actively pursue sustainability, while larger ports might view regulatory compliance already as their sustainability efforts. Efficient operations remain a universal priority, irrespective of port size.
Objectives by Governance Structure: Objectives vary among governance structures. Public ports focus on efficiency, while landlord ports place equal importance on sustainability. Private ports display a scarcity of objectives. Tool ports highlight sustainability, warranting further investigation due to limited representation.
Common Challenges in Port Operations: Port challenges include inaccurate information, resistance to new technologies, weather-related obstacles, regulatory constraints, and employee-related issues. These challenges transcend size and governance structure, suggesting the need for further examination.
Variations in Challenges: Large ports encounter greater challenges in stakeholder resistance and information sharing, influenced by their complexity. Smaller ports face fewer challenges in these aspects but grapple with inaccurate information and challenging weather conditions.
Port Call Optimization (PCO): PCO is revealed as a multifaceted concept, encompassing infrastructure enhancements, pre-arrival strategies, technology integration, and stakeholder communication. Ports recognize its importance in enhancing efficiency and effectiveness.
Centralization: The study highlights the role of centralization in streamlining port call processes. Most interviewees advocate for centralized planning, whether led by Port Authorities or through external platforms, underscoring its importance in enhancing port operations.
Key Stakeholders and Competition: Key stakeholders in the port call process include the Port Authority, pilots, tugs, shipping agents, captains, and terminals. Competition influences some ports more than others, fostering competition among service providers and between ports.
Challenges in Achieving PCO: Ports integrating PCO measures face stakeholder resistance. Transparent communication, gradual transitions, and trust-building are critical in overcoming this resistance.
Role of Decision-Makers and Stakeholder Mindset: Initiating change relies on decision-makers' willingness to embrace innovative solutions. Positive influence on stakeholder mindset through trust-building and mutual benefit is essential for smooth transitions.

In summary, the findings emphasize centralization, effective communication, and the multifaceted nature of Port Call Optimization (PCO) as key elements in enhancing port operations and the port call more specifically. This research provides a solid foundation for further exploration and improvement in the maritime sector.

5
Conceptual Model Framework

In the course of this study, the stakeholders influencing port call decisions and measure adoption were carefully identified through a comprehensive literature review, and these findings were substantiated through conducted interviews. Notably, stakeholders with both high power and high interest, prominently featuring the Port Authority and key nautical service providers such as pilot and towage organizations, emerged as pivotal players in the implementation of port call optimization measures. The objectives identified in the interviews, along with the means to achieve the objectives, have laid a solid foundation for understanding the complex dynamics at play. A significant portion of the challenges encountered during port calls resides at interorganizational or organizational levels, presenting a potential nexus for resolution through effective (collaborative) PCO measures. However, prior to implementation, a thorough understanding of all relevant conditions is imperative. While chapter 2 and chapter 4 have identified several critical conditions, a comprehensive summary and visualization of the complete list of prerequisites are still pending. The following chapter will therefore deal with the development of a conceptual model that closes the gap between the literature and interview analysis and the practical implementation of measures to optimize port calls.
In the pursuit for collaborative port call optimization, traditional frameworks like the Technology, Organization, and Environment (TOE) framework fall short in capturing the intricate relationships within the port call ecosystem. Recognizing the importance of harmonizing stakeholder efforts, the TOE framework is enhanced with an "Interorganizational Arrangements" dimension, acknowledging the collaborative synergy crucial for overall progress. This context clarifies mechanisms nurturing collaboration, transforming it into a shared endeavor among individuals and organizations. The following sections explain the emerge of the framework on a theoretical basis (section 5.1), discuss components and assign pre-conditions previously identified in literature and interview analysis (section 5.2),validate the models through industry and academia experts (section 5.3), introduce the PCO adoption framework (section 5.4), leading to an intermediate conclusion (section 5.5).

5.1. Theoretical Foundation - TOE Framework

The relevant literature that contributed to the development of this model includes references such as Baltazar and Brooks [12], Adrichem [4], Zhang et al. [101], Brinkmann [17], Baker [11], Premkumar and Ramamurthy [72], Grover [34], Vairetti et al. [95], De Martino et al. [23], and Zeng, Chan, and Pawar [100]. This literature could be identified searching for existing (port) governance frameworks (resulting in Baltazar and Brooks [12], Adrichem [4], Zhang et al. [101], Brinkmann [17], and Baker [11]) as well as interorganizational adoption ([72, 34, 95, 23, 100]. The framework, as illustrated in Figure 5.3, is primarily based on the insights gathered through interviews and the analysis of the following literature including Baker [11], Premkumar and Ramamurthy [72], Grover [34], Vairetti et al. [95], De Martino et al. [23], and Zeng, Chan, and Pawar [100]. To start of, the TOE framework by Tornatzky, Fleischer, and Chakrabarti [89] is briefly described as it's elements provide the basis of the underlying framework.

The TOE (Technology-Organization-External Environment) framework presents a comprehensive organizational level theory that explains the factors influencing adoption decisions within firms. It is widely used for describing technology adaptation in organizations in general [4]. The framework consists of three fundamental elements comprising the technological context, organizational context, and environmental context, all exerting substantial influence on technological innovation.

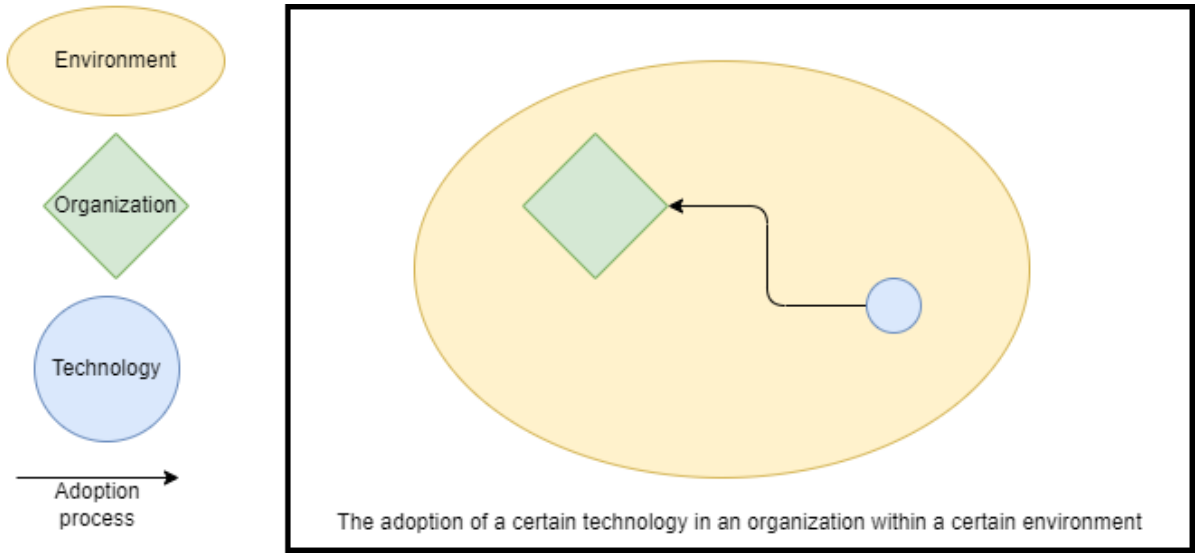


Figure 5.1: TOE Framework by [89]

Figure 5.1 visualizes the adoption of a certain technology in an organization within a certain environment as envisioned in the TOE-framework.

Technology: The technological context encompasses the entirety of technologies pertinent to a firm, encompassing both those currently in use and those available in the marketplace but not yet adopted. Existing technologies within a firm set boundaries for the scope and velocity of technological transformations. In addition, innovations that already exist but have not yet been implemented by the company highlight the range of possibilities and provide insight into how technology can drive development and adaptation [11].
Organization: The organizational context characterizes a firm's attributes and resources, including internal communication structures, size, and resource availability. Various facets of this context impact adoption and implementation decisions. Mechanisms fostering internal collaboration and spanning organizational boundaries promote innovation. The presence of informal linking agents such as product champions, boundary spanners, and gatekeepers is associated with adoption. Cross-functional teams and employees with formal or informal links to other departments or value chain partners exemplify such mechanisms. Furthermore, studies have examined the relationship between organizational structure and the innovation adoption process.
External environment: The environmental context includes industry structure, the presence of technology service providers, and the regulatory environment. The impact of industry structure on innovation adoption has been studied and shown that intense competition creates incentives for innovation. Dominant firms within the value chain can exert influence on other partners to drive innovation [11].

Tornatzky, Fleischer, and Chakrabarti [89]'s TOE framework focuses on understanding the interplay between technology, organization, and the environment. It's a well-established framework for analyzing how technology adoption and implementation are influenced by organizational factors and the external environment. In the conventional TOE framework, which takes a systematic and comprehensive perspective on systems, these three elements are the sole considerations. However, when multiple organizations are involved in collaborative efforts, this framework necessitates an additional layer of classification to account for the interactions among these organizations.

TOE vs. TOEI - Interorganizational Arrangements Environment

In contrast to the TOE framework and similar to Vairetti et al. [95], the new approach recognizes the presence of multiple organizations and acknowledges the complex dynamics at play between these entities. It emphasizes the collective nature of these interactions, highlighting intersubjectivity as a key factor. In doing so, a more nuanced view that goes beyond the traditional organization-technology-environment triad is taken, providing a more comprehensive understanding of adoption conditions when multiple

organizations collaborate.

A port is not an organization but a complex system in which multiple organizations settle down. Those individual organizations have to collaborate to successfully conduct a port call. When talking about multi-adoption or multi-stakeholder problems, the conventional TOE-framework is not sufficient as it does not cover something that needs to be adopted by multiple organizations. Before being able to adopt, the various organizations need to be aligned so that everybody moves at the same time and does exactly what is needed. They all adopt together. In order for that multi-adoption to take place an orchestrator is needed. The orchestrator is a separate process which is defined by the interorganizational arrangements.
A port call optimization measure adopted in the port needs to be adopted by all of the involved parties. However, as there are high dependencies between the different organizations it can be assumed that only if the different organizations cooperate and work together, the adoption of the technology can be successful. In order to optimize the port call it is not enough to locally optimize per organization but an interorganizational optimization needs to take place. Figure 5.2 visualizes the adoption of a certain technology within a certain environment on a multi-organizational level. In the extended TOE-Framework the “Interorganizational Arrangements” was added to the framework and is illustrated in the figure with red lines. It shows that the organizations have to work together interorganizationally and only then the adoption will succeed.

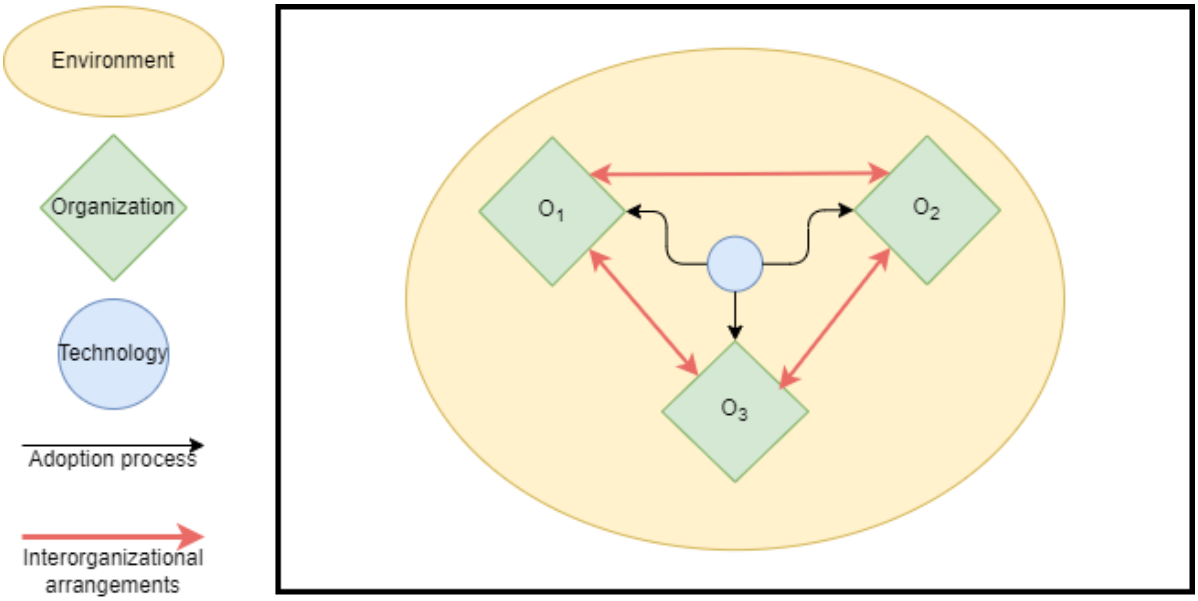


Figure 5.2: Extension of TOE framework

Based on the reasoning given above, an adoption of the original TOE-framework is required to determine what the pre-conditions of adoption of collaborative PCO in a port are. To answer that question, an additional layer, namely the *”Interorganizational Arrangements”* was added to the framework. Figure 5.3 provides an overview of the adapted framework. In a later stage, empirical research is required for validating the framework and making it applicable in practice within the port industry. In section 5.3 the results of this validation step can be found.

5.2. Components of the Conceptual Model

The underlying framework visualized in Figure 5.3 consists of four contexts which all have an influence on the adoption of PCO. As mentioned in section 5.1 are the three contexts based on the framework designed by Tornatzky, Fleischer, and Chakrabarti [89], namely Technology, Organization and (external) environment. In the TOEI-framework, the adapted version of the TOE-framework, a fourth context, the ”interorganizational arrangements”, is added. The four contexts are framed by the port as a whole system in which the adoption takes place. Figure 5.3 shows the simplified or general version of the

TOEI-framework.

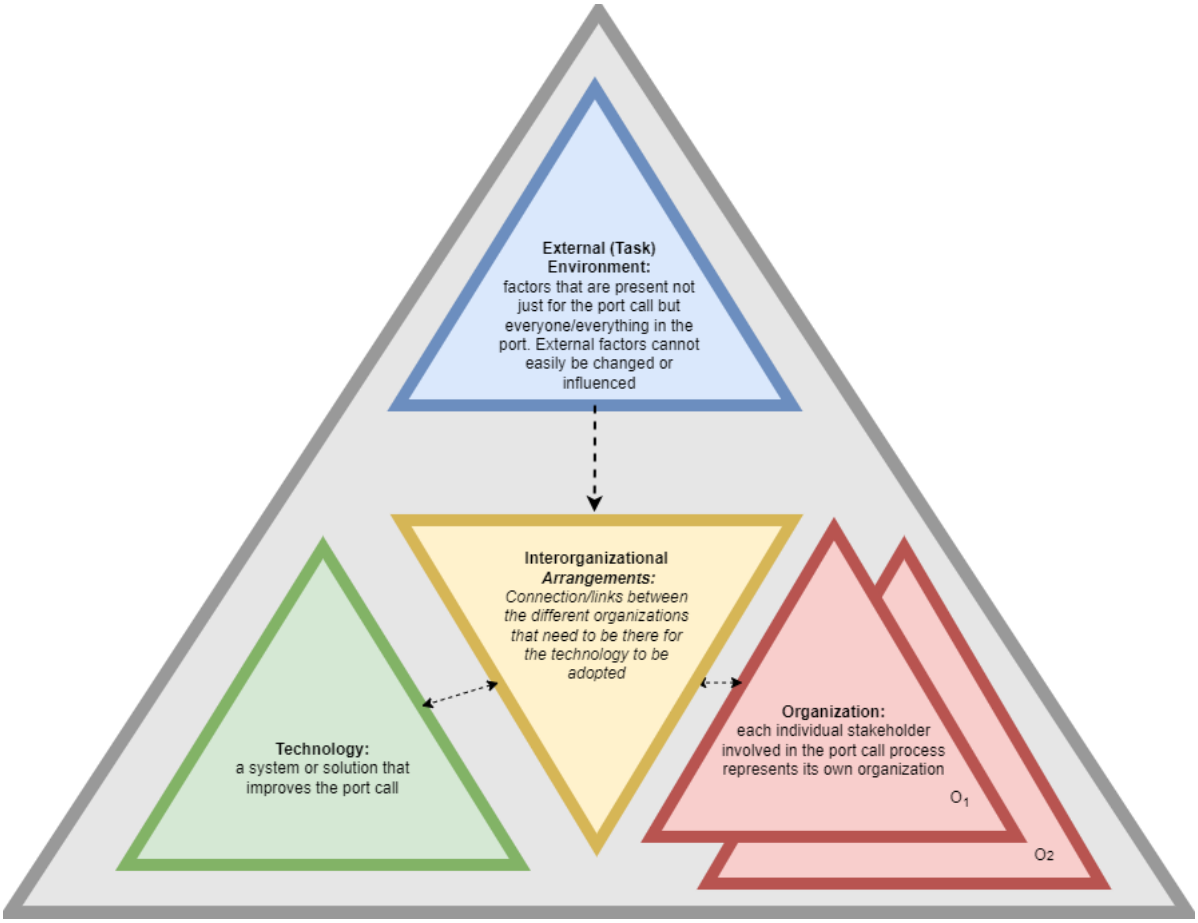


Figure 5.3: Conceptual Framework for the interorganizational adoption of technology

The gray triangle encircling the other four triangles serves as a representation of the port as a whole. It symbolizes the system in which the adoption occurs and where individual organizations operate. It also indicates the geographical focus of this context. Retaining the grey triangle, symbolizing an individual port, which is additional to the external environment context is crucial as it enables the potential for future collaborative Port Community Systems Operations on an inter-systematic scale, facilitating the utilization of this framework for more intricate adoption processes down the line.
Conversely, the green triangle highlights the technological dimension within the TOEI framework. Technology represents a system or solution that enhances port call operations, aligning with port call optimization measures to be implemented. Technology is subject to influence from organizations and the external environment through interorganizational arrangements, and it, in turn, exerts influence on them. It's a dependent variable intertwined with these relationships, and only when this interplay is mutual can successful technology adoption occur.
The red triangles represent the organizations. In contrast to the traditional TOE framework, multiple independent organizations coexist within the port, necessitating the depiction of two triangles to signify this complexity. Similar to the technology context, organizations are dependent variables influenced by and exerting influence on the other two contexts, namely interorganizational arrangements and technology. They do not, however, impact the external environment, which, in turn, can't be influenced and is symbolized by the blue triangle.
Lastly, the yellow triangle symbolizes interorganizational arrangements, introducing a new facet of the TOEI framework. These arrangements serve as the connection between different organizations, technology, and the external environment. They establish the mechanisms and structures that govern interorganizational dynamics, effectively facilitating interconnectivity and collaborative efforts within this context.

