Development of a maturity model for dry ports in The Netherlands

Master thesis project

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Challenge the future

DEVELOPMENT OF A MATURITY MODEL FOR DRY PORTS IN THE NETHERLANDS

MASTER THESIS PROJECT

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PREFACE

This thesis is the culmination of my graduation project for the masters program in Transport, Infrastructure and Logistics at Delft University of Technology. It represents the conclusion of extensive research and analysis conducted in the field of dryport development. I am grateful to Hogeschool Rotterdam for providing me the opportunity to be part of the joint project, "Greening Corridors: The Road to Sustainable Freight Transport," which involved collaboration among five universities of applied sciences in the Netherlands.

I would like to express my sincere gratitude to my main supervisor, Ron, whose guidance and support were invaluable throughout every stage of this project. His expertise and insights greatly contributed to the development and refinement of the research questions, methodology, and overall direction of the thesis.

I would also like to extend my thanks to Mahnam, who played a crucial role in helping me structure and present my report. Her assistance in organizing the content and improving the overall presentation of the thesis was instrumental in achieving a cohesive and coherent final product.

Special appreciation goes to Erik, my external supervisor, for his invaluable guidance and support. Erik's deep knowledge and insights into the world of dryports were instrumental in shaping the research focus and connecting me with relevant stakeholders in the industry.

Last but not least, I would like to express my gratitude to my chair, Lori, for his critical feedback. His expertise and attention to detail greatly contributed to the refinement and improvement of the thesis, elevating its overall quality.

I would also like to acknowledge the contributions of all the stakeholders, experts, and professionals who generously shared their insights and experiences during the interviews and consultations. Their valuable input and perspectives provided a practical context to the research and enriched its findings.

Lastly, I would like to thank my family and friends for their unwavering support, encouragement, and understanding throughout this journey. Their belief in my abilities and constant motivation played a significant role in bringing this thesis to fruition.

It is my hope that this thesis contributes to the existing body of knowledge on dryport development and serves as a valuable resource for researchers, practitioners, and policymakers in the field of logistics and transportation.

Chandusha Thati
August, 2023

SUMMARY

This thesis presents the development of a maturity model for dryports, addressing the existing research gap in this field. Dryports play a crucial role in facilitating the efficient and sustainable movement of goods, acting as strategic hubs connecting various modes of transportation. However, the absence of a specific maturity model tailored for dryports has hindered their development and optimization. The research gap inspired the main research question which is:

How to develop a maturity model for dryports?

The following sub-questions need to be clarified in order to answer the main research question:

1. What are the key functions involved in the operations of dryports?
2. What are the development steps involved in transforming an intermodal terminal into a dryport, considering the requirements and the processes?
3. How can the developed maturity model for dryports be effectively operationalized, ensuring its applicability and linkage to decision-making processes?

A thorough literature review was conducted, exploring the existing research on dryports, maturity models. This review provided a solid foundation for understanding the concept of dryports and identifying the key elements and functions associated with their development.

Stakeholder analysis was conducted through interviews with experts and professionals in the field, gathering valuable insights on the requirements, challenges, and best practices in transforming intermodal terminals into dryports. These interviews provided a real-world perspective and helped shape the maturity model development process. The requirements for an intermodal terminal to be converted into a dryport were identified through a combination of stakeholder interviews and a thorough literature review.

Subsequently, a morphological chart was created to delineate the identified functions and their corresponding potential solutions. This analytical tool serves as a valuable resource for terminal operators. It facilitates the process of aligning the functions with the appropriate solutions, ensuring a strategic and informed approach to implementation. By referring to the morphological chart, terminal operators can effectively assess their readiness to adopt specific functions and select the most suitable solutions that align with their operational requirements. This aids in streamlining the decision-making process and optimizing the integration of functions within the terminal operations. Later, the functions are ranked by experts using Best-Worst method. This helps in finding the importance of functions with respect to dryports. This ranking provided a clear understanding of the critical functions that should be addressed at different maturity levels.

The final output of this research is the developed maturity model for dryports which can be seen in the Figure 1. The model defines four dimensions which covers different functional aspects of a dryport and five maturity levels, each representing a stage in the evolution of an intermodal terminal towards a fully functional dryport. The functions are placed within these levels based on their ranking and importance, providing a roadmap for the progressive development and optimization of dryports.