5.2.1. Technology

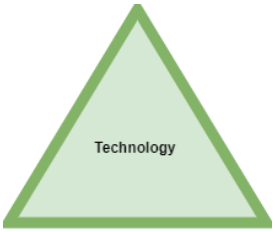


Figure 5.4: Technology context

The first context consists of technology. In the traditional TOE framework, the technological environment refers to the set of factors related to technology that can impact an organization's ability to adopt new innovations. For this research technologies can be defined as a "solution or system that makes the port call work better". It is an idea to do something; a package or formula and enabler to success but not a process. A technology should not be limited to hardware or software as it can take many other forms. If it a package that needs to be adopted not just by one organization but by the whole port community. However, it is possible that a certain technology, practice or measure points more towards specific organizations that then have to take the lead. But only if parties work together, PCO can work.

There are different levels of technology bringing discontinuous change or radical change, synthetic change or incremental change. Depending on the type of technology that should be adopted, more or less drastic change (i.e. including infrastructure or societal changes) needs to happen in order for the adoption to be successful. For more explanation on the different levels of technology, please refer to Tushman and Anderson [93].

Technology can be related firstly to the general digital infrastructure the port or the individual service providers are already providing. This can include ICT's (Information and Communication Technologies) like Port Community Systems, digital planning or scheduling tools, an external organization formed to take over the planning and scheduling like the HVCC represents it for the Port of Hamburg [Source: interview 11] or other collaboration measures. In chapter 2 several PCO measures have been identified and sources discussing port call optimization measures in general been analyzed. For a more detailed overview of the different measures, please refer to this chapter. However, this context also relates to the level of technology that is already implemented (ie. does the port solely communicate via "traditional" communication channels such as VHF and email or does the port provide advanced digital solutions which can potentially be integrated by other actors or even ports [34, 60, 100].
First identified in literature and later confirmed by the conducted interviews, technology has a big impact on Port Call optimization as it enables the streamlining of complex maritime operations, enhances efficiency, and minimizes costly delays [44]. Through real-time data collection, analysis, and communication systems, technology offers ports the capability to monitor vessel movements, berth availability, cargo handling, and weather conditions with precision [Source: interview 8, 18] [70]. This information empowers port authorities and stakeholders to make informed decisions, allocate resources effectively, and coordinate port activities seamlessly. Additionally, digital platforms and automated systems facilitate collaboration among various actors in the supply chain, enabling smoother information sharing and improving the overall planning and execution of port calls [49]. Ultimately, technology-driven solutions not only optimize port operations but also contribute to reduced emissions, lower operational costs, and enhanced competitiveness in the global maritime industry [49].

The **function** of the technology context plays a pivotal role in collaborative Port Call Optimization by delineating the current and potential technological landscape within a port. It defines the parameters for technological advancements, guiding the selection and integration of innovative solutions. This context serves as a roadmap for leveraging existing technologies and exploring untapped innovations, providing a foundation for the strategic development and adaptation of technology-driven solutions.

As already mentioned is technology in this context not only limited to hard- or software but it includes a solution or system that makes the port call work better in general. In section D.1, an extensive inventory of pre-conditions identified during the literature analysis in section 3.1 and validated and enhanced during the interview analysis in chapter 4 have been categorized into two distinct groups: must-haves and nice-to-haves. This categorization comes complete with an explanation of the rationale behind their placement in each category.

Must-haves on the one hand represent specific conditions or criteria that a product, system, or project must satisfy to be deemed successfully completed. On the other hand, nice-to-haves encompass a

broader vision and purpose, serving as guiding principles for the system's adoption efforts in pursuit of its desired goals.

To provide a quick overview of both the requirements and objectives, Table 5.1 can be referred to. More detailed explanations of the requirements are presented in the subsequent paragraphs.

Table 5.1: Must-haves and Nice-to-haves of Technology Context

Technology Context	
Must-haves	**Nice-to-haves**
Technology Readiness Data sharing standards Multi-User	Technology integration complexity Internal Technologies External Technologies Information intensity Technology competence

Technology Readiness:
Technology readiness mentioned by several authors including Grover [34] and Nikghadam et al. [60] and in different interviews [Source: interview 11, 18, 21] refers to the state of preparedness and suitability of the solutions that are required for the collaborative port call optimization process. It involves assessing whether the necessary technology tools, software, and infrastructure are in place, functional, and capable of supporting the intended operations. Again, it is important to note that technology readiness encompasses not only hardware and software but also the entire approach, methodology, and tools that contribute to making the port call operations more efficient, coordinated, and effective.
Technology readiness is a must-have because it encompasses the readiness of the comprehensive solution or approach that drives the optimization of port call operations. It includes the entire package that facilitates improved performance. Without a state of readiness for this holistic solution, the adoption process cannot effectively proceed. The readiness of the technology solution ensures that the port call process can be streamlined, leading to better resource allocation, enhanced coordination among stakeholders, and overall optimization. In general, collaborative PCO is often brought in context with technology and digital solutions [Source: interview 1-8,12-14,18-20 and chapter 3]. Without the readiness of the required technology, the adoption process cannot effectively proceed. The technology must be in a state where it can meet the specific needs of the port, enabling efficient data sharing, communication, and optimization processes. Any technological shortcomings can hinder the success of the adoption, as it depends on these tools to streamline port operations, optimize resource allocation, and enhance coordination among stakeholders.

Data Sharing Standards:
Data sharing standards refer to the established protocols and formats for exchanging information and data among different stakeholders involved in port operations. These standards define how data should be structured, transmitted, and received to ensure consistency and interoperability [34, 60, 70].
Data sharing standards are a must-have or requirement for the adoption of collaborative PCO because they provide a common language for information exchange among diverse organizations and entities in the port. Standardized data sharing ensures that data is accurately and seamlessly transmitted and received, preventing data incompatibility or miscommunication. Without these standards, data sharing can become chaotic and inefficient, undermining the effectiveness of collaborative port call optimization. It's essential for stakeholders to have a shared understanding of how data should be structured and shared to achieve the optimization goals.
In the conducted interviews it was discovered that inaccurate information is a frequently occurring challenge [Source: interview 8]. By implementing data sharing standards this problem can be partially counteracted.

Multi-User:
In the technology context, multi-user can be referred to as the ability of the technology/PCO measure to be adopted and integrated by multiple users. It should connect multiple stakeholders and allow for collaboration in one way or another [95].

Especially for the adoption of *collaborative* PCO Multi-User is a must-have, as it allows multiple stakeholders, including port authorities, shipping companies, and nautical service providers, to interact within a unified technology/platform. This is essential for effective collaboration, real-time decision-making, transparency, operational efficiency, scalability, and security. Ports involve complex, simultaneous activities, and a ”multi-user” system ensures that all parties have access to the same real-time data, promoting streamlined operations and preventing miscommunication. ”Multi-user” technology is vital for achieving the collaborative optimization goals of diverse port operations stakeholders.

5.2.2. Organization

Figure 5.5: Organization context

The organizational environment, a crucial dimension in the TOE framework, plays a pivotal role in the successful integration of collaborative PCO. In the port call context, where each stakeholder is treated as its own organization, encompassing entities like Port Authorities, towage organizations, shipping companies, and pilots, the power dynamics and interests during the port call are diverse (see Figure 2.1 in section 2.2). Balancing these different interests is an integral part of the functions of inter-organizational agreements, which introduce a balancing system that requires the resolution of optimization priorities. Determining what to optimize for and establishing arrangements among stakeholders, guiding their behavior for successful optimization, becomes a key challenge. Unlike the traditional TOE framework, the extended TOEI framework recognizes these complexities. Within collaborative PCO, the organizational context becomes a critical factor, shaping internal dynamics, communication structures, and resource availability. Understanding the organizational structure becomes imperative for effective collaboration, ensuring resource alignment, and creating an environment conducive to the successful implementation of optimization initiatives.

In Table 5.2, a general overview of the must-haves and nice-to-haves in this context can be found. Similar to the previous context are the pre-conditions again based on literature and interview analysis discussion in chapter 2 and chapter 3. The extended list including also the reasoning behind the categorization is provided in section D.2.

Table 5.2: Must-haves and Nice-to-haves of the Organizational Context

Organization Context	
Must-Haves	**Nice-to-haves**
Financial resources	Organization/firm size
PCO awareness	Perceived financial cost
PCO necessity awareness	Managerial obstacles
Perceived benefits	Satisfaction with existing systems
Intra-firm communication	Stakeholder pressure
	Wages

Financial Resources:
Financial resources refer to the availability of sufficient funds and capital within the organizations involved in port operations to support the adoption and ongoing implementation of collaborative port call optimization. This includes budgetary allocations, financial investments, and funding necessary for technology, infrastructure, and human resources [95].
Financial resources are a must-have because collaborative port call optimization often requires large investments in technology, infrastructure, training, and other resources. Without adequate financial resources, organizations may not have the means to acquire the necessary tools, implement the required changes, and sustain the optimization efforts over time. Financial resources are essential for covering the costs associated with technology integration, process improvement, and coordination efforts. According to the interviewee of the Smart Port Alliance it can be difficult to get investors for PCO implementation measures as large investments are often required upfront which are then used up over 10-15 years [Source: interview 21]. Before adopting any PCO measures the implementing parties should be aware of the financial costs and make sure the willingness to use as well as the availability

of the resources is given. To enhance the willingness of an organization to use their resources for collaborative PCO adoption, a compensation system based on the incentives of the stakeholder can help. The compensation and incentive structure is further discussed in the interorganizational context.

PCO Awareness:
PCO awareness refers to the knowledge and understanding of collaborative port call optimization among the various stakeholders involved in port operations. It involves being aware of the concepts, benefits, and objectives of PCO and how it can enhance port efficiency and effectiveness. While conducting and later on analyzing the interviews it became evident that different ports have a different understanding of Port Call Optimization and the measures that can lead to PCO. For some including TangerMed, Hamburg and Rotterdam, among others, PCO correlated strongly with collaboration. For others (i.e. the Port of Hadera and Chittagong) PCO could also be achieved by updating the physical infrastructure inside the port. The interviews were mostly conducted with representatives from the Port Authorities. Therefore, it is not clear, how much knowledge the other actors involved in the Port Call of the different ports have on PCO. However, as especially the nautical service providers hold a high power and interest during the port call (see Figure 2.1 and Figure 4.23) it is important that they are aware of the applied definition of PCO inside their port.
PCO awareness is essential for the adoption of collaborative PCO because without a clear understanding of what collaborative port call optimization entails and the potential benefits it can bring, organizations may not be motivated to support its adoption. Awareness is the foundation for alignment and buy-in among organizations and individuals. When stakeholders are aware of PCO and its advantages, they are more likely to actively engage in the adoption process and work toward its successful implementation.
PCO awareness is not to be mistaken with PCO necessity awareness. PCO awareness includes the general awareness of the organizations that PCO exists and includes being aware of the kind of measures and possibilites that exist in the market and could potentially be adopted.

PCO Necessity Awareness:
PCO necessity awareness involves recognizing the vital importance of collaborative port call optimization within the port environment, emphasizing that it is not solely a technological solution but a crucial strategy for enhancing port efficiency, reducing costs and emissions, and improving overall operations. This awareness extends to acknowledging that current processes and operations may not be optimal, requiring an understanding of existing flaws and challenges, such as ”long waiting times,” ”unavailable resources,” ”inaccurate information,” and ”information sharing among stakeholders.” Recognizing these challenges and understanding the potential impact of collaborative PCO adoption in addressing them is crucial for motivating organizations to participate in PCO initiatives [60, 72, 29, 59].
PCO necessity awareness is a must-have because it lays the foundation for stakeholder buy-in and commitment to the adoption of collaborative port call optimization. When stakeholders are aware of the necessity and value of PCO, they are more likely to actively support its implementation. They understand that it is not just a technology but a strategic imperative for the port’s competitiveness and sustainability. PCO necessity awareness encourages stakeholders to align their efforts and resources with the optimization goals, making it more likely for the initiative to succeed. It drives a sense of purpose and urgency for adopting PCO.

Perceived Benefits:
Perceived benefits, in the context of collaborative port call optimization, refer to the anticipated advantages and positive outcomes that stakeholders expect to achieve from the adoption of the comprehensive solution or approach. These benefits can include increased efficiency, reduced costs, improved coordination, and optimized resource utilization, among other advantages associated with port operations. Several sources including De Martino et al. [23], Nikghadam et al. [60], and Vairetti et al. [95] have identified this pre-condition as a relevant factor for PCO adoption. This pre-condition is considered a requirement because it drives motivation and buy-in from stakeholders. It is important to recognize that in different ports, various stakeholders may possess different levels of power and interest in the port call process (as previously identified in the power-interest, see Figure 2.1), leading to distinct perceived benefits. Therefore, ensuring that each stakeholder group receives tangible benefits from the adoption

of PCO measures is crucial. If the perceived benefits are not clear to the stakeholders, there is a risk that they may not be willing to join the initiative. In cases where the benefits are not evident, it becomes essential to establish a compensation system to guarantee stakeholder willingness to participate and to create an artificial benefit that aligns with their interests and concerns.

Intra-Firm Communication:
Intra-firm communication refers to the exchange of information and messages within an organization. It involves effective communication channels and practices among different departments, teams, and individuals within the same organization. Information sharing standards and protocols are also included in this pre-condition.
Intra-firm communication is a requirement because it is fundamental to internal coordination and collaboration. Effective communication within an organization ensures that teams and departments can work together smoothly, share vital information, and align their efforts toward the successful implementation of PCO. It is essential to break down silos, improve teamwork, and facilitate the changes required for optimization. Without strong intra-firm communication, the adoption process can be hindered by internal barriers and misalignment. Good intra-firm communication increases the chances of achieving local optimization. If the organization has well-working communication flows, the required information for the port call will be available at the requested time, and even short-term process changes can easily be communicated and therefore be handled accordingly, ultimately leading to global optimization which is the goal of collaborative PCO.

5.2.3. External Environment

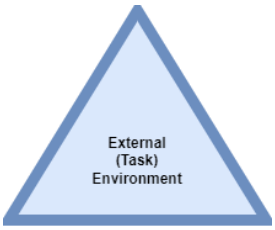


Figure 5.6: External Environment context

This third context in the TOEI-framework considers not only the traditional external factors but also factors related to interorganizational dynamics. Identified pre-conditions include regulatory frameworks that support collaboration, industry-wide standards for data exchange, and a culture of cooperation among port stakeholders. Additionally, traditional factors like the geographical location of the port, taking into account natural constraints like tidal or light restrictions, the port's size, typically measured in TEUs (twenty-foot equivalent units), and the diverse range of cargo types it handles, such as container vessels, break bulk, car carriers, passenger transport and others, are also integral components of this context. The available infrastructure, notably the distance between the port station and terminals, also falls under the purview of this context. It is important to note that these factors are often predetermined and less accessible to rapid changes, given that they form fundamental aspects of the port's operational framework. Therefore, there is only a one-way relationship between the external environment and the interorganizational arrangements directed from the external environment (see Figure 5.3). The external environment consists of independent variables that influence the port call (such as the weather), but which are difficult or impossible to influence through human intervention. This property makes this dimension special compared to the other three contexts, as it is the only independent dimension. The other contexts are dependent variables, which are characterized by relationships in both directions (see Figure 5.3). Understanding the external elements is critical because they underpin the unique conditions and motivations for port call optimization (PCO) implementation. Factors included in the external environment context refer to the general environment which is not just there for the Port Call but for everyone and everything that is related to the port.
The external environment context is a guiding force in collaborative Port Call Optimization, considering industry structure, technology service providers, and regulatory frameworks. It influences the collaborative dynamics within a port by creating incentives for innovation in competitive environments. Recognition of the impact of dominant firms within the value chain shapes the collaborative agenda. This context functions as a strategic compass, helping ports identify external opportunities and challenges, ultimately guiding the collaborative efforts toward effective Port Call Optimization.

In the context at hand, a range of pre-conditions has been identified. The comprehensive list, encompassing both requirements and objectives, along with their definitions can be accessed in section D.3. For a broad summary of these requirements and objectives, Table 5.3 can be referred to. Detailed explanations of the requirements follow in the subsequent paragraphs.

Table 5.3: Must-Haves and Nice-to-haves of External Environment Context

External Environment Context	
Must-haves	**Nice-to-haves**
Geographical Location of the Port Type of Port Legal Structure/Regulatory Environment	Demand Factors/Demand Level Perceived Industry Pressure Location of Port External Restrictions Level of Competition Size of the Port Number of Movements in Port Amount of Resources Distance to Berth Amount of Activity Besides Container Vessels Number of Actors Involved in the Port Call Management Risk Position

As the contexts the ports are located can vary, many of the ”traditional external factors that cannot really be influenced have been classified as nice-to-haves. They are important to consider when adopting port call optimization, however when a customized solution is considered, they are usually not the factors hindering the implementation.

Geographical Location of the Port:
Geographical location refers to the specific physical location of the port within its region or along the coast. It includes factors such as the proximity to shipping routes, neighboring ports, and the accessibility of the port from land and sea. Factors like competition to other neighboring ports play into this pre-condition among others.
This pre-condition is a must-have because it significantly impacts the port’s role and operations. Ports located at strategic positions relative to major shipping routes or in proximity to significant markets have a competitive advantage. The geographical location of a port can affect the volume of shipping traffic it receives, the types of vessels it accommodates, and the complexity of its operations. For collaborative port call optimization, a port’s geographic location can influence the extent of coordination required, the diversity of stakeholders involved, and the need for efficient optimization processes.

Type of Port:
The type of port refers to the classification of the port based on its primary function and the types of cargo or vessels it handles. Ports can be categorized as container ports, bulk cargo ports, general cargo ports, oil terminals, and more. Depending on the cargo handled, different stakeholders are involved in the port call and the incentive to adopt port call optimization changes. Furthermore, even though the stakeholders might be similar in different ports, their decision power and interest might vary. It is crucial to be aware of the underlying stakeholder power grid in the port to be able to identify the incentives and drives of the stakeholders towards the participation of PCO initiatives. Additionally to the varying stakeholders does also the plannability of vessel arrivals change. While container vessels and passenger ships usually have designated routes as they are considered liner traffic it is easier to plan the port call. However, the planning of a container vessel is more short noticed than the one of a cruise ship which is often already planned around two years in advance [Source: interview 3]. Bulk vessels frequently lack fixed routes and seldom make repeat visits to a specific port within a ”short” timeframe [Source: interview 13].
The type of port is a ”must-have” consideration because it dictates the nature of port operations and the specific challenges and opportunities faced. Different types of ports have distinct characteristics and requirements. For collaborative port call optimization, understanding the type of port is essential to tailor optimization strategies to the unique demands of that port. Optimization processes and technologies must be aligned with specific cargo and vessel handling procedures, which vary depending on the type of port.

Legal Structure and Regulatory Environment:
The legal structure encompasses the framework of laws and regulations governing port operations, including ownership models, property rights, and the legal rights and responsibilities of port operators and stakeholders. As previously discussed in section 2.4 currently exist four different governance structures including public, tool, landlord and private ports. However, it has also been identified that those existing structures do not always cover the reality of the pre-existing structures inside the ports [Source: interview 10, 17]. Therefore, an individual evaluation of the existing governance structure inside the port is recommended. The regulatory environment comprises all laws, rules, and regulations governing port activities, covering safety standards, environmental requirements, and other operational aspects. Legal structure and the regulatory environment are critical considerations for the adoption of collaborative port call optimization. Together, they shape the governance, authority, and decision-making processes within the port. Legal structures influence the control and authority of various stakeholders, impacting their willingness to collaborate. Furthermore, they give the direction of who should facilitate the adoption of the PCO measure. Depending on the existing legal structure and regulatory environment a centralized or decentralized structure for the adoption should be opted for. Understanding and adhering to the legal framework is crucial to ensure that optimization efforts are in compliance with regulations, particularly in areas such as safety, environmental impact, and security. It also affects how contracts and agreements are structured and enforced, which is essential for coordination. Compliance with these legal and regulatory requirements is indispensable for obtaining permits and approvals necessary for successful optimization initiatives.

5.2.4. Interorganizational Arrangements

Figure 5.7: Interorganizational Arrangements context

The ”Interorganizational Arrangements” context represents a significant advancement within the TOEI framework. The introduction of the new context also makes it possible to analyze complex systems in which more than one organization needs to adopt the technology, which is is only possible in collaboration with the other organizations involved. This context acknowledges the critical role played by specific structures, agreements, and mechanisms in fostering collaboration and mutual understanding among the diverse stakeholders that constitute the port call ecosystem. This dimension recognizes that while the traditional TOE framework provides valuable insights into technological, organizational, and environmental factors, it often overlooks the intricate web of interdependencies and interactions among these stakeholders. In the area of port call optimization, where seamless collaboration is key to success, this dimension is a significant addition that highlights the nature of collaborative efforts. This context is specifically tailored to recognize the intricate dynamics between multiple collaborating entities. It emphasizes the collective nature of interactions, highlighting intersubjectivity as a key factor. This context provides a nuanced understanding beyond the conventional organization-technology-environment triad, shedding light on conditions and dynamics that influence successful adoption. By recognizing and navigating the complexities of collaborative relationships, this context functions as a critical guide for ports seeking to optimize their port call processes through collaborative endeavors.
The pre-conditions assigned to the interorganizational arrangements-context, required for the adoption of collaborative PCO are the following listed in Table 5.4. Again, the full list of preconditions including the definitions and reasoning behind the categorization into must-haves and nice-to-haves can be found in section D.4.

Table 5.4: Must-haves and Nice-to-haves of Interorganizational Arrangements

Interorganiztional Arrangements Context	
Must-haves	**Nice-to-haves**
Inter-Organizational Communication and Collaboration	Incentive Structures
Collaboration Agreements	Communication Protocols
Information Sharing Protocols	Collaborative Platforms
Governance and Decision-Making	Data Governance
Conflict Resolution Mechanisms	Performance-Based Contracts
Cultural Awareness	Planning Horizon Structure

Inter-Organizational Communication and Collaboration:
Inter-organizational communication and collaboration refer to the active and effective exchange of information, data, and resources among the various stakeholders and organizations involved in port operations. It involves open and transparent communication, cooperation, and joint efforts to achieve common goals.
Inter-organizational communication and collaboration are ”must-haves” because they are the core elements of successful collaborative port call optimization. For stakeholders to work together seamlessly, they must communicate and collaborate. Efficient information sharing, real-time updates, and coordinated actions are critical for optimizing port operations. Additionally, considering that different stakeholders often have varied interests and incentives to share information, it is crucial to communicate transparently and clearly about the importance of sharing relevant information and what that shared information will be used for [Source: interview 18]. By articulating the specific benefits that information sharing can bring to individual stakeholders, such as increased efficiency, reduced costs, and improved decision-making, the motivation to collaborate and share information can be enhanced. Without strong communication and collaboration, stakeholders may work in isolation, leading to inefficiencies, delays, and missed opportunities for optimization.

Collaboration Agreements:
Collaboration agreements are formal contracts or arrangements established among different stakeholders and organizations involved in port operations. These agreements outline the terms, responsibilities, and commitments of each party regarding collaborative port call optimization [23, 59, 95].
Literature including Nikghadam et al. [59] and Vairetti et al. [95] discuss that collaboration agreements are ”must-haves” because they provide a structured framework for collaboration. They clarify the roles, responsibilities, and expectations of each stakeholder, fostering a common understanding and commitment to the optimization goals. These agreements address issues like data sharing, resource allocation, and dispute resolution. Additionally, the agreements are essential for aligning stakeholders and ensuring that everyone is pulling in the same direction.
Having collaboration agreements is a way to ”formally” ensure trust which can be difficult to achieve when competition is present or the managerial role is not completely neutral. Contracts might give people the security to adopt a solution even though they do not fully trust it yet.

Information Sharing Protocols:
Similar to the collaboration agreements define information sharing protocols the rules, methods, and standards for exchanging data and information among stakeholders. These protocols ensure that data is shared securely, accurately, and in a format that all parties can use effectively [59, 95].
Information sharing protocols are considered a must-have for the adoption of collaborative PCO because they ensure the quality and consistency of data exchange. In collaborative port call optimization, data accuracy and timeliness are crucial [59] [Source: interview 4]. These protocols set the standards for data sharing, making sure that information is readily available, up to date, and compatible with the systems used by various stakeholders. Consistent data sharing enhances decision-making and optimization efforts.

Governance and Decision-Making:
Governance and decision-making mechanisms involve establishing the structures and processes for making collective decisions among stakeholders. This includes defining roles, authority, and respon-

sibilities for governance bodies or committees. During the interviews, the importance of centralization as well as the recommendation of action when centralization cannot or should not be achieved, which is covered by this pre-condition, has been identified.
Governance and decision-making mechanisms are requirements or must-haves because they provide a framework for managing the collaborative process. They ensure that decisions related to port call optimization are made collectively, with input from all relevant parties. These mechanisms prevent conflicts and power struggles and help in achieving consensus. Clear governance structures also facilitate accountability and oversight. It is important to note that the governance structures in this context are not limited to the traditional structures public, tool, landlord and private port but go beyond those conventional definitions.

Conflict Resolution Mechanisms:
Conflict resolution mechanisms are processes and procedures for addressing disputes and conflicts that may arise among stakeholders during collaborative port call optimization. They offer a structured approach to resolving disagreements.
They are considered must-haves because conflicts can emerge when multiple stakeholders collaborate closely. These mechanisms provide a way to address disputes in a fair and transparent manner. They prevent conflicts from derailing the optimization process and ensure that disagreements are resolved in a way that preserves collaboration and alignment. This must-have is linked to several other pre-conditions, including how willing the stakeholders are to share accurate information and collaborate with other organizations. The interests of the different stakeholders need to be taken into account to find fitting conflict resolution mechanisms. Depending on the power and interest of the affected stakeholders, the proposed compensation or solution needs to be adjusted to individual interests, ensuring that conflicts are resolved effectively and that collaborative efforts can proceed smoothly.

Cultural Awareness:
Cultural awareness as recognized by De Martino et al. [23] as a pre-condition for any kind of port relation innovation adoption refers to the recognition and understanding of the diverse cultural backgrounds, values, norms, and practices of the various stakeholders and organizations involved in port operations. It involves being aware of the different cultural perspectives and approaches to business, decision-making, and collaboration and acknowledges that different cultural perspectives can influence behaviour, communication, and decision-making.
This pre-condition is a must-have for the adoption of collaborative PCO because it acknowledges that stakeholders come from diverse cultural backgrounds, and their cultural values and practices can significantly influence how they approach collaboration and decision-making. Understanding and respecting these cultural differences is crucial for effective communication, building trust, and ensuring that collaboration and optimization efforts are culturally sensitive. It helps prevent misunderstandings, conflicts, and misalignment that can hinder the success of collaborative port call optimization. It promotes a collaborative environment where stakeholders value each other's perspectives, leading to more successful collaborative port call optimization.

5.3. Model Validation

The validation serves as a tool through which the quality of the conceptual model is refined and improved. To ensure a comprehensive and well-rounded evaluation, three experts with different backgrounds were consulted: the first, a person with dual expertise from academia and industry, the second, an experienced industry expert and the third another academia expert. Their insights and critiques have been invaluable in assessing the robustness and practicality of the conceptual framework and have ultimately led to its further development to a more refined and ready-to-use state. This section presents the constructive feedback received, the revisions made in response, and the profound impact of this validation process on the clarity, relevance, and potential of the model for real-world implementation.

The first two feedback discussions were held via validation interviews while the third one with the expert from academia took place through email contact. The validation interviews were conducted at different points in time. The first interview with an expert from the UPT Erasmus, the Erasmus Centre for Urban, Port and Transport Economics in the Netherlands was conducted immediately after the finalization of the data collection period and only shortly, after the first draft of the model was developed. The second validation interview with the Port Call Optimisation Lead from the Port Authority of the Port of Rotterdam took place two weeks after the first interview. The second interviewee was also interviewed during the first round of interviews which have served to collect data regarding port call in the various ports. The third round of validation with a Professor of Information Systems and Business Analytics from the American University of Sharjah (United Arab Emirates (UAE)) followed again, two weeks after the second interview. Therefore, it was possible to already implement the feedback received in the first and second interview.

The three interviewees were selected to cover both the industrial perspective as well as the scientific/academic one. This way it can be ensured that the model is relevant for both research and practice.

Expert Profiles

The first interviewee has been actively involved in the Rotterdam innovation ecosystem for more than ten years, with a strong commitment to advance innovation in partnership with corporations, government entities, and academia. Currently, the interviewee holds the position of senior advisor in the field of energy transition at the independent research center, the Erasmus Center for Urban, Port, and Transport Economics (Erasmus UPT).
The second interviewee holds the role of Port Call Optimization Lead at the Port Authority of Rotterdam. He has been in that role for one and a half years. Previous experience was also in the field of shipping and logistics making him highly skilled to evaluate and validate the model.
The third interviewee, currently serving as a Professor of Information Systems and Business Analytics at the American University of Sharjah (UAE), was selected for the interview based on his extensive expertise in the TOE framework. This proficiency was demonstrated through his prior publications exploring various applications of the TOE framework in the literature.

Interview Set-up

The initial validation interview followed a structured procedure. It commenced with a general introduction and topic discussion, swiftly moving to identify the research scope and the overarching goal of the conceptual model. The interviewee was introduced to the original framework, and any arising questions were addressed. Subsequently, the adapted conceptual framework was presented, allowing the interviewee to review the pre-conditions and grasp the interrelationships within the model. The discussion then delved into the connections between different contexts, yielding immediate feedback. Further exploration included a comprehensive examination of each context, supported by explicit definitions and illustrative examples of the presuppositions associated with each context. In-depth discussions of each presupposition followed. Throughout the interview, the interview coordinator diligently documented all feedback, encompassing both positive and negative remarks. The in-person interview lasted approximately 60 min.
In preparation for the second interview, the framework, complete with an introductory theory section and a comprehensive written explanation covering the framework, individual contexts, and pre-conditions, was shared in advance. This proactive step allowed the interviewee to acquaint themselves with the framework before the online-interview took place. The interview was set-up similar to the first interview

and lasted approximately 45 min.
As with the second validation interview, prior to the third validation session, the framework and its corresponding explanatory sections were shared in advance. An email was sent beforehand outlining the underlying research, the objectives of the conceptual framework, and the rationale for extending the original TOE framework. The expert was then able to provide written feedback based on this information.

Feedback Validation Interview 1:
During the validation session with the first expert, several crucial points were raised to refine and enhance the conceptual model. The interviewee emphasized the importance of aligning the model with the research question, prompting a careful reassessment of its core purpose. In this process, the central drivers of PCO, namely efficiency, sustainability, safety, and costs, were clarified ensuring that these focal points were properly integrated.

Further investigation included a comprehensive examination of each context, supported by explicit definitions and illustrative examples of the assumptions associated with each context. The definitions were rigorously examined and ultimately reaffirmed, clarifying that technology is a system or solution designed to enhance operations, while 'organization' encompasses the various stakeholders involved in the Port Call, notably nautical service providers, carriers, and the Port Authority, collectively referred to as the operational organizations. An interesting consideration emerged concerning the potential inclusion of the 'Captain' as a key stakeholder.
The geographical scope, which concentrates on the Port itself, coming from the sea side, was also clearly delineated.

The expert then briefly summarized the core components of the model for clarity, emphasizing the interplay between technology and interorganizational arrangements and the influence of organizations on these arrangements. It was noted that although the external environment acts as an influencing factor, it is not mutually influenced by the interorganizational arrangements. These elements were critically evaluated and provided valuable feedback for improving the model.

Notably, the feedback highlighted the importance of distinguishing between different levels of technology, specifically incremental and radical advancements, with a primary focus on incremental adoptions. Additionally, a suggestion was made to categorize preconditions as 'nice to have' and 'need to have,', hence requirements and objectives, emphasizing their critical role in the model's effectiveness, and the recommendation to create a table providing explanations for each pre-condition. Overall, the feedback emphasized the need for clarity and categorization in the model's structure.

Feedback Validation Interview 2:
In the second model validation session, a structured approach was followed, with an initial request for the interviewee's holistic perspective. Clarity of context definitions was emphasized, with some additional explanations provided to ensure shared understanding. The rationale behind the TOE-framework and the need for the extension to the TOEI-framework tailored to Port Call Optimization was expounded, with the interviewee expressing approval.

Discussions unfolded around requirements and objectives, with key feedback emerging. Within the Technology triangle, the significance of adaptability and scalability was appreciated, while the "multi-user" objective sparked discussion, with the consensus that it should be a requirement due to its impact on global optimization. In the Organization triangle, the distinctions between "PCO awareness" and "PCO necessity awareness" were clarified, though naming considerations were suggested. Intra-firm communication and managerial obstacles were deemed important but the researcher retained their categorization. Regarding the External environment, the interviewee raised a pivotal question about the influence of industry pressure, ultimately satisfied with the explanation. The remaining requirements and objectives in this context were swiftly approved. In the interorganizational arrangements, the inclusion of the incentive structure was appreciated, deemed a motivator but not mandatory.

The simplicity of the framework was approved by the interviewee, who expressed a readiness to use

the model, both as a guide for new projects and for validating ongoing initiatives. Strengths included the model's ability to emphasize the importance of incentives and stakeholder relations, often underestimated in practice. However, limitations were noted, particularly the prerequisite of prior PCO familiarity, suggesting an additional layer of depth for immediate context understanding. The general framework was perceived as clear, although potential variances in pre-condition categorization or naming were acknowledged. The level of detail was deemed adequate, with a recommendation to integrate context definitions directly into the framework to enhance accessibility. Practical implications were underscored, offering valuable guidance to ports embarking on PCO initiatives, emphasizing the importance of the distinction between requirements and objectives, providing flexibility to adapt strategies to individual port characteristics and inspiring the consideration of context-specific objectives. Finally, the framework was viewed as a proactive tool for ports to contemplate improvements without awaiting customer complaints, signifying a shift from the traditional reactive approach to PCO.

Feedback Validation Interview 3:
In the third validation interview, the expert acknowledged the limitation of the TOE framework in neglecting interorganizational linkages, pointing out its focus on explaining organizational technology adoption rather than inter-organizational adoption. The suggestion to consider previous research on interorganizational adoption was made, highlighting relevant papers with significant citations. The expert advised referencing these papers, noting their recognition within the Information Systm and Operations research community, to strengthen the theoretical foundation.

Additionally, the expert emphasized the importance of considering different perspectives in Figure 5.1 and Figure 5.2, suggesting a potential adjustment in the direction of arrowheads to align with the conceptualization of technology adoption. Specific guidance was given on how to present Figure 5.2, urging a more direct statement about the addition of ”Interorganizational Arrangements” to the framework.

The expert commended the overall quality of the work, expressing satisfaction with the clarity of figures and the reasonableness of requirements and objectives for each section. The feedback concluded with positive remarks about the presentation of the framework's clarity and practical implications, along with some constructive suggestions to refine specific aspects for a more effective communication of ideas.