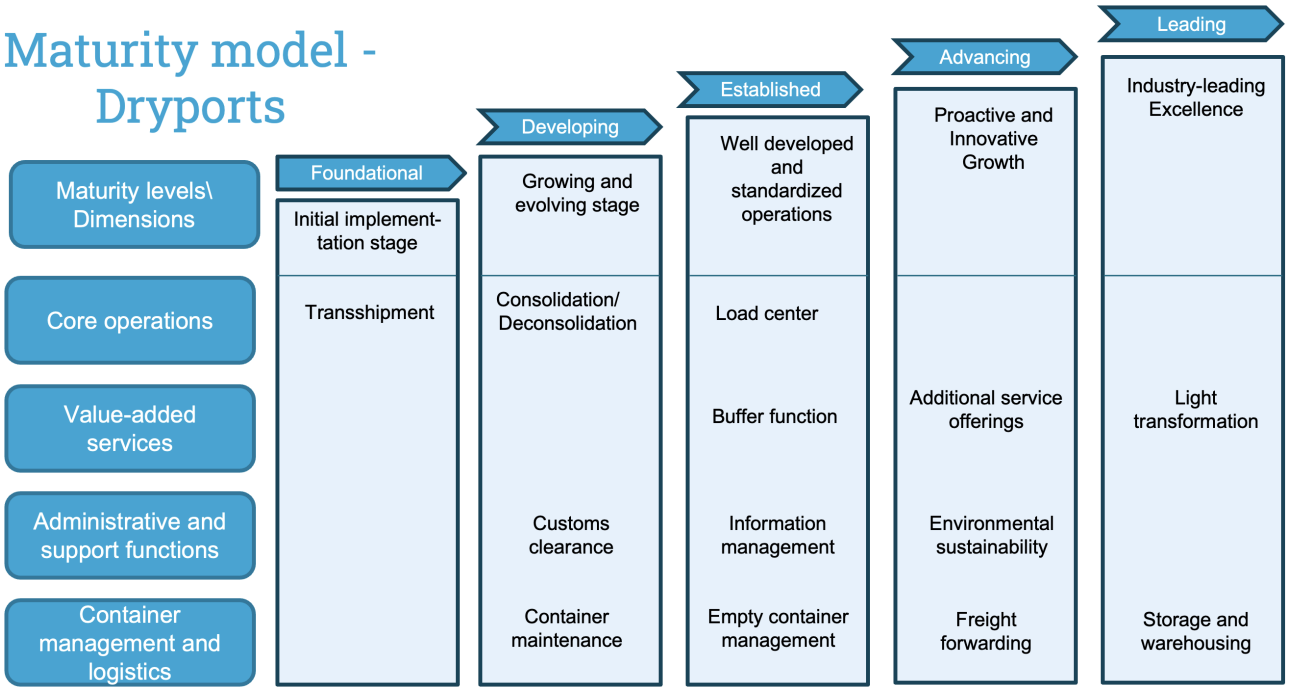

Figure 1: Maturity model of dryports

The developed model has been reviewed by experts in order to verify model's applicability and usefulness. The model has been refined according to expert feedback to enhance its clarity and utility. In order to validate the model, it is applied to two case studies: BCTN and CTU. This helped in capturing the real-world context and providing actionable insights for improving dryport operations.

This research not only contributes to the academic knowledge on dryports but also offers practical implications for industry professionals, policymakers, and stakeholders involved in the development and management of dryports. The maturity model serves as a valuable tool for strategic decision-making, resource allocation, and continuous improvement in the dynamic and evolving field of dryport development. By bridging the research gap and providing a comprehensive maturity model, this thesis aims to enhance the understanding, efficiency, and sustainability of dryports, ultimately supporting the growth and optimization of global supply chains.

While this research has provided valuable insights into creating a dryport maturity model, it's important to acknowledge its limitations. The stakeholder interviews were mainly conducted in the Netherlands, potentially restricting the applicability of findings globally. The reliance on a small sample size (16 participants) for the best-worst method ranking might affect function rankings' generalizability. Similarly, verifying the model with only 4 experts could limit its broader usability. The research operated within a specific timeframe, possibly constraining data collection's depth and breadth for dynamic dryport operations. Inherent subjectivity in function identification and ranking using the best-worst method, despite expert validation, introduces potential bias. Lastly, the study focused on internal dryport aspects, neglecting thorough exploration of external factors like regulations and economic shifts. Despite these limitations, recognizing external dynamics' potential impact on dryports could offer insights for future research and industry application.