Revisions and Adaptations:
The adaption of the model based on the received feedback happened in three phases. A first model adaption took place immediately after the first feedback session. The two major remarks that were made during the first session were that the external environment is an independent variable which influences the other contexts but is not influenced by them. A one-sided relationship is present. The second remark was that a classification of ”must-haves” and ”nice-to-haves” will improve the model as it helps set the focus to what is really needed for the adoption of collaborative PCO and make it more understandable and structured in general. Those two feedback points were taken into account and the model was adjusted accordingly.

The second model adaptation took place after receiving feedback from the second expert. The second interviewee already received the updated model to validate and provide feedback on. The expert agreed with the one-sided relationship of the external environment towards the other contexts and pointed out that the differentiation between requirements and objectives is very good and necessary. He said that ”it helps ports to see what really needs to be considered but also leaves room to think of more objectives specific to their port”. Further suggestions included changing individual pre-conditions from objectives to requirements which was evaluated but only implemented for the pre-condition ”multi-user” in the technology context. An adaption of the other pre-conditions was voted against as it is believed the suggested pre-conditions might be more relevant for the Port of Rotterdam than for other ports.
A major adaption that resulted from the second feedback session was that context definitions were added to the framework to make the model more self-explanatory. The remark that a person should be able to understand the model without having to read the explanation text provided additionally was taken to heart and the framework adapted accordingly. It is believed that with the feedback received by the two experts, the model can now be used in practice to help guide especially port authorities or

other companies interested in adopting collaborative PCO measures to get started with their projects. The third validation session didn't primarily lead to adjustments in the framework's visualization but rather prompted a deeper exploration of literature on interorganizational adoption. This search yielded the identification of various pertinent sources, such as Premkumar and Ramamurthy [72], Grover [34], Vairetti et al. [95], and De Martino et al. [23]. Consequently, this additional literature review lead to the validation of several pre-conditions not just through the interviews but also through literature.

5.4. Applied PCO System Framework

In addition to the general framework introduced in section 5.2, which is applicable to every interorganizational adoption, a specialized framework tailored to the PCO system has been developed, as outlined in Figure 5.8. This advanced framework provides a more detailed perspective by integrating key elements, offering enhanced clarity and deeper insights into its components.

The applied framework maintains the four core contexts – technology, organization, external environment, and interorganizational arrangement – with the port system represented by the grey triangle encompassing these contexts. Notably, must-haves for collaborative PCO adoption, identified through literature analysis and interviews, are visually linked to their respective contexts, with pre-conditions represented by circles matching the color of the assigned context.
A significant aspect of the framework lies in the interplay between technology, interorganizational arrangements, and organization, where the technology supports interorganizational arrangements, and these arrangements, in turn, support the organization. This relationship is visually indicated by prominent white arrows labeled "support" connecting the relevant pre-conditions.
Complementing the core elements connected to the main contexts via dashed arrows, the framework incorporates additional influences denoted by white square elements. These elements represent factors such as the level of change accompanying technology adoption, potential PCO measures manifesting as technology, and Williamson's organizational classification. These influences are interconnected with different contexts through arrows, illustrating their multifaceted impact and interrelationships.

Beyond the visual aspects, understanding the practical implementation of this framework is crucial. It transcends the involvement of a single actor within the port call, extending its applicability to the entire port community. This comprehensive tool is designed to collectively address shared challenges.
To foster widespread participation, emphasis should be placed on the framework's ability to shift focus from individual organizational issues to a collective acknowledgment of shared challenges within the port community. This approach promotes unity and cooperation among diverse entities involved in the port call process.

The success of implementing the framework hinges on the commitment and collaboration of all stakeholders. Regular communication, established feedback mechanisms, and a shared sense of purpose will be essential in ensuring the framework's effectiveness in optimizing port call processes collaboratively.

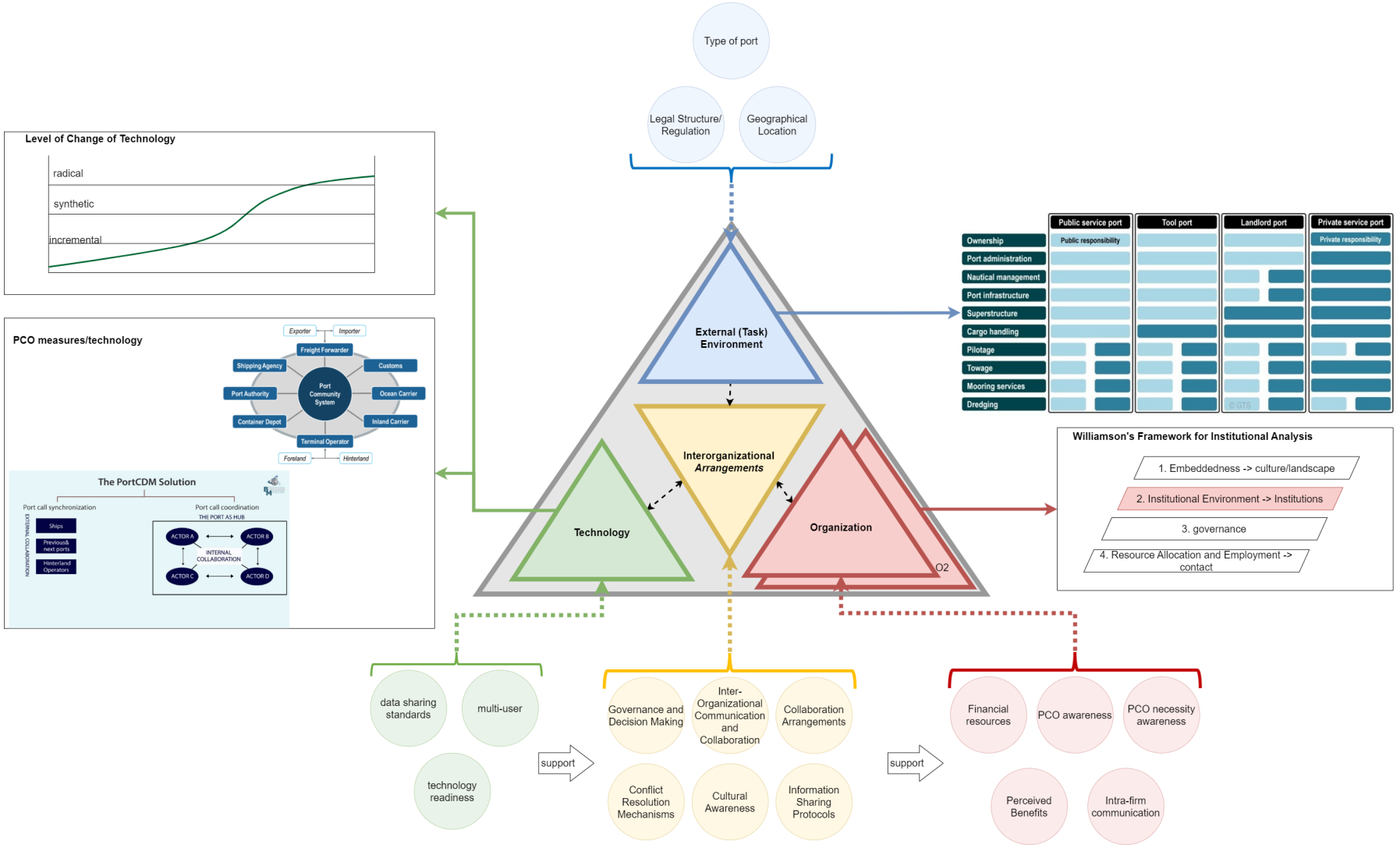


Figure 5.8: Applied PCO System Framework using elements from [74]

5.5. Key Findings and Implications

In conclusion, the Conceptual Model chapter presents a robust framework for understanding the factors influencing the adoption of collaborative Port Call Optimization within port operations. The main findings and conclusions from this chapter underscore the following key points:

1. The foundation of the model is based on the TOE - framework by Tornatzky, Fleischer, and Chakrabarti [89], extended to TOE-I (Technological- Organizational- Environmental- Interorganizational Arrangements), which recognizes the complexities of adoption conditions when multiple organizations collaborate in the context of PCO. The TOE-I framework is specifically tailored to address the interorganizational dynamics and arrangements that are crucial in the port industry.
2. PCO within ports necessitates interorganizational optimization, emphasizing the importance of multiple organizations working in tandem to achieve efficiency and effectiveness. Technology alone is insufficient; successful PCO adoption requires alignment across diverse stakeholders, making interorganizational arrangements a crucial component.
3. The adapted TOEI framework incorporates four key contexts: Technology, Organization, External Environment, and Interorganizational Arrangements. Each context plays a vital role in shaping the adoption of PCO, addressing requirements and objectives essential for collaboration and optimization.

The extended TOEI framework offers a more comprehensive and tailored approach to understanding the pre-conditions for collaborative PCO adoption. The model highlights the importance of technology, individual organizations, the external environment, and the intricate web of interdependencies and interactions among stakeholders. This approach acknowledges that successful PCO implementation goes beyond technology; it is about fostering collaboration and mutual understanding among diverse stakeholders within the port call ecosystem.

The model's validation with two experts further strengthens its practicality and application in real-world scenarios. It helps guide port authorities and other stakeholders interested in adopting collaborative PCO measures to navigate the challenges and requirements of this complex, multi-organizational environment. While the model has demonstrated its potential, it is important to consider its limitations and the need for broader validation from experts with diverse backgrounds, including those well-versed in the TOE framework.

6
Discussion and Limitations

In this chapter, a comprehensive discussion of the findings and their implications, further substantiating the development of the TOEI framework is provided in section 6.1. In section 6.2 the limitations of this research are discussed. The chapter begins with an exploration of how the interview analysis and the conceptual model align with and enhance the existing literature, providing insights into why the TOEI framework is better suited than any other existing framework for addressing the pre-conditions of collaborative Port Call Optimization adoption in various ports. Subsequently, the identified limitations are discussed, underlining the areas that warrant further investigation and refinement. This chapter serves as a reflective synthesis of the study's contributions and the paths for future research in the dynamic landscape of PCO in the maritime industry.

6.1. Discussion

Previous studies, such as those conducted by Jahn and Scheidweiler [38], Johnson and Styhre [39], and Arjona Aroca et al. [8], predominantly focused on achieving JIT-arrivals to minimize waiting times. However, they mainly neglected the role of collaborations among stakeholders. Although the exploration of port efficiency and ship turnaround time has been conducted before (see Poulsen and Sampson [70], Nikghadam et al. [60], and Schoneveld [81] for reference) these studies often neglected a thorough examination of collaboration dynamics, stakeholder interactions, and the impact of emerging technologies within the nautical chain and Port Governance structures.

To bridge this gap, the current research aims to offer a comprehensive understanding of pre-conditions by integrating these overlooked aspects, including collaboration dynamics, stakeholder interactions, and the influence of emerging technologies within the nautical chain and Port Governance structures. This holistic perspective is presented through the development of a conceptual model, providing a well-rounded overview of all relevant prerequisites for the adoption of collaborative PCO.

The empirical and exploratory nature of this study involved a seven-step methodology, starting with a literature analysis, followed by the design of a semi-structured interview guide. This semi-structured interview, which enjoyed a broad participant pool and a wide geographical scope aimed to identify pre-conditions crucial for the adoption of collaborative PCO (total of 20 interviews with harbor masters and innovation officers from various ports worldwide and an additional two expert discussions were conducted). This study used a combination of word frequency, concept mapping, sentiment analysis, and categorization based on port size, governance, and location, which not only confirmed the existing assumptions found in the literature, as described by Vairetti et al. [95], De Martino et al. [23], and Grover [34], but also revealed new insights into new pre-conditions for port call optimization.

For instance, incentive structures and conflict resolution mechanisms are identified as two pre-conditions for enabling collaborative PCO in the literature. However, although the importance of collaboration has been emphasized in the literature, including Lind et al. [48] and Nikghadam et al. [60], the agreement between the various stakeholders is often taken for granted. In the interviews conducted, it became clear that the agreement among stakeholders, and as a result, the collaboration often does not exist. This leads to additional problems, such as inaccurate information sharing, the willingness to use the collaborative measure, and ultimately less optimized port calls. To achieve agreement and collaboration, the various stakeholders must be considered, and their power and interest in the port call must be evaluated. Their incentive towards the port call and its optimization must also be identified. Also, in case of any conflicts of interest, resolution mechanisms need to be established. Port call optimization will only occur if there is assurance that all parties involved have an incentive to optimize the port call process. Therefore, the incentive structure of the involved actors and the conflict resolution mecha-

nisms are critical to the adoption of collaborative PCO and must be considered as a requirement. Moreover, the interview analysis revealed distinctive patterns in the objectives and means of different organizations, emphasizing the importance of efficiency, safety, and sustainability. During the port call, it is important that the safe navigation of incoming and outgoing ships is ensured, otherwise collisions and consequently the endangerment of employees and resources may follow. Especially for Port Authorities, whose purpose it is to ensure safety [76], this objective has a high priority. In addition to ensuring safety, the efficient execution of port calls should also be guaranteed, as this can increase the attractiveness of the port in general, but also reduce the waiting times of the ships in front of the port and a more seamless utilization of resources during the port calls. Furthermore, sustainability has swiftly become a key objective in port operations, evident in explicit commitments during port calls in surveyed ports like Copenhagen-Malmö, Gothenburg, Kobe, and Vancouver. The Port of Kobe's initiatives, such as substituting fossil fuels with LNG, exemplify this shift, driven not only by ethical considerations but also regulatory mandates highlighted in the International Maritime Organization's 2020 report [1]. This growing emphasis on sustainability is poised to reshape industry norms, reflecting a global commitment to environmentally conscious practices.

In addition, the analysis revealed significant challenges perceived during the port call, including inaccurate information, resistance to digital solutions, weather-related issues, and regulatory restrictions. For instance, port calls rely on accurate and timely information about vessel schedules, cargo status, and port conditions. However, such accurate information is not always available, and these inaccuracies can lead to misalignment of resources such as pilots and tugs and disruptions in the port call planning process. If a vessel arrives earlier or later than scheduled due to incorrect information, it can cause congestion at the port or unnecessary waiting times, affecting overall efficiency. Implementing a centralized, real-time information-sharing platform can be one way to ensure that all stakeholders have access to accurate and up-to-date data. This could include standardized data formats and protocols. However, inaccurate information sharing can also be a result of stakeholders resistance to adopt to digital solutions. During the interviews it became clear that traditional practices, lack of awareness, or concerns about cyber-security often hold people from adopting to new measures or accepting changed processes in general. However, providing trainings and implementing changes in a gradual process can reduce the resistance and increase the willingness to use the digital solutions [Source: interview 18]. Moreover, encouraging and incentivizing the adoption of digital solutions can enhance communication and streamline processes and improve the willingness to use.

Furthermore, during the literature and interview analysis, it emerged that no uniform definition of collaborative PCO exists. The concept of collaborative PCO was evaluated differently by the ports, underlining the need for tailored strategies. However, the successful optimization of port calls relies on a collaborative approach and a common understanding of collaborative PCO. More specifically, the implementation of pre-conditions such as data sharing protocols, ensuring standardized data sharing, willingness of the stakeholders to adopt (digital) solutions, contingency planning, and regulatory harmonization all require that different ports have similar definition of collaborative PCO. Only if these and more pre-conditions are considered the adoption of collaborative PCO can succeed. This diversity in understanding PCO emphasizes the complexities involved and underscores the necessity for adaptable approaches to suit the unique characteristics of each port. The discussion extends beyond merely implementing pre-conditions to a nuanced consideration of the diverse perspectives within the industry, emphasizing the need for flexibility in collaborative PCO strategies.

Building upon this analysis, all findings from the literature and interview assessment were systematically categorized into four distinct contexts: technology, organization, external environment, and interorganizational arrangements. Subsequently, a comprehensive conceptual model, namely the TOEI-framework was developed. This model serves as a valuable tool for port authorities and operators, offering a structured framework to navigate the complexities of adopting PCO measures. For instance, within the technology context, the conceptual model delineates how the integration of digital platforms and data-sharing protocols can streamline information flow, addressing challenges such as inaccurate information and resistance to digital solutions highlighted earlier. The organization context considers how stakeholder willingness and collaboration can be fostered, while the external environment context addresses factors like regulatory restrictions and weather-related issues. Lastly, the interorganizational

arrangements context explores how relationships and incentives can be optimized for successful PCO adoption. This conceptual model, tailored to the specific nuances of each port, provides actionable insights for industry participants striving to enhance efficiency and collaboration in their port call processes.

The developed TOEI-framework extends the traditional TOE framework, emphasizing Interorganizational Arrangements for comprehensive progress in port call optimization. The positive achievements outlined in this framework include the identification of four types of pre-conditions crucial for successful collaborative PCO adoption, the development of the TOEI-framework, and insights into the nuanced dynamics of port call processes across diverse stakeholders and governance structures. The findings have meaningful implications for academia, policymakers, Port Authorities, and nautical service providers. Academic communities stand to benefit significantly from these findings. The identification of pre-conditions and the development of the TOEI-framework provide a conceptual basis for further research and exploration. Scholars can build upon this foundation to delve deeper into specific aspects of collaborative PCO, contributing to the academic discourse on maritime logistics, organizational behavior, and interorganizational relationships. Policymakers can leverage these findings to inform the development of policies that encourage and support collaborative PCO adoption. Understanding the pre-conditions and dynamics highlighted in the TOEI-framework allows policymakers to create regulatory environments that facilitate digital integration, incentivize stakeholder collaboration, and address key challenges in the maritime industry. Port Authorities play a central role in optimizing port calls. The TOEI-framework equips Port Authorities with a strategic tool to assess their current state of readiness and identify areas for improvement. By aligning their strategies with the identified pre-conditions, Port Authorities can enhance collaboration with stakeholders, implement effective digital solutions, and streamline port call processes for increased efficiency. For nautical service providers, understanding the nuanced dynamics of port call processes is crucial for tailoring services to the specific needs of each port. The TOEI-framework offers insights into the inter-organizational arrangements necessary for successful collaboration. Nautical service providers can use this knowledge to adapt their offerings, improve communication with other stakeholders, and contribute to the overall optimization of port calls.

The TOEI-framework provides a comprehensive perspective on collaborative PCO adoption, offering specific insights and recommendations to enhance port call processes and overall port efficiency. In contrast to the study by Poulsen and Sampson [70], which primarily focuses on abating shipping greenhouse gas emissions through PCO, this research extends beyond a singular environmental aspect. While Poulsen's work emphasizes swift turnaround and emissions reduction, this study takes a more holistic approach, delving into the complexities of collaborative PCO adoption. The novelty of this work lies in the comprehensive analysis of PCO adoption, encompassing not only technological aspects but also emphasizing the crucial need for interorganizational alignment. Poulsen's work, though valuable in its focus, does not delve into the broader spectrum of collaborative dynamics among diverse stakeholders in the port call ecosystem. By introducing the TOEI-framework, this research contributes significantly to the existing literature by recognizing the collective nature of interactions among organizations involved in port operations. This broader perspective goes beyond the scope of Poulsen's study, providing a more nuanced understanding of the intricate relationships and conditions influencing successful collaborative PCO adoption.

6.2. Limitations

While this research has yielded valuable insights and contributed to the development of the TOEI framework for collaborative PCO adoption, several limitations should be acknowledged:

This research primarily centered on the port call process for arriving vessels, not explicitly considering the planning related to vessel departures. It was also assumed that the port call process concludes upon vessel arrival at the terminal. Nonetheless, the importance of terminals and berth planning as influential factors emerged during interviews, suggesting the need for holistic consideration of the entire port call process, the cargo operations at the terminal and the container backyard and the departing vessels.
Another limitation concerning the research scope lies in the exclusive consideration of container ves-

sels in the study. Many ports are multi-functional, handling various cargo types and offering different services. Therefore, certain requirements and objectives may be more relevant in ports not accommodating container ships. Accordingly, inclusion of the different cargo types can lead to more realistic results for such ports.
Although, the interviews conducted in this study cover a wide range of countries with a relatively wide geographical distribution, still the interviewed ports might not be representative of the global spectrum. A concentration of interviews in Europe, with limited representation in South and North America may impact the generalizability of findings. Differences in regional practices, infrastructure, and regulatory environments could potentially lead to variations in PCO pre-conditions that are not adequately represented in the framework. Inclusion of more ports from the Americas, South Africa and East Asia, will enrich the findings of this research.
Moreover, the majority of interviewees belong to port authorities or governmental organizations, potentially neglecting pre-conditions significant for nautical service providers. For instance, towage companies, who are often private companies standing in competition with other service providers might prefer local PCO over collaborative one. A broader representation of stakeholders could enhance the framework's comprehensiveness.

The analysis of the interview transcripts could be prone to subjective interpretation. Moreover, the manual process of labeling the interview summaries carries the risk of overlooked or misinterpreted insights. Therefore, use of more unbiased interview analysis methods, such as automatic labelling, together with the manual labelling can decrease the risk of subjectivity in the interview analysis.

7
Conclusion

7.1. Main Findings

At the very beginning of this thesis project, it was discovered that there is only limited research examining holistic collaboration within the port environment, with existing studies often only focusing on individual stakeholder interactions or specific aspects of collaboration rather than ”the bigger picture”. Current research has a significant focus on local optimization incentives and often lacks practical implementation insights for the entire port environment, necessitating a more comprehensive study with a larger sample size. Furthermore, it was discovered that there is a lack of comparative studies involving different ports with unique features and operational settings, limiting the generalizability of findings to a broader context. Despite the existing body of literature on port call optimization, there is no systematic identification of fundamental factors that influence the port call process and the necessary prerequisites for its successful implementation, often overlooking the role of human factors in the process.

Therefore, the following research question was proposed to resolve this research gap:

> ***What are the pre-conditions of adoption of collaborative port call optimization in different ports?***

To support the answering of the main research question, several sub-research questions were formulated. A comprehensive summary of the results of these supporting questions is provided below:

What is the potential relationship between port structures and collaborative PCO?
Based on the conducted literature review and the analysis of the interviews, the relationship between port structures and collaborative PCO was found out to be influenced by the Port governance structures which impact the priorities and objectives of the Port Authorities for PCO. Both public and landlord ports (the most frequently interviewed structures) are interested in improving efficiency and enhancing safety but the interviewed landlord ports also highlighted the importance of sustainability improvement and collaboration with other ports among other objectives. Besides the Governance structure the size of the port also could affect the complexity of PCO challenges. It seems that larger ports face overall more challenges including information sharing, resistance and regulatory restrictions, while smaller port encounter less but different challenges like inaccurate information and weather-related issues like ice-breaking during winter. Furthermore, the interorganizational arrangements including stakeholder collaboration are shaped by the port governance and size, individual stakeholder objectives and occurring common challenges are linked to the port structure. They are all important factors for collaborative PCO leading to the conclusion that the relationship between port structures and collaborative PCO is dynamic, with governance, size, objectives and challenges playing crucial roles.

What are collaborative PCO measures that could enhance the port call?
A wide range of collaborative measures that could enhance the Port Call. In general, these measures vary from big implementations such as specifically designed port collaboration applications to small and ”simple” adjustments such as customer satisfaction. Measures discussed in the literature include information sharing, PortCDM and Port Community systems. Other additional measures were identified in the interview analysis, including platform technologies, additional or advanced resources that could optimize or improve the port call have been stated by the interviewees.

What is the impact of collaborative PCO measures in different ports?
The impact of collaborative PCO measures varies across different ports due to variations in governance structures, port size, interorganizational arrangements, stakeholder objectives, and the ability to address common challenges. Depending on the governance structure of the port, the number of involved stakeholders as well as their power and incentive to optimize the port call might differ. For instance, in ports with centralized governance, decision-making processes are often streamlined, enabling efficient execution of PCO measures. Conversely, in ports with decentralized structures involving multiple stakeholders, achieving consensus and coordinated action becomes more complex, demanding effective communication and collaboration mechanisms to address diverse interests and priorities. The governance model, therefore, plays a pivotal role in shaping the success and dynamics of collaborative PCO initiatives.
Additionally, the impact of collaborative PCO measures is also intricately linked to the size of the port. Larger ports, with higher traffic volumes and a greater number of involved stakeholders, may face challenges in achieving seamless coordination and communication among various entities. While collaborative PCO initiatives have the potential to enhance efficiency, the complexity of operations in larger ports may necessitate more robust communication structures and advanced technological solutions. Conversely, smaller ports may find it comparatively easier to implement and coordinate PCO measures due to their more compact operations. However, their impact might be more pronounced in smaller ports, where incremental improvements can lead to proportionally significant enhancements in overall port call efficiency. Tailoring collaborative strategies to the specific challenges and opportunities posed by different port sizes is crucial for optimizing the impact of PCO initiatives across the maritime landscape.
Understanding these dynamics is essential for tailoring PCO measures to the specific characteristics of each port, and therefore enhancing their impact. For instance, in ports with centralized governance, decision-making processes are often streamlined, enabling efficient execution of PCO measures. Conversely, in ports with decentralized structures involving multiple stakeholders, achieving consensus and coordinated action becomes more complex, demanding effective communication and collaboration mechanisms to address diverse interests and priorities. The governance model, therefore, plays a pivotal role in shaping the success and dynamics of collaborative PCO initiatives.

Based on the determined collaborative PCO measures, what pre-conditions can be conceptionally identified?
After conducting the interviews, discussing with the experts and analyzing literature, it can be summarized that the identified collaborative PCO measures, come with several pre-conditions related to Technology, Organization, the Environment and Interorganizational Arrangements (TOEI). Examples for relevant pre-conditions are Technology Readiness on the technology level, perceived benefits on the organizational level, geographical location of the port on the external environment level and conflict resolution mechanisms on the interorganizational level. These pre-conditions, stated in chapter 5 form the foundation for successful adoption of collaborative PCO measures in different ports.
The TOEI framework, an extension of the Technology-Organization-External Environment framework by Baker [11], serves as a robust conceptual base for understanding the adoption of collaborative Port Call Optimization within port operations. This adapted framework provides valuable insights into the complexities of PCO adoption and offers guidance on the essential pre-conditions for successful implementation. The TOEI framework's strength lies in its comprehensive approach. It recognizes that the success of PCO is not solely dependent on technology but also on the collaboration and alignment of various stakeholders, adherence to regulations and standards, and the effectiveness of interorganizational arrangements. This conceptual base offers a holistic understanding of PCO adoption, emphasizing that no single aspect can be considered in isolation.
By utilizing the TOEI framework, researchers and practitioners, including Port Authorities or organizations providing nautical services can assess the readiness of a port for collaborative PCO adoption. They can identify the pre-conditions within each context (T, O, E, I) and evaluate the port's capacity to meet these requirements. This, in turn, facilitates informed decision-making and the development of tailored strategies for successful PCO implementation in various port settings.

By systematically addressing the sub-research questions, this research has unraveled the pre-conditions required for the adoption of collaborative Port Call Optimization in various ports. The examination of

port structures has clarified how governance models and port size influence the readiness and prerequisites for PCO adoption. Furthermore, the exploration of the impacts of these measures (i.e. information sharing, PortCDM and others) on port operations has underscored the benefits of enhanced efficiency, safety, sustainability, and stakeholder collaboration within the port environment. Collectively, these findings constitute a holistic understanding of the pre-conditions pivotal in the adoption of collaborative PCO, offering valuable guidance for port authorities, stakeholders, and policymakers as they navigate the intricate process of implementing PCO, thereby promoting more efficient, interconnected, and sustainable port operations.

7.2. Recommendations for Research and Practice

Recommendations for research

The researcher acknowledges that this study serves as a pioneering effort in utilizing and adapting the TOE-framework for collaborative Port Call Optimization adoption in different ports. However, future research is encouraged to enrich the framework and explore its application in diverse port settings. For instance, the consideration of the whole port call process and inclusion of port areas geographically not thoroughly explored can lead to a more robust validation of the framework and better generalizability of it.

Furthermore. this research focuses on the identification and categorization of essential pre-conditions for collaborative PCO adoption. Future research may focus on more detailed specifications of these pre-conditions and providing practical guidance on the design, implementation, and customization of these pre-conditions. Such research can contribute to translating the insights gained from this study into tangible strategies and practices, offering a comprehensive roadmap for stakeholders in the port industry on ”how” to structure these pre-conditions effectively.

Recommendations for practice

When considering the adoption of collaborative PCO measures, it is recommended for companies and stakeholders to conduct a comprehensive assessment of the TOEI framework before the actual implementation. This entails examining all the elements within the Technology, Organization, External Environment, and Interorganizational Arrangements contexts. A thorough evaluation will ensure that no critical pre-conditions or factors are overlooked, providing a solid foundation for effective PCO implementation.

Furthermore, it should be recognized that the TOEI-framework serves as a foundational guide. Companies and stakeholders are encouraged to customize the framework to align with their specific port’s needs and characteristics. The ”Interorganizational Arrangements” context, in particular, should be seen as an open space for innovation and adaptation. It is crucial for organizations to fill in this context with more tailored strategies and arrangements that suit their unique environment.

PCO is an ongoing process. Companies should view the implementation of PCO measures as a continuous journey, rather than a one-time task. Regular evaluations, feedback loops, and adaptations are necessary to refine and improve the effectiveness of PCO practices within the port. Embrace a culture of continuous improvement to enhance port operations continually.

Lastly, the growing importance of sustainability in port operations should be recognized. While not explicitly mentioned in the TOEI framework, sustainability considerations are increasingly vital. The integration of sustainability goals and practices into the PCO adoption process to align with evolving industry trends and environmental responsibilities is therefore significant.

In conclusion, this thesis significantly contributes to the academic understanding of collaborative Port Call Optimization adoption in the maritime industry and its practical application. Through the development of the TOEI-framework and the insights gathered from interviews and literature analysis, this study advances the comprehension of the critical factors influencing PCO adoption. It lays the groundwork for fostering efficient, collaborative, and optimized port call processes. The findings from this research have the potential to bring about positive changes in the maritime sector, improving port operations, reducing costs, and enhancing the predictability of ship arrivals and departures, which will, in turn, have a broader impact on global trade and economic growth as well as sustainability.

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A
Stakeholder overview

Port Authority:
The Port Authority is a governmental or quasi-governmental body, managing and regulating ports to ensure safe and smooth operations, economic growth, and trade promotion [98]. The Port Authority aims to boost regional/country benefits like revenue, jobs, and infrastructure. It adopts a facilitator role, working with carriers, shippers, and more to enhance efficiency and trade growth [64]. Despite challenges from market actors favoring minimal interference and government pressures, Port Authorities play a pivotal role in port management and development [98]. Variations in government objectives exist, however safe navigation is always considered as one of the main objectives [98].

Pilot Organizations:
The Pilot Organization, responsible for safe vessel navigation in ports, offers services including Sea pilotage, Deep-Sea pilotage, Coastal pilotage, and more [37]. Pilots possess local knowledge [55] and work with the captain while ensuring safe navigation [75]. The main goal of pilots is accident prevention and safe navigation, collaborating with the Vessel Traffic Center and authorities [75]. In decentralized ports, the primary objective remains safety, but competition may arise in private or landlord environments like the Port of Sydney [68].
One challenge is getting pilots to vessels, typically via ship or helicopter transport. Pilots are involved throughout the port call, boarding upon entry and leaving after docking [75]. Resource planning should consider their extended presence.

Towage Organizations:
Mega-sized vessels rely on tugboats for safe navigation in narrow passages [20]. Towage Organizations optimize their asset allocation and collaborate with Pilot Organizations and Vessel Traffic Centers [81, 59]. Tugs are usually planned before port calls, but the pilot assigned to the vessel movement decides the final count and duration of tugs based on weather and other factors [15]. Some pilots may quickly return tugs, while others require longer assistance, impacting availability [15].
In decentralized ports like the Port of Rotterdam, multiple tug operators may compete [76]. Besides that, licensing requirements may vary, affecting service providers [81]. Resource management in the different ports differs, with companies retaining control or leaving the planning to other planning entities like the Port Authority, potentially affecting overall resource availability [59].

Terminals:
Terminals play a critical role in ports, facilitating cargo handling, storage, and transfers between different modes of transportation. Their main responsibility is to efficiently manage cargo operations, ensuring swift vessel loading and unloading, as well as smooth transitions to other transportation methods [74]. Terminal operations are often profit-driven, as they earn revenue from cargo handling fees, storage charges, and value-added services. To optimize their performance, terminal operators collaborate closely with carriers, customs, and the Port Authority to streamline cargo processes [35]. They often engage in resource sharing, like quay cranes and stacking locations, which enhances efficiency and reduces vessel waiting times [59]. Through close collaboration with carriers, customs, and other logistics providers, they effectively facilitate cargo operations. To enhance throughput and optimize terminal capacity, terminals often actively participate in supply chains, implementing operational considerations such as berthing windows, dwell time charges, and truck slots. They also act as buffers in supply chains, offering cost-effective storage and absorbing inefficiencies occurring elsewhere [35]. Depending on the existing governance structure in the port can terminals be governmental or privately

owned and operated.

Carriers:
Shipping companies or vessel owners, known as carriers, bear the responsibility of transporting goods and cargo between different ports. Out of the presented key stakeholders, they are the only entity that is always private no matter the underlying governance structure of the port. The primary objective of carriers is to ensure the safe and efficient transportation of cargo from one port to another. With the aim of maximizing profits, carriers strive to provide customers with reliable and cost-effective transportation services [63]. Carriers engage in coordination with terminals for cargo loading and unloading, as well as collaborate closely with the Vessel Traffic Center for navigation and safety guidance [48]. While carriers often do not directly influence the port call of arriving vessels, it is essential for harbors to prioritize meeting the carriers' expectations and requirements due to carriers' capacity to choose alternative (transshipment) ports if they are dissatisfied with the performance [29]. Additionally, in private or landlord ports, it is more common for carriers to own their own terminals, providing them with flexibility in terms of hinterland accessibility and resource planning and scheduling [43].