Several recommendations can be drawn from the research. Future research should integrate the morphological chart with the maturity model and validate function improvement strategies through collaboration with industry experts, bridging theory and practice. Extensive validation of the maturity model across various dryports is essential for its applicability, refining it according to real-world contexts. Cross-country comparisons provide insights into different development approaches. Exploring collaborative initiatives among inland terminals for the Green Corridor project can enhance sustainability and efficiency, considering environmental impacts. These recommendations collectively contribute to advancing dryport research and practice.

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INTRODUCTION

In this chapter the thesis project is introduced. The first section elaborates on the context of the research. Following is a description of the research problem. Next, the objective of this research is explained and the scope of the research is given. Subsequent to the description of the objective and scope, the main research question that will be answered is stated together with the sub-questions that need to be answered. Then, the theory and methods that are used to answer the research questions are explained. Finally, the structure of the research is discussed.

1.1. RESEARCH CONTEXT

The Netherlands has long been recognized as a global hub for international trade, thanks in large part to its strategic location at the heart of Europe's transportation network. The country's extensive system of ports, waterways, and highways makes it a natural choice for companies looking to move goods into and out of Europe quickly and efficiently. The port of Rotterdam, in particular, has emerged as one of the world's busiest and most important seaports, handling millions of tons of cargo each year. However, despite the success of Rotterdam and other Dutch ports, inland terminals in the Netherlands may not be as efficient as desired. The primary contributing factor to these inefficiencies can be attributed to the fragmented nature of the market. In the Netherlands, the inland terminal sector is characterized by a multitude of small operators independently managing their terminals, leading to challenges in coordination and standardization. Additionally, certain terminals suffer from inadequate infrastructure, despite the country's extensive waterway and port network, hampering their overall efficiency. Furthermore, a lack of sufficient volume and imbalances in imports and exports further compound the issue.

However, a promising solution lies in the adoption of the dryport concept. Dry ports, also known as inland ports or intermodal terminals, are inland transportation hubs where cargo can be transferred between different modes of transportation, such as ships, trains, and trucks (Roso and Lumsden, 2010). These facilities can help to reduce congestion and transportation costs, improve supply chain efficiency, and provide access to markets that are not easily accessible by sea. (Roso et al., 2009) explores the concept of dry ports as a catalyst for transforming alternative transport network configurations. Dry ports are recognized for their ability to consolidate cargo and cater predominantly to a community of cargo interests and operators. The primary objective of dry ports is to divert activities from seaports to alleviate congestion and reap various advantages. Notably, it emphasizes the potential of dry ports in facilitating modal shift as one of the key benefits. They perform several functions in the logistics supply chain, including:

1. Transshipment: Dryports provide a location for the transfer of goods from one mode of transport to another. For example, goods arriving by train can be transferred to trucks for local delivery, or goods arriving by truck can be loaded onto trains for long-distance transport.
2. Consolidation: Dryports can serve as a location for consolidating goods from multiple suppliers or destinations, which can reduce transportation costs by enabling larger shipments.
3. Distribution: Dryports can serve as a distribution center for goods, providing a location for inventory management, order fulfillment, and other logistics functions.
4. Customization: Dryports can provide value-added services such as labeling, sorting, and repackaging of goods to meet customer or regulatory requirements.
5. Information management: Dryports can provide real-time information on the status of goods, transportation schedules, and inventory levels, which can help to optimize logistics operations and im-

prove supply chain visibility.

Overall, the functions of dryports are designed to improve the efficiency, reliability, and sustainability of logistics operations by providing a seamless connection between different modes of transport and enabling the consolidation and distribution of goods.

Given the importance of the Dutch logistics sector, it is surprising that dry ports have not been more widely adopted in the Netherlands. However, this may be changing, as there is growing interest in converting the country's inland terminals into dry ports. One of the main challenges facing the development of dry ports in the Netherlands is the country's extensive system of waterways and ports. While this network has been a boon for international trade, it has also made it difficult to identify suitable locations for dry ports. Despite these challenges, there are a number of inland terminals in the Netherlands that could potentially be converted into dry ports. For example, the port of Venlo, located near the Dutch-German border, is already a major transportation hub for goods moving between Europe and Asia. With its proximity to major highways and rail lines, as well as its existing infrastructure, Venlo could be an ideal location for a dry port. Other potential locations for dry ports in the Netherlands include the port of Amsterdam and the city of Rotterdam itself. While these locations may face some logistical challenges, such as limited space for expansion, they could still offer significant benefits for companies looking to move goods into and out of Europe.

The rising interest in converting inland terminals to dry ports presents a significant opportunity for the Dutch logistics landscape. As the concept of "extended gate" gains traction, inland terminals can effectively serve as extensions of major seaports, providing smoother cargo handling, reducing congestion, and fostering efficient trade flows. According to (Veenstra et al., 2012a), an extended gate is "an inland intermodal terminal directly connected to seaport terminal(s) with high capacity transport mean(s), where customers can leave or pick up their standardised units as if directly with a seaport, and where the seaport terminal can choose to control the flow of containers to and from the inland terminal". By embracing this transformative approach, the Netherlands can further enhance its logistics capabilities, reinforcing its position as a key player in the global supply chain.

Dryports, despite adding an additional link in the supply chain, offer several benefits that outweigh the potential risks. Firstly, dryports improve overall supply chain efficiency by bridging the gap between seaports and inland regions. By providing seamless intermodal connectivity, they enable faster and more reliable transportation of goods, reducing transit times and enhancing supply chain responsiveness. This contributes to leaner and more streamlined operations, minimizing delays and optimizing inventory management. Additionally, dryports promote sustainability by reducing carbon emissions and congestion associated with long-haul trucking. By strategically locating inland, they facilitate shorter transportation distances, shifting freight from congested roads to more environmentally friendly modes such as rail and waterways. This promotes greener supply chains and aligns with sustainability goals. Furthermore, dryports enhance supply chain reliability by offering alternate routes and transportation options. In the event of disruptions or congestion at seaports, having a well-functioning dryport network provides flexibility and resilience, allowing for efficient cargo diversion and redistribution. This helps mitigate risks associated with port-related bottlenecks and ensures a more reliable and robust supply chain.

In conclusion, the development of dry ports in the Netherlands has the potential to greatly enhance the country's logistics sector and boost its standing as a global hub for international trade. By converting existing inland terminals into dry ports, the country can take advantage of its extensive transportation network and improve supply chain efficiency, while also reducing congestion and transportation costs. While there are certainly challenges to be addressed, the opportunities offered by dry ports make them a promising area for future investment and development in the Netherlands.

1.2. Research problem

An overview of the dryports is given in the Section 2.1. Although the dryport concept is already well established in countries like China, India, North America, Myanmar, Sweden and Finland, the Netherlands has seen less development. The motivation for research on the development of dry ports in the Netherlands is driven by the country's position as a major player in international trade. Dry ports can provide significant benefits for companies looking to move goods into and out of Europe, including reduced transportation costs, improved supply chain efficiency, and access to new markets. However, despite the potential benefits of dry ports, their development in the Netherlands has been limited. By conducting research on the development of dry ports, researchers can help to address the logistical challenges associated with their development, identify potential locations for new facilities, and support the country's economic growth and sustainability goals.

It can be seen in the Subsection 2.2.2 that plenty of research has been done on the quantitative and qualitative analysis of the dry ports. It is interesting to note that many studies have performed an extensive literature review by comparing all the dryports around the world. Quantitative methods like simulation model, linear programming and p-hub median models were developed to see the percentage savings on costs and emissions. SWOT analysis, case study analysis, stakeholder analysis, multi-criteria analysis has been done qualitatively to know the potential advantages of the dryports. However, maturity model for dry ports has not been developed. It is a tool used to assess the development and maturity level of a dry port. Such a model typically involves a framework or set of criteria that can be used to evaluate different aspects of the dry port, including its infrastructure, processes, and technology.

1.3. Research objective

The objective of this research will be to develop a framework that helps the inland terminal operators to assess and improve in order to convert into dry ports and also to evaluate what a maturity model does to dryports. The model can help stakeholders to identify the strengths and weaknesses of a dry port, as well as the areas that require improvement. By developing a maturity model, the objective is to provide a standardized approach to evaluating dry ports, which can facilitate benchmarking and knowledge sharing across different facilities. Also, finding a way to assess the maturity level of a dry port has not been studied yet according to Section 2.2, which will therefore be a contribution to the literature review as well.

1.4. Research scope

There are three main levels of planning in organizations: strategic, tactical, and operational planning. As can be seen in the Figure 1.1, strategic planning is the highest level of planning and involves setting long-term goals and objectives, determining the overall direction of the organization, and allocating resources to achieve those goals. Tactical planning involves developing short to medium-term plans that support the organization's strategic goals, while operational planning focuses on day-to-day operations (Badri et al., 2013).