B

Literature overview existing vs. new

B.1. Research Aspects in Previous PCO Studies

Table B.1: Different research aspects on Port Call Optimization

	Port Optimization	Port Innovation	Nautical Chain	Collaboration	Port Governance
W.Buch	⋆	⋆	⋆	⋆	⋆
Acciaro and Sys [2]		⋆		⋆	
Alvarez, Longva, and Engebrethsen [6]	⋆		⋆		
Andersen et al. [7]				⋆	⋆
Braidotti et al. [16]	⋆	⋆			
Brooks and Pallis [18]					⋆
Cullinane, Yap, and Lam [20]					⋆
El Mekkaoui, Benabbou, and Berrado [26]	⋆				
Fransen and Davydenko [29]			⋆		
Gan [30]	⋆		⋆		
Gogas, Papoutsis, and Nathanail [31]	⋆		⋆	⋆	⋆
González Laxe, Sánchez, and Garcia-Alonso [33]					⋆
Henesey, Notteboom, and Davidsson [36]	⋆		⋆	⋆	
Kaljouw, Bouman, and Azadeh [40]	⋆		⋆		
Keceli [42]		⋆		⋆	
Li, Zhou, and Yuen [46]		⋆			
Lin, Chang, and Chung [47]				⋆	⋆
Lind et al. [48]	⋆	⋆		⋆	
Lind et al. [49]	⋆	⋆			
Lind et al. [50]	⋆	⋆		⋆	
Lind et al. [51]	⋆	⋆		⋆	⋆
Merkel, Kalantari, and Mubder [56]	⋆	⋆			
Nikghadam, Rezaei, and Tavasszy [58]	⋆		⋆	⋆	
Nikghadam et al. [59]	⋆		⋆	⋆	
Nikghadam et al. [60]	⋆	⋆	⋆	⋆	
Notteboom [61]					⋆
Notteboom, Pallis, and Rodrigue [62]		⋆			⋆
Oganesian [65]					⋆
Poulsen and Sampson [70]	⋆				⋆
Shin et al. [82]		⋆			
Schoneveld [81]	⋆	⋆	⋆	⋆	⋆
Song and Lee [84]				⋆	⋆
Suvadarshini and Dandapat [86]	⋆	⋆	⋆		

Continued on the next page

Table B.1 – continued from previous page

	Port Optimization	Port Innovation	Nautical Chain	Collaboration	Port Governance
Tijan et al. [88]		⋆			⋆
Turpin [92]					⋆
Venturini et al. [97]	⋆	⋆		⋆	
Zhang et al. [102]				⋆	⋆

B.2. Methods used in previous Port Call Studies

Table B.2: Methods used in the previous studies on Port Call Optimization

	Conceptual Framework	Case Study	Machine Learning	Literature Analysis	Stakeholder analysis	AIS data	Simulation	Comparative Analysis	MCA	Impact Analysis
W.Buch	⋆	⋆		⋆	⋆					
Acciaro and Sys [2]		⋆						⋆		
Alvarez, Longva, and Engebrethsen [6]		⋆					⋆			
Andersen et al. [7]		⋆								
Braidotti et al. [16]				⋆			⋆		⋆	
Brooks and Pallis [18]	⋆									
Cullinane, Yap, and Lam [20]		⋆		⋆						
El Mekkaoui, Benabbou, and Berrado [26]		⋆	⋆			⋆				
Fransen and Davydenko [29]				⋆			⋆			
Gan [30]	⋆	⋆		⋆			⋆			
Gogas, Papoutsis, and Nathanail [31]		⋆							⋆	
González Laxe, Sánchez, and Garcia-Alonso [33]				⋆				⋆		
Henesey, Notteboom, and Davidsson [36]							⋆			
Kaljouw, Bouman, and Azadeh [40]		⋆				⋆	⋆			
Keceli [42]		⋆			⋆					
Li, Zhou, and Yuen [46]	⋆								⋆	
Lin, Chang, and Chung [47]		⋆							⋆	
Lind et al. [48]	⋆									
Lind et al. [49]								⋆		⋆
Lind et al. [50]	⋆			⋆	⋆					
Lind et al. [51]	⋆									
Merkel, Kalantari, and Mubder [56]		⋆				⋆				
Nikghadam, Rezaei, and Tavasszy [58]	⋆	⋆								
Nikghadam et al. [59]							⋆			⋆
Nikghadam et al. [60]	⋆	⋆			⋆					
Notteboom [61]	⋆									
Notteboom, Pallis, and Rodrigue [62]	⋆			⋆						
Oganesian [65]		⋆		⋆						
Poulsen and Sampson [70]		⋆								
Schoneveld [81]				⋆					⋆	
Shin et al. [82]	⋆			⋆						
Song and Lee [84]		⋆		⋆						
Suvadarshini and Dandapat [86]		⋆								
Tijan et al. [88]				⋆						
Turpin [92]	⋆									
Venturini et al. [97]		⋆								
Zhang et al. [102]				⋆						

C
Interviews - Data Collection

C.1. Interview Guide

Introductory questions:

1. Could you please introduce yourself and your role within your organization?
2. Can you provide an overview of your organization's role and contributions within the maritime industry?

General Port Call process questions:

1. Can you describe the step-by-step process of a typical port call for arriving vessels in your port?
2. Who are the key stakeholders involved in each step of the port call process?
3. Where do you/does your organization stand in that process? What specific responsibilities do you undertake?
4. How are incoming and departing vessels served? Who gets priority? First-come-first-serve?
5. How many tugboat organizations, linesmen, and pilots are there in the port?
6. How would you characterize the relationships and interactions between tugboat organizations, linesmen, and pilots in terms of competitiveness or cooperation?
7. Who are your main points of contact among the various stakeholders, and how do you collaborate with them? Who do you rely on or get information from?
8. Could you outline the typical duration of each process step in the port call process? How long does each process step take?
9. What types of information are shared between stakeholders during the port call process, and at what points is this information exchanged?
10. How is this information shared? Is it documented, conveyed orally, or transmitted through specific communication platforms?
11. Are there specific challenges or complexities associated with sharing information across different communication channels? How does this impact collaboration and efficiency?

Port Call Optimization Efforts:

1. How does your organization currently approach and facilitate the optimization of the port call process?
2. Are there any specific technologies, tools, or platforms that your organization uses to aid in port call optimization?
3. Can you provide examples of successful instances where your optimization efforts have led to improved port call efficiency and stakeholder collaboration?
4. Are there any challenges or limitations you face when implementing optimization strategies, such as resistance to change or compatibility issues with existing systems?
5. When performing activities for the port call, what are your company's objectives?
6. How relevant do you think port call optimization is for your port?

Critical Stakeholders for Port Call Performance:

1. Among the following service providers - Terminals, Carriers, Towage/Tugboats, Pilots, Linesmen, Port Authority, Customs, Vessel Traffic Services - which do you consider most crucial for ensuring a well-performed port call, and why?
2. How do the roles and contributions of these critical stakeholders intersect and affect each other during the various steps of the port call process?

Challenges and Problem Identification:

1. Could you identify specific process steps or interactions where problems and challenges arise during the port call process?
2. What are some of the common problems encountered in those steps or interactions? (e.g. inaccuracies in information, resource availability issues, delays,...)
3. Can you share specific examples of instances where these challenges have lead to disruptions or inefficiencies in the port call process?
4. From your perspective, what are the underlying reasons for those problems, and are there any patterns or trends you've observed?
5. What other port content factors could have a positive or negative influence on your processes? (e.g. natural influences like weather conditions, very long gateway,...)
6. How do these external factors interact with stakeholder collaboration efforts and impact the overall efficiency of the port call process?

Collaborative Solutions and Innovations:

1. Are there any proposed solutions or innovations, such as for example Optiport or other collaboration mechanisms like a Port Community System, that you believe could address the problems identified?
2. How do you envision these solutions addressing the issues and challenges in the port call process?
3. What role do you see technology playing in fostering collaboration among stakeholders and streamlining the port call process?

Port Governance questions:

1. Have you encountered variations in the order of the port call process when compared to other ports? Do you believe these variations are influenced by the governance structure of the port?
2. Can you elaborate on the role and influence of the Port Authority within the port call operations? How does their involvement impact the overall planning and execution?
3. Under what contract type are the nautical service providers operational in the port? (Licensed, concession, free market) Are there any regulations you set for the nautical service providers in terms of pricing or operations?
4. How do regulatory frameworks or policies set by the Port Authority affect collaboration and optimization initiatives among stakeholders?
5. Do you have a centralized scheduling/planning body and if you don't have that why don't you have that?

Future Perspectives and Industry Trends:

1. From your perspective, what future trends or developments do you foresee regarding stakeholder collaboration and the optimization of the port call process in the maritime industry?
2. What will your port specifically look like? How will it be organized and what will your specific role be?
3. How do you envision the maritime industry evolving in terms of technological advancements, regulatory changes, and stakeholder engagement over the next few years?
4. If you had a card-blanche what would you change in your port to improve efficiency?

C.2. Overview Interviewed Ports

Table C.1: Overview Interviewed Ports

Ref #	Organization	Port	Country	Role of Interview Partner	Ref #	Organization	Port	Country	Role of Interview Partner
1	Port Authority (PA)	Port of Algeciras	Spain	Chief Information & Innovation Officer	**11**	HVCC	Port of Hamburg	Germany	Managing Director
2	Ashdod Marine Services Company	Port of Ashdod	Israel	Harbor Master (HM)	**12**	Kobe City of Design	Port of Kobe	Japan	Assistant Manager
3	PA	Port of Barcelona	Spain	Head of the Control Tower	**13**	PA	Port of Kokkola	Finland	HM
4	PA	Port of Bremen/ Bremerhaven	Germany	Head of Port Authority | HM	**14**	PA	Port of London	United Kingdom	Master Mariner | Pilot | Duty Port Controller
5	PA	Port of Chittagong	Bangladesh	Assistant HM	**15**	PA	Port of RAK*	UAE*	Group HM
6	PA	Port of Copenhagen/ Malmö	Denmark/ Sweden	Public Affairs Lead	**16**	PA	Port of Rotterdam	Netherlands	PCO Lead
7	PA	Port of Cork	Ireland	Harbor Master and Chief Operations Officer (COO)	**17**	PA	Port of Sohar	Oman	HM
8	PA	Port of Gothenburg	Sweden	Port Control Manager	**18**	PA	Port of TangerMed	Morocco	PCO and Invoicing Manager
9	PA	Port of Hadera	Israel	HM | Senior Pilot	**19**	PA	Port of Vancouver	Canada	Deputy HM
10	Haifa Marine Services	Port of Haifa	Israel	HM	**20**	Adani Ports SEZ	Port of Mundra (and others)	India	CEO
21	Smart Port Alliances	-	-	Founder	**22**	Erasmus UPT	-	-	Sr. Researcher ports in (energy-)transition

D
Contexts Conceptual Model

D.1. Technology Context

Table D.1: Technology Context - Preconditions

Technology Context	
Must haves	
Definition	**Explanation**
Technology Readiness	For any technology adoption, the technology must be ready and reliable to serve its purpose effectively.
Data sharing standards	Standardized data sharing is essential to ensure interoperability and effective collaboration among different stakeholders in the port.
Nice to have	
Definition	**Explanation**
Multi-user	Collaborative port call optimization typically involves multiple stakeholders working together, making multi-user support a necessity. However, even though multi-user support is essential for collaborative processes, the absence of this feature in the beginning may not prevent the initial adoption and only becomes a must-have in a later implementation stage.
Technology integration complexity	While this is important, it is more about the ease of integrating the technology. If the benefits outweigh the complexity, it can still be adopted, but it's not a necessity.
Internal Technologies	While having internal technologies can be advantageous, they might not be a strict requirement if the collaborative system can operate independently. It can even be beneficial to not have any internal technologies so that the transition towards a joint solution is easier.
External Technologies	Similar to internal technologies, external technologies may enhance the process but are not mandatory for the initial adoption of collaborative port call optimization.
Information intensity	This can be valuable for providing a richer data environment, but it's not a prerequisite for getting started with collaborative optimization.
Technology competence	While competence in technology is beneficial, the lack of it can be addressed through training and learning as part of the adoption process. It's not an absolute must-have.

D.2. Organization Context

Table D.2: Organization Context - Preconditions

Organization Context	
Must have	
Definition	**Explanation**
Financial resources	Adequate financial resources are crucial for investing in the necessary technologies and infrastructure for collaborative port call optimization.
PCO awareness	Stakeholders need to be aware of what collaborative port call optimization is and how it can benefit them. This awareness is essential for initiating the adoption process.
PCO Necessity Awareness	Awareness of the necessity of collaborative port call optimization is a fundamental requirement. Stakeholders must recognize why PCO is essential for the port's operations and efficiency.
Perceived benefits	Stakeholders must perceive clear benefits in adopting collaborative port call optimization. The perceived benefits drive motivation for adoption.
Intra-firm communication	Effective communication within an organization is critical for successful collaboration and implementation of new processes.
Nice to have	
Definition	**Explanation**
Organization/firm size	While the size of an organization can influence its capacity and resources, small organizations can still adopt collaborative port call optimization. It's more about how they allocate and utilize their resources.
Perceived financial cost	The perception of financial costs can vary, and while it can influence decision-making, it's not an absolute requirement.
Managerial obstacles	Overcoming managerial obstacles is important, but these obstacles can be addressed or mitigated over time. They are not inherent barriers to adoption.
Satisfaction with existing systems	While satisfaction with existing systems can affect the motivation to change, it's not a strict requirement for adoption.
Stakeholder pressure	While stakeholder pressure can be a driving force, it's not an absolute requirement for adoption.
Wages	Wages may be relevant in the context of motivation but are not a direct prerequisite for adoption.

D.3. External Environment Context

Table D.3: External Environment Context - Preconditions

External Environment Context	
Must haves	
Definition	**Explanation**
Geographical Location of the Port	The geographical location of the port is a key factor in determining the port's specific needs and challenges. It is a must-have as it influences the port's unique requirements.
Type of Port	The type of port (e.g., transshipment port, import/export) directly affects the port's operations and the relevance of PCO. It's essential to consider the type of port for effective adoption.
Legal Structure/Regulatory Environment	The legal and regulatory environment plays a significant role in shaping the port's operations. Understanding and complying with regulations is a fundamental requirement for the adoption process.
Port Coordination	Effective coordination within the port is crucial for collaborative optimization. This is a must-have for successful adoption.
Nice to haves	
Definition	**Explanation**
Demand Factors/Demand Level	While demand factors are important, they may not be a strict requirement for the initial adoption. Demand can vary and can be influenced by various factors.
Perceived Industry Pressure	Perceived industry pressure is a motivator but not a strict requirement.
Location of Port	The location of the port is a must-have, but the specific geographical location is more critical in determining unique needs.
External Restrictions	While external restrictions can be important, their presence does not preclude the adoption of collaborative port call optimization. It's about understanding and addressing these restrictions.
Level of Competition	While competition can be a factor, it may not be a strict requirement for the initial adoption.
Size of the Port	The size of the port can influence its capacity and resources, but it is more about how those resources are allocated and utilized.
Number of Movements in Port	This can be important but not necessarily a strict requirement for adoption.
Amount of Resources	The amount of resources can be considered, but it's more about their effective allocation and utilization.
Distance to Berth	While distance to the berth is relevant, it is not an absolute requirement for the initial adoption.
Amount of Activity Besides Container Vessels	The amount of activity besides container vessels can be a consideration but is not a primary requirement for the initial adoption.
Number of Actors Involved in the Port Call	The number of actors involved is important for coordination, but it can often be managed as part of the adoption process.
Management Risk Position	While risk considerations are important, they can be addressed over time.

D.4. Interorganizational Arrangements Context

Table D.4: Interorganizational Arrangements Context - Preconditions

Interorganiztional Arrangements Context	
Must haves	
Definition	**Explanation**
Inter-Organizational Communication and Collaboration	Effective communication and collaboration among various organizations and stakeholders are fundamental to the success of collaborative port call optimization. This is a must-have.
Collaboration Agreements	Formal collaboration agreements are essential to outline the roles, responsibilities, and expectations of different stakeholders in the collaborative process. They are a must-have to ensure clarity and accountability.
Information Sharing Protocols	Standardized protocols for sharing information are critical for smooth data exchange among stakeholders. This is a must-have to ensure consistency and interoperability.
Governance and Decision-Making	Clear governance structures and decision-making processes are vital to manage the collaborative efforts effectively. This is a must-have to ensure accountability and coordination.
Conflict Resolution Mechanisms	Given the potential for conflicts in collaborative environments, mechanisms for resolving disputes are crucial. This is a must-have to maintain harmony and progress.
Cultural Awareness	It acknowledges that stakeholders come from diverse cultural backgrounds, and their cultural values and practices can significantly influence how they approach collaboration and decision-making. Understanding these cultural differences is crucial for effective communication, building trust, and ensuring that collaboration and optimization efforts are culturally sensitive. It helps prevent misunderstandings, conflicts, and misalignment that can hinder the success of collaborative port call optimization.
Nice to haves	
Definition	**Explanation**
Incentive Structures	While incentive structures can motivate stakeholders, they are not an absolute requirement for the initial adoption.
Communication Protocols	Communication protocols can enhance efficiency, but they may not be a strict requirement for the initial adoption.
Collaborative Platforms	Collaborative platforms can facilitate the process but may not be necessary from the outset of adoption.
Data Governance	Data governance is relevant but may not be an immediate requirement for initial adoption.
Performance-Based Contracts	Performance-based contracts can be considered but are not necessarily a primary requirement for the initial adoption.
Planning Horizon Structure	The structure of planning horizons can be a consideration but is not an absolute requirement for the initial adoption.

E
Scientific Article

Enabling Collaborative Port Call Optimization: An Empirical Study and Conceptual Model of Pre-Conditions

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Abstract

Collaborative Port Call Optimization (PCO) is a key strategy to improve port efficiency. This study aims to bridge existing research gaps by providing a holistic understanding of collaborative PCO adoption, emphasizing the complexities of multi-organization collaboration and the influence of emerging technologies within the nautical chain and Port Governance structures. The TOEI-framework, a novel conceptual model extending the Technological-Organizational-Environmental (TOE) framework, offers a valuable tool for port authorities and operators, providing specific insights and recommendations to enhance the port call processes collaboratively. The study targets not only academics but also policymakers, port authorities, and nautical service providers. The findings uncovered through the empirical analysis and the development of the TOE framework provide valuable insights for ports aiming to enhance their port calls collaboratively, laying the groundwork for future research, encouraging further exploration of specific contextual factors, in-depth case studies, and the developing of tailored strategies for diverse ports globally.

Keywords: Collaborative Port Call Optimization, Adoption, Multi-Organization collaboration, Empirical analysis, Governance, Semi-Structured Interviews

1. Introduction

Ports are vital for global trade, handling 80% of sea freight [1, 2]. Challenges such as increased vessel size, unpredictable weather, and congestion lead to extended waiting times, impacting port and vessel performance [3]. Optimizing port call processes is crucial for maintaining competitiveness.
A port call involves scheduled vessel arrival, departure, and operational activities, with waiting times reaching approximately 19 hours, a substantial portion spent at anchorage [4]. The associated challenges include potential unavailability of essential services, resulting in high costs and emissions. Collaborative Port Call Optimization (PCO) addresses these challenges by coordinating stakeholders, leveraging technology, and streamlining processes.

While recent literature highlights PCO's role in reducing turn-around times and emissions [5, 3, 6], this study extends the focus beyond waiting times. Building on [6], it explores the conditions for collaborative PCO adoption, addressing a gap in holistic collaboration analysis.
Existing research, e.g., [5, 7, 8], underscores cooperation but lacks comprehensive collaboration analysis. To fill this gap, a thorough literature review was conducted, analyzing factors influencing successful port calls and the adoption of PCO. Additionally, semi-structured interviews were carried out with industry experts from 20 different ports worldwide, a unique aspect not covered in existing literature. The interviewees, mainly harbor masters and innovation officers working for the Port Authority, provided insights into the main objectives of the companies for the port call, the influence of existing port governance structures, port size and location, and the most occurring challenges. The interviews were a crucial step in identifying and interpreting the pre-conditions derived from both the literature and the interview analysis. Four types of pre-conditions, namely technology, organizational, external environment and interorganizational related conditions were identified, shedding light on the main objectives and means of companies, the influence of port governance structures, port size and location, and the challenges faced. The study revealed that successful PCO adoption goes beyond technology, emphasizing the need for fostering collaboration and mutual understanding among diverse stakeholders within the port call ecosystem.
Building on these findings, the study introduces the TOEI-framework, a novel conceptual model extending the Technological-Organizational-Environmental (TOE) framework and emphasizing Interorganizational Arrangements for col-

laborative PCO adoption.
The findings aim to contribute to existing research, offering empirical evidence and a new conceptual model. The TOEI-framework provides a holistic perspective on collaborative PCO adoption, addressing complexities when multiple organizations collaborate. The study targets not only academics but also policymakers, Port Authorities, and nautical service providers, providing specific insights and recommendations to enhance the port call process and overall port efficiency.

2. Literature review

PCO discussed in literature is gaining more and more attention [5, 9, 10] often aims for Just-in-Time (JIT)-arrivals and collaboration to minimize waiting times, reduce costs, and enhance predictability [11]. Only a few studies investigate collaboration, information sharing, and coordination among stakeholders and the significance of these factors for PCO, especially considering the nautical chain and in-port processes [7, 8, 6]. Various stakeholders involved in the port call process, such as terminals, tugboat operators, pilots, and customs, play critical roles in port operations, requiring effective collaboration for port call efficiency [12]. While stakeholder engagement is crucial, research gaps remain in understanding relationships within different port structures and their influence on Port Call Optimization. Insights from simulations and agent-based modeling highlight the complexity of PCO, but generalizability to different ports needs further exploration [13, 14].

Another topic frequently studied in literature are the Port Governance structures. Four different governance structures exist including public, landlord, tool and private ports with landlord ports being the most dominant ones around the world. Moving from the exploration of Port Governance structures, it's evident that existing models often fall short of capturing the intricate realities [15, 16], as exemplified by the unique case of the Port of Haifa. While the acknowledged impact of governance structures on port operations raises intriguing questions, such as those highlighted by [16], there's a distinct gap in delving into specific models and understanding the implications of emerging technologies within these structures.
To address this gap and investigate the influence of technology adoption, conceptual models become invaluable. Despite the plethora of existing models and frameworks for technology adoption, a notable absence persists—a gen-

eralizable adoption framework tailored to collaborative otimization measures in diverse port settings. Remarkably, other methods have failed to bridge this particular research gap.

Overall, the existing literature on PCO highlights a growing emphasis on achieving JIT-arrivals and fostering collaboration to enhance predictability and reduce waiting times. However, significant gaps persist, particularly in understanding collaboration dynamics, stakeholder interactions, and the influence of emerging technologies within the nautical chain and Port Governance structures. This study aims to address these gaps by employing qualitative methods, including interviews and ethnographic observations, to provide nuanced insights into port call delays. By developing a generalizable adoption framework for collaborative PCO in diverse port settings, this research not only contributes to the existing literature but also offers practical implications for policymakers, industry practitioners, and researchers. The broader impact of the study extends to driving positive changes in port operations and advancing discussions on sustainability and efficiency in maritime transportation.

3. Methodology

In this empirical and exploratory study, the goal is to capture the preconditions influencing the successful adoption of collaborative PCO measures in diverse ports through a qualitative research method. The methodology unfolds in seven main steps. The first step involves a literature analysis to identify challenges and pre-conditions relevant to PCO, laying the groundwork for subsequent framework development. The second step focuses on the design of a semi-structured interview guide, drawing inspiration from established methods. Subsequently, 20 interviews with industry experts from various ports are conducted to validate pre-conditions, ascertain the current port call situations, and unveil new challenges. The interviews were held with Harbor Masters (HM), Innovation Managers and other experts mostly employed by the Port Authority, hence a governmental organization. Furthermore, the CEO of Adani Ports SEZ, India's largest integrated ports and logistics company was interviewed as well. The diversity of ports was chosen to cover many different port contexts and structures (e.g., port size, ownership and management model, governmental regulations, etc.) and ultimately catch all of the preconditions no matter the setting of the port. The third step

delves into the description of interview analysis methods, encompassing word frequency, concept mapping, sentiment analysis, and categorization based on port size, governance, and location. The fourth step involves applying these methods to analyze interview results, seeking to comprehend the current port call landscape, challenges, and stakeholder relationships, ultimately identifying additional pre-conditions. Moving forward, the fifth step encompasses the development of a prototype framework, visually representing pre-conditions derived from both literature and interviews. Following this, step six initiates an iterative feedback process with academia and industry experts, refining the prototype framework based on their insights. The methodology concludes with the seventh step, the finalization of the TOEI Framework, synthesizing insights from literature, interviews, and expert feedback. Simultaneously, a concurrent literature analysis examines the relevance of governance structures, stakeholder relationships, and other influencing factors in port calls. This analysis aims to identify key factors that influence the adoption of collaborative PCOs and to understand the underlying rationales, providing a comprehensive approach that integrates theoretical insights with practical expertise.

4. Data Analysis and Model Development

4.1. Data Analysis

In order to answer the question of what the relevant pre-conditions for the successful adoption of collaborative PCO are, a literature and interview analysis was conducted. The extensive literature review undertaken for this study revealed crucial pre-conditions for collaborative PCO. Researchers such as [17] and [18] emphasized the significance of factors like Technology Readiness and Stakeholder Pressure, shedding light on their empirical effects. Additionally, [19] contributed insights into Multi-User adaptability and Financial Resources as influential factors, while [20] and [21] provided valuable perspectives on PCO Necessity Awareness and Perceived Industry Pressure, respectively. Additionally, 20 semi-structured interviews with industry experts from various ports were conducted. The interviews are analyzed using a combination of word frequency, concept mapping, sentiment analysis, and categorization based on port size, governance, and location, leading to the development and refinement of the TOEI Framework. This methodology ensures a robust exploration of the PCO landscape, combining theoretical insights with practical expertise from a diverse set of ports and stakeholders.

During the content and frequency distribution analysis which is based on the pre-work of the word frequency-, concept- and sentiment analysis, the following categories were identified: 1. Objectives and means of the interview respondents/their organization, 2. Perceived Challenges during the Port Call, 3. Port Call Optimization, 4. Centralization, 5. Key Stakeholders and Relationships between them. To be able to draw conclusions and find relationships, the various ports were assigned into the categories "Port size", "Port Location" and "Port Governance Structure". Using those categories in the data analysis is a sensible approach because these factors play crucial roles in shaping the dynamics of ports and can significantly influence various aspects of port operations. Based on these categories, the interviews were analyzed, leading to the following key findings

4.1.1. Objectives and means of the interview respondents/their organization

In scrutinizing the objectives and means relevant for the port call process, the study unearthed distinctive patterns among the interviewed companies. Improving efficiency stands out as the most recurrently cited objective, identified by 13 ports. The emphasis on efficiency aligns with its pivotal role in cost management and competitive positioning, as highlighted by the Port of Algeciras, Port of Gothenburg, and Port of Rotterdam. The pursuit of efficiency involves strategies such as reducing waiting times and optimizing vessel movements, as elucidated by various interviewees. Safety, the second most prevalent objective, surfaces as a priority for 10 interviewees, emphasizing the paramount importance of secure navigation and accident prevention. Sustainability, a focal point for seven ports, underscores the industry's growing commitment to emission reduction and environmentally conscious practices. Notably, sustainability emerges prominently among smaller ports, potentially motivated by local influences and a proactive stance. Means to achieve these objectives vary but prominently include stakeholder coordination, port call optimization, and information sharing. The prevalence of stakeholder coordination as the top mean underscores its significance in navigating the intricate processes of port calls. However, differences arise in the priorities of private, public, landlord, and tool ports. While efficiency dominates public ports' objectives, tool ports uniquely highlight sustainability, prompting further exploration of the relationship between governance structure and objectives. Similarly, private ports exhibit a distinctive focus on safety and growth with a humanitarian angle. These nuanced findings underscore the need for tailored strategies in port call optimization, considering

the diverse objectives and means across ports with varying sizes and governance structures. Further research is recommended to delve deeper into the nuanced dynamics, ensuring a comprehensive understanding for effective and collaborative port call optimization strategies.

4.1.2. Perceived Challenges during the Port Call

Examining challenges in port calls unveils a nuanced landscape with a maximum of ten and a minimum of four mentions for each challenge. Unlike objectives and means, challenges exhibit greater diversity, revealing external, stakeholder-related, process, and people-related hurdles. Inaccurate information emerges as a pervasive challenge, notably with 50% of interviewees highlighting its impact on port call efficiency. Surprisingly, despite this, information sharing is not prominently acknowledged as a means to address this challenge. "Willingness to use" digital solutions surfaces as a recurrent issue, echoing resistance from employees, especially among seasoned staff. Weather-related challenges, such as those faced by Northern ports like Kokkola and Vancouver or storm-prone Hadera, underscore the geographical influence on challenges. Regulatory restrictions, entangled with bureaucratic delays and limited flexibility, pose a significant hurdle, with contrasting perspectives between ports like Barcelona and Algeciras revealing varied regulatory impacts. Comparing these challenges across port sizes indicates that large ports grapple with more complexities, emphasizing the unique issues faced by each size category. Understanding these intricacies is pivotal for tailored strategies addressing the challenges that shape the dynamic landscape of port calls.

4.1.3. Port Call Optimization

The concept of PCO among interviewed ports reveals a diverse spectrum of interpretations, underscoring the multifaceted nature of this crucial maritime element. Disparities in definitions range from physical enhancements like berths and tugboats (e.g., Port of Ashdod, Port of Haifa) to pre-port call strategies such as JIT-arrivals (Port of Kobe). PCO extends further into the realm of technology and digital platforms, exemplified by measures like platform, Port Community Systems (PCS), and technology. Noteworthy is the perception that regular meetings can constitute PCO (Port of Barcelona, Port of Bremen/Bremerhaven). Despite recognizing the significance of PCO, some ports exhibit uncertainty regarding specific measures, revealing potential gaps in understanding or skepticism about the efficacy of certain platforms, as expressed by the Port of Hadera, Port of Bremen/Bremerhaven,

and Smart Ports Alliance. This nuanced perspective emphasizes the need for comprehensive exploration and tailored strategies, ensuring that PCO initiatives align with the unique challenges and visions of each port.

4.1.4. Centralization

The ideal level of centralization in port call optimization (PCO) emerged as a focal point in the interviews, with a clear consensus among the interviewees regarding its crucial role in enhancing efficiency. This unanimous perspective aligns with existing literature findings, particularly those presented by [8]. The distinct central roles assumed by public, tool, and landlord ports underscore the impact of port structure on centralization feasibility, with public and tool ports naturally leaning towards more centralized approaches. This nuanced insight contributes to the ongoing discourse on the optimal level of centralization in PCO, reinforcing the need for tailored strategies that consider a port's unique structure and objectives.

The diverse views on what centralization should look like reveal a rich tapestry of opinions within the industry. The preference for a centralized entity, as articulated by 15 interviewees, signifies a shared recognition of the benefits of streamlining the port call process. The disagreement on whether a neutral party or the Port Authority should spearhead this centralization underscores the complexity of decision-making in this context. The endorsement of models like the HVCC by some ports and the emphasis on entrusting neutral parties for effective decision-making and data security resonates with the findings in [8]. However, the recognition of potential drawbacks, such as resistance and compromised sustainability, adds a layer of critical evaluation to the discourse. The ongoing trend towards centralized planning, as revealed by 9 out of 17 interviewees, reflects a collective industry push for increased efficiency across diverse port sizes and types. The acknowledgment that different ports may respond differently to centralized decisions further emphasizes the importance of cultural awareness in implementing effective PCO measures.

In instances where centralization faces challenges or proves unfeasible, the interviews offer valuable insights into alternative strategies. The emphasis on enhanced collaboration among stakeholders, facilitated communication channels, and industry-wide forums or alliances underscores the adaptability and resilience of ports facing centralization hurdles. The practical examples of ports advocating for regulatory adjustments, as illustrated by the Port of Rotterdam in tug price regulation, highlight the proactive approach some

ports take to overcome barriers. The emphasis on cultural awareness, change management strategies, and compensation measures, such as performance-based contracts, paints a comprehensive picture of the multifaceted strategies employed by ports in the absence of centralized models. This recognition of the limitations of a one-size-fits-all approach and the advocacy for tailored strategies based on port characteristics contribute valuable nuances to the ongoing discourse on PCO.

The consideration of when a decentralized organization might be preferred over a centralized one, as exemplified by the case of the Port of Chittagong, introduces a layer of pragmatism to the discussion. The acknowledgment that government regulations can hinder the effectiveness of a centralized structure highlights the importance of aligning centralization strategies with the broader regulatory environment. The recognition that a certain degree of decentralization could stimulate profitability, innovation, and industry evolution adds a nuanced perspective to the prevailing narrative favoring centralization. This divergence in views reflects the industry's recognition of the need for flexibility and adaptability in the pursuit of optimization, fostering a more holistic understanding of the PCO landscape.

4.1.5. Key Stakeholders and Relationships between them

The interviews robustly affirmed the literature's identification of key stakeholders, such as the Port Authority, pilots, tugs, and shipping agents, pivotal in the port call process. The direct operational involvement of key stakeholders, like pilots and tugs, or their critical roles in planning stages, underscores their indispensable contributions to port call success. Notably, the influence of public authorities, evident in the Port of Barcelona, Port of Vancouver, and Port of Hadera, emphasizes external factors shaping port decisions. While the figure provides a comprehensive overview, further exploration into the dynamic relationships among stakeholders and their varying degrees of influence could enrich the findings.

The examination of competition's impact, offers a nuanced perspective on its role in the port call process. The positive and negative attributes associated with competition reveal its multi-faceted nature. The varying opinions among interviewees and the depiction of competition in different forms, both within the port boundaries and between different ports, highlight the complexity of managing competition. However, a deeper dive into specific instances or case studies, showcasing how ports navigate and capitalize on competition, could provide actionable insights for ports seeking to enhance

their port call optimization strategies.
In the realm of compensation and incentives in PCO, the experiences of the Port of Kokkola and TangerMed offer valuable lessons. TangerMed's strategic approach to information sharing, gradually building trust among stakeholders over four years, demonstrates the importance of transparent communication and negotiation. The challenges faced, such as occasional complaints and the necessity for ongoing workshops, shed light on the continuous effort required in fostering collaboration. Additionally, the consensus among interviewees, including HVCC, Adani Ports, and the Smart Port Alliance, regarding the prolonged timeline for implementing change highlights a critical aspect often underestimated in the port industry. The emphasis on influencing the mindset of decision-makers and frontline workers underscores the human factor's significance, surpassing technical hurdles. Lastly, the cautionary note on legal enforcement as an enforcement tool adds a layer of complexity to the discussion, emphasizing the need for a balanced approach.

4.2. Conceptual Model Development

This study meticulously identified influential stakeholders in port call decisions and measure adoption through literature review and interviews. Key players, such as the Port Authority and nautical service providers, emerged with high power and interest, laying the groundwork for understanding complex dynamics. Challenges at interorganizational and organizational levels offer opportunities for resolution through collaborative PCO measures. The upcoming subsection provides a conceptual model for collaborative PCO adoption, bridging literature and interview analysis for practical PCO implementation. Traditional frameworks like the Technology, Organization, and Environment (TOE) framework are enhanced to incorporate the "Interorganizational Arrangements" dimension, emphasizing collaborative synergy for comprehensive progress in port call optimization. This adapted framework recognizes the collective nature of interactions among organizations, emphasizing the need for interorganizational alignment before technology adoption. The "Interorganizational Arrangements" dimension addresses the complexities arising from multi-organization collaboration, crucial for optimizing port calls. This theoretical foundation guides the development of a conceptual model, offering a more comprehensive understanding of adoption conditions in the port industry. Empirical research is anticipated to validate and apply this framework effectively. Figure 1 shows the generalized version of the TOEI-framework.

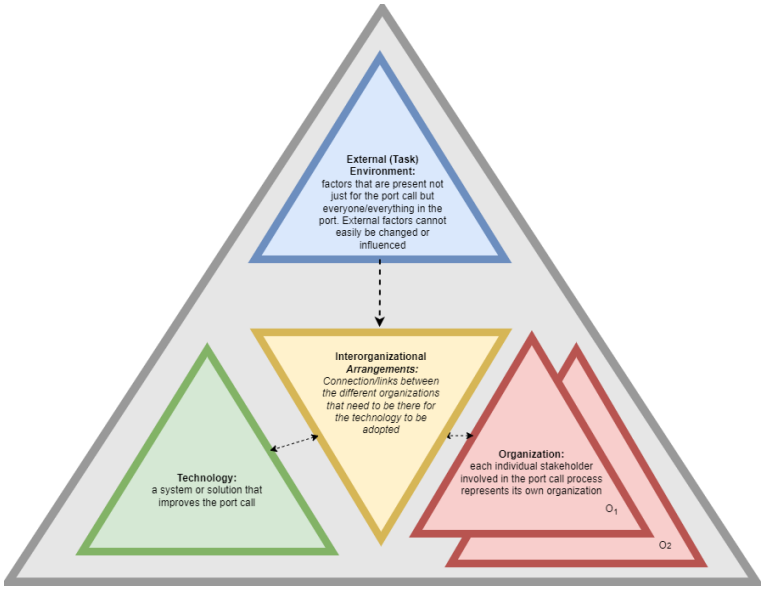

Figure 1: Conceptual Framework for the adoption of collaborative PCO

4.2.1. Technology

The first critical context for collaborative PCO is technology (visualized by the green triangle). Traditionally, the TOE framework considers technology as factors influencing an organization's ability to adopt innovations. For this research, technology encompasses solutions or systems improving the port call process, extending beyond hardware or software. It must be adopted collaboratively by the entire port community to effectively enhance PCO. The impact of technology on PCO is substantial, streamlining maritime operations, improving efficiency, and minimizing delays [22]. Real-time data collection, analysis, and communication facilitated by technology enable precise monitoring of vessel movements, berth availability, cargo handling, and weather conditions. This information empowers stakeholders to make informed decisions, allocate resources effectively, and coordinate port activities seamlessly [23]. Technology-driven solutions not only optimize port operations but also contribute to reduced emissions, lower costs, and enhanced competitiveness in the global maritime industry. The Technology Context plays a pivotal role in collaborative PCO, guiding the selection and integration of innovative solutions. It defines the parameters for technological advancements, serving as a roadmap for leveraging existing technologies and

exploring untapped innovations. Technology readiness, data sharing standards, and multi-user capabilities are identified as must-haves for successful technology adoption in collaborative PCO [24, 17, 5, 19]. Technology readiness ensures the comprehensive solution's state of preparedness, while data sharing standards and multi-user capabilities establish structured information exchange and collaboration among diverse stakeholders, critical for effective PCO. The conceptual model, detailed in Table 1, provides an overview of must-haves and nice-to-haves in the Technology Context, laying the foundation for successful collaborative PCO adoption.

4.2.2. Organization

The organizational context (represented through the red triangles in Figure 1), integral to the TOE framework, is paramount for a successful collaborative PCO [24]. In the port call scenario, where stakeholders function as separate organizations, including Port Authorities, towage entities, shipping firms, and pilots, diverse power dynamics and interests complicate optimization efforts [19]. The extended TOEI framework acknowledges these complexities, emphasizing the critical role of the organizational context in shaping internal dynamics and communication structures [5]. Key must-haves for effective PCO adoption include financial resources, PCO awareness, PCO necessity awareness, perceived benefits, and intra-firm communication [19, 7]. Financial resources are essential for large investments in technology, while PCO awareness ensures stakeholder alignment by fostering a common understanding of PCO concepts and objectives [19]. PCO necessity awareness propels the recognition of PCO's strategic importance, motivating organizations to participate [5, 20]. Perceived benefits drive stakeholder buy-in by anticipating positive outcomes, and intra-firm communication is fundamental for internal coordination, breaking down silos, and facilitating smooth changes for optimization [21, 5].

4.3. External Environment

The external environment context within the TOEI framework (presented by the blue triangle) considers both traditional external factors and interorganizational dynamics, emphasizing regulatory frameworks, industry-wide data exchange standards, and a cooperative culture among port stakeholders. This context includes predetermined factors such as the port's geographical location, size, cargo types, and infrastructure, which significantly influence port operations but are less amenable to rapid change [17]. As

the only independent dimension, it encompasses external variables difficult to influence, like weather, impacting the port call [24]. The must-haves for this context include the geographical location of the port, type of port, and legal structure/regulatory environment, vital for understanding the unique conditions and motivations for Port Call Optimization (PCO) implementation [19]. Recognizing the impact of dominant firms within the value chain shapes the collaborative agenda [17]. The geographical location influences the volume and complexity of port operations, the type of port defines cargo handling and stakeholder involvement, and the legal structure/regulatory environment shapes governance, authority, and decision-making processes, essential for successful PCO adoption [5]. The external environment acts as a strategic compass, guiding collaborative efforts toward effective Port Call Optimization.

4.4. Interorganizational Arrangements

The "Interorganizational Arrangements" context (visualized by the yellow triangle) is a crucial addition to the TOEI framework, addressing the complex systems in which multiple organizations must collaboratively adopt technology. This context recognizes the significance of structures, agreements, and mechanisms in fostering collaboration and mutual understanding among diverse stakeholders within the port call ecosystem. It acknowledges the limitations of the traditional TOE framework in capturing the intricate web of interdependencies and interactions among stakeholders. Emphasizing intersubjectivity as a key factor, this context provides nuanced insights into conditions and dynamics influencing successful adoption beyond the conventional organization-technology-environment triad. The must-haves for this context, include inter-organizational communication and collaboration, collaboration agreements, information sharing protocols, governance and decision-making, conflict resolution mechanisms, and cultural awareness, all essential for optimizing port call processes through collaborative endeavors [19, 7]. These must-haves emphasize the core elements of successful collaborative port call optimization, including effective information exchange, formalized collaboration agreements, standardized information sharing, collective decision-making, conflict resolution mechanisms, and cultural awareness to navigate diverse stakeholder backgrounds [7, 21]. Overall, this context serves as a critical guide for ports seeking successful collaborative optimization, addressing the complexities of collaborative relationships in the port call ecosystem.

4.5. Model validation

The "Model Validation" section illustrates a meticulous validation process that refines and enhances the conceptual model for Collaborative PCO. Three experts, chosen for their diverse backgrounds in academia and industry (interview 1: industry expert from UPT Erasmus, the Erasmus Centre for Urban, Port and Transport Economics in the Netherlands, interview 2: Port Call Optimization Lead from the Port Authority of the Port of Rotterdam, interview 3: Professor of Information Systems and Business Analytics from the American University of Sharjah with publications on the TOE-framework) provided invaluable feedback through interviews and email correspondence, leading to iterative model adjustments. The experts' insights played a crucial role in assessing the model's robustness and practicality, ultimately contributing to its refinement and readiness for real-world implementation. The feedback emphasized aligning the model with the research question, clarifying core drivers, and distinguishing between incremental and radical technology advancements. The importance of differentiating "must-haves" and "nice-to-haves" was highlighted, influencing the adaptation of the model. Additionally, the three validation interviews provided perspectives from both industrial and academic angles, ensuring the model's relevance for research and practice. The iterative adaptation process resulted in enhanced clarity, relevance, and potential for real-world application, making the model a valuable guide for ports embarking on PCO initiatives.

5. Discussion

Previous studies, such as those conducted by [25], [26], and [2], predominantly focused on achieving JIT-arrivals to minimize waiting times. However, they mainly neglected the role of collaborations among stakeholders. Although the exploration of port efficiency and ship turnaround time has been conducted before (see [6, 5, 8] for reference) these studies often neglected a thorough examination of collaboration dynamics, stakeholder interactions, and the impact of emerging technologies within the nautical chain and Port Governance structures.

To bridge this gap, the current research aims to offer a comprehensive understanding of pre-conditions by integrating these overlooked aspects, including collaboration dynamics, stakeholder interactions, and the influence of emerging technologies within the nautical chain and Port Governance structures.

This holistic perspective is presented through the development of a conceptual model, providing a well-rounded overview of all relevant prerequisites for the adoption of collaborative PCO.
The empirical and exploratory nature of this study involved a seven-step methodology, starting with a literature analysis, followed by the design of a semi-structured interview guide. This semi-structured interview, which enjoyed an broad participant pool and a wide geographical scope aimed to identify pre-conditions crucial for the adoption of collaborative PCO (total of 20 interviews with harbor masters and innovation officers from various ports worldwide and an additional two expert discussions were conducted). This study used a combination of word frequency, concept mapping, sentiment analysis, and categorization based on port size, governance, and location, which not only confirmed the existing assumptions found in the literature, as described by [19, 21, 17], but also revealed new insights into new pre-conditions for port call optimization.
For instance. incentive structures and conflict resolution mechanisms are identified as two pre-conditions for enabling collaborative PCO in the literature. However, although the importance of collaboration has been emphasized in the literature, including [9, 5], the agreement between the various stakeholders is often taken for granted. In the interviews conducted, it became clear that the agreement among stakeholders, and as a result, the collaboration often does not exist. This leads to additional problems, such as inaccurate information sharing, the willingness to use the collaborative measure, and ultimately less optimized port calls. To achieve agreement and collaboration, the various stakeholders must be considered and their power and interest in the port call must be evaluated. Their incentive towards the port call and its optimization must also be identified. Also, in case of any conflicts of interest, resolution mechanisms need to be established. Port call optimization will only occur if there is assurance that all parties involved have an incentive to optimize the port call process. Therefore, the incentive structure of the involved actors and the conflict resolution mechanisms are critical to the adoption of collaborative PCO and must be considered as a requirement.
Moreover, the interview analysis revealed distinctive patterns in the objectives and means of different organizations, emphasizing the importance of efficiency, safety, and sustainability. During the port call, it is important that the safe navigation of incoming and outgoing ships is ensured, otherwise collisions and consequently the endangerment of employees and resources may

follow. Especially for Port Authorities, whose purpose it is to ensure safety [27], this objective has a high priority. In addition to ensuring safety, the efficient execution of port calls should also be guaranteed, as this can increase the attractiveness of the port in general, but also reduce the waiting times of the ships in front of the port and a more seamless utilization of resources during the port calls. Furthermore, sustainability has swiftly become a key objective in port operations, evident in explicit commitments during port calls in surveyed ports like Copenhagen-Malmö, Gothenburg, Kobe, and Vancouver. The Port of Kobe's initiatives, such as substituting fossil fuels with LNG, exemplify this shift, driven not only by ethical considerations but also regulatory mandates highlighted in the International Maritime Organization's 2020 report [28]. This growing emphasis on sustainability is poised to reshape industry norms, reflecting a global commitment to environmentally conscious practices.

In addition, the analysis revealed significant challenges perceived during the port call, including inaccurate information, resistance to digital solutions, weather-related issues, and regulatory restrictions. For instance, port calls rely on accurate and timely information about vessel schedules, cargo status, and port conditions. However, such accurate information is not always available, and these inaccuracies can lead to misalignment of resources such as pilots and tugs and disruptions in the port call planning process. If a vessel arrives earlier or later than scheduled due to incorrect information, it can cause congestion at the port or unnecessary waiting times, affecting overall efficiency. Implementing a centralized, real-time information-sharing platform can be one way to ensure that all stakeholders have access to accurate and up-to-date data. This could include standardized data formats and protocols. However, inaccurate information sharing can also be a result of stakeholders resistance to adopt to digital solutions. During the interviews it became clear that traditional practices, lack of awareness, or concerns about cyber-security often hold people from adopting to new measures or accepting changed processes in general. However, providing trainings and implementing changes in a gradual process can reduce the resistance and increase the willingness to use the digital solutions [Source: interview 18]. Moreover, encouraging and incentivizing the adoption of digital solutions can enhance communication and streamline processes and improve the willingness to use.

Furthermore, during the literature and interview analysis, it emerged that

no uniform definition of collaborative PCO exists. The concept of collaborative PCO was evaluated differently by the ports, underlining the need for tailored strategies. However, the successful optimization of port calls relies on a collaborative approach and a common understanding of collaborative PCO. More specifically, the implementation of pre-conditions such as data sharing protocols, ensuring standardized data sharing, willingness of the stakeholders to adopt (digital) solutions, contingency planning, and regulatory harmonization all require that different ports have similar definition of collaborative PCO. Only if these and more pre-conditions are considered the adoption of collaborative PCO can succeed. This diversity in understanding PCO emphasizes the complexities involved and underscores the necessity for adaptable approaches to suit the unique characteristics of each port. The discussion extends beyond merely implementing pre-conditions to a nuanced consideration of the diverse perspectives within the industry, emphasizing the need for flexibility in collaborative PCO strategies.

Building upon this analysis, all findings from the literature and interview assessment were systematically categorized into four distinct contexts: technology, organization, external environment, and interorganizational arrangements. Subsequently, a comprehensive conceptual model, namely the TOEI-framework was developed. This model serves as a valuable tool for port authorities and operators, offering a structured framework to navigate the complexities of adopting PCO measures. For instance, within the technology context, the conceptual model delineates how the integration of digital platforms and data-sharing protocols can streamline information flow, addressing challenges such as inaccurate information and resistance to digital solutions highlighted earlier. The organization context considers how stakeholder willingness and collaboration can be fostered, while the external environment context addresses factors like regulatory restrictions and weather-related issues. Lastly, the interorganizational arrangements context explores how relationships and incentives can be optimized for successful PCO adoption. This conceptual model, tailored to the specific nuances of each port, provides actionable insights for industry participants striving to enhance efficiency and collaboration in their port call processes.

The developed TOEI-framework extends the traditional TOE framework, emphasizing Interorganizational Arrangements for comprehensive progress in port call optimization. The positive achievements outlined in this framework

include the identification of four types of pre-conditions crucial for successful collaborative PCO adoption, the development of the TOEI-framework, and insights into the nuanced dynamics of port call processes across diverse stakeholders and governance structures. The findings have meaningful implications for academia, policymakers, Port Authorities, and nautical service providers. Academic communities stand to benefit significantly from these findings. The identification of pre-conditions and the development of the TOEI-framework provide a conceptual basis for further research and exploration. Scholars can build upon this foundation to delve deeper into specific aspects of collaborative PCO, contributing to the academic discourse on maritime logistics, organizational behavior, and interorganizational relationships. Policymakers can leverage these findings to inform the development of policies that encourage and support collaborative PCO adoption. Understanding the pre-conditions and dynamics highlighted in the TOEI-framework allows policymakers to create regulatory environments that facilitate digital integration, incentivize stakeholder collaboration, and address key challenges in the maritime industry. Port Authorities play a central role in optimizing port calls. The TOEI-framework equips Port Authorities with a strategic tool to assess their current state of readiness and identify areas for improvement. By aligning their strategies with the identified pre-conditions, Port Authorities can enhance collaboration with stakeholders, implement effective digital solutions, and streamline port call processes for increased efficiency. For nautical service providers, understanding the nuanced dynamics of port call processes is crucial for tailoring services to the specific needs of each port. The TOEI-framework offers insights into the inter-organizational arrangements necessary for successful collaboration. Nautical service providers can use this knowledge to adapt their offerings, improve communication with other stakeholders, and contribute to the overall optimization of port calls.

The TOEI-framework provides a comprehensive perspective on collaborative PCO adoption, offering specific insights and recommendations to enhance port call processes and overall port efficiency. In contrast to the study by [6], which primarily focuses on abating shipping greenhouse gas emissions through PCO, this research extends beyond a singular environmental aspect. While Poulsen's work emphasizes swift turnaround and emissions reduction, this study takes a more holistic approach, delving into the complexities of collaborative PCO adoption. The novelty of this work lies in the comprehensive analysis of PCO adoption, encompassing not only techno-

logical aspects but also emphasizing the crucial need for interorganizational alignment. Poulsen's work, though valuable in its focus, does not delve into the broader spectrum of collaborative dynamics among diverse stakeholders in the port call ecosystem. By introducing the TOEI-framework, this research contributes significantly to the existing literature by recognizing the collective nature of interactions among organizations involved in port operations. This broader perspective goes beyond the scope of Poulsen's study, providing a more nuanced understanding of the intricate relationships and conditions influencing successful collaborative PCO adoption.

Limitations:
While this research has yielded valuable insights and contributed to the development of the TOEI framework for collaborative PCO adoption, several limitations should be acknowledged:

This research primarily centered on the port call process for arriving vessels, not explicitly considering the planning related to vessel departures. It was also assumed that the port call process concludes upon vessel arrival at the terminal. Nonetheless, the importance of terminals and berth planning as influential factors emerged during interviews, suggesting the need for holistic consideration of the entire port call process, the cargo operations at the terminal and the container backyard and the departing vessels.
Another limitation concerning the research scope lies in the exclusive consideration of container vessels in the study. Many ports are multi-functional, handling various cargo types and offering different services. Therefore, certain requirements and objectives may be more relevant in ports not accommodating container ships. Accordingly, inclusion of the different cargo types can lead to more realistic results for such ports.
Although, the interviews conducted in this study cover a wide range of countries with a relatively wide geographical distribution, still the interviewed ports might not be representative of the global spectrum. A concentration of interviews in Europe, with limited representation in South and North America may impact the generalizability of findings. Differences in regional practices, infrastructure, and regulatory environments could potentially lead to variations in PCO pre-conditions that are not adequately represented in the framework. Inclusion of more ports from the Americas, South Africa and East Asia, will enrich the findings of this research.
Moreover, the majority of interviewees belong to port authorities or gov-

ernmental organizations, potentially neglecting pre-conditions significant for nautical service providers. For instance, towage companies, who are often private companies standing in competition with other service providers might prefer local PCO over collaborative one. A broader representation of stakeholders could enhance the framework's comprehensiveness.

The analysis of the interview transcripts could be prone to subjective interpretation. Moreover, the manual process of labeling the interview summaries carries the risk of overlooked or misinterpreted insights. Therefore, use of more unbiased interview analysis methods, such as automatic labelling, together with the manual labelling can decrease the risk of subjectivity in the interview analysis.

6. Conclusion

In conclusion, this study bridges existing research gaps by providing a holistic understanding of collaborative PCO adoption, emphasizing the complexities of multi-organization collaboration and the influence of emerging technologies within the nautical chain and Port Governance structures. The TOEI-framework, with its focus on Interorganizational Arrangements, extends the traditional TOE framework, offering a valuable tool for ports aiming to optimize their port call processes collaboratively. The insights gained from this study contribute not only to academic literature but also provide practical implications for policymakers and industry practitioners, fostering positive changes in port operations. The nuanced dynamics uncovered through the empirical analysis and the development of the TOEI-framework provide valuable insights for ports aiming to enhance their port call processes collaboratively.
This study's findings lay the groundwork for future research in collaborative PCO adoption, encouraging further exploration of specific contextual factors, in-depth case studies, and the development of tailored strategies for diverse ports globally. Overall, the TOEI-framework, with its emphasis on Interorganizational Arrangements, offers a fresh perspective on collaborative PCO adoption, recognizing the complexity of interactions among diverse stakeholders within the port call ecosystem.

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