Developing a maturity model for a dry port requires considering all three levels of planning - strategic, tactical, and operational - because each level plays a crucial role in determining the overall maturity of the dry port. At the strategic level, the focus is on long-term planning, including identifying goals, objectives, and priorities for the dry port. This level of planning helps to ensure that the dry port is aligned with the overall vision and mission of the organization and is positioned to achieve its long-term objectives. The tactical level of planning is concerned with the implementation of strategies and plans that have been developed at the strategic level. This involves developing specific action plans, allocating resources, and identifying performance metrics to measure progress towards achieving the strategic goals. Finally, the operational level of planning is focused on the day-to-day activities of the dry port, such as managing cargo flows, handling operations, and ensuring compliance with regulations. This level of planning is critical for ensuring that the dry port is operating efficiently and effectively to support the overall strategic and tactical objectives. By

considering all three levels of planning, a maturity model for a dry port can provide a comprehensive assessment of the dry port's maturity, identifying areas of strength and weakness across all levels of planning and providing a roadmap for improvement.

Figure 1.1: Different levels of planning *Note. Retrieved from Aniskoff and Lumpkins (2011)*

1.5. Research questions

In order to reach the objective of this research, given in Section 1.3, and stay with the defined scope in Section 1.4, a main research question is given as follows:

How to develop a maturity model for dryports?

The following sub-questions need to be clarified in order to answer the main research question:

1. What are the key functions involved in the operations of dryports?
2. What are the development steps involved in transforming an intermodal terminal into a dryport, considering the requirements and the processes?
3. How can the developed maturity model for dryports be effectively operationalized, ensuring its applicability and linkage to decision-making processes?

1.6. Research theory and methods

In order to answer the main research question and the sub-questions, the used methods will be described in the following subsections.

1.6.1. Literature Review

The literature study is used to gain more insight on the concepts dryports and maturity model. It is also used to obtain a research gap in the literature, which can be filled by answering the mentioned research question. Furthermore, functions that are required in a dryport can be found from the research.

1.6.2. Stakeholder analysis

Different stakeholders are involved in the development and operation of dryports. These stakeholders can include:

- Inland terminals operators: Terminal operators are important stakeholders in the development of a maturity model for dryports as they are the primary operators of facilities and infrastructure within the dryport. Their expertise and involvement can provide valuable input into the development of the model, ensuring its practicality and effectiveness in improving dryport operations and performance.

- Government agencies: Government agencies at the national, regional, and local levels play a critical role in supporting the development and operation of dryports. They may provide funding, regulatory support, and infrastructure development to help facilitate the growth of the dryport.
- Port authorities: Port authorities are responsible for the management and operation of the dryport, including the provision of infrastructure, services, and security.
- Freight forwarders and logistics companies: Freight forwarders and logistics companies are key users of the dryport, as they rely on the facility to facilitate the movement of goods between different modes of transportation and to provide value-added services.
- Shipping lines: Shipping lines may use the dryport as a hub for the consolidation and deconsolidation of cargo, as well as for the provision of value-added services.
- Customers: Customers, such as importers and exporters, use the dryport to facilitate the movement of their goods, to access value-added services, and to benefit from reduced transportation costs and improved supply chain efficiency.
- Residents: They can be directly impacted by the operations of the dryport, including noise, traffic, and environmental issues. Their involvement can provide insight into the potential social and environmental impacts of the dryport and can help ensure that the model addresses concerns and minimizes negative impacts. The participation of residents can also help build trust and support for the development and operation of the dryport.

The maturity level of a dryport can have a significant impact on these stakeholders. As the dryport matures, it can attract more stakeholders and offer a wider range of services, which can lead to increased efficiency, reduced costs, and improved customer satisfaction. This, in turn, can lead to further growth and development of the dryport, creating a virtuous cycle of improvement and growth. Requirements from all the stakehoders will be taken into consideration in order to develop the maturity model.

1.6.3. Interviews

In order to gain insight on the dryports and inland terminals, interviews are conducted with inland terminal operators, academic experts and logistic consultants. These interviews will help in establishing requirements and functions of a dryport. They also help in verifying the developed maturity model.

1.6.4. Morphological chart

Morphological chart will be developed in order to map and explore the functions and potential solutions related to the development of dryports. It allows for a systematic analysis of various function-solution combinations, providing valuable insights into the requirements and possibilities of transforming an intermodal terminal into a dryport.

1.6.5. Case studies

The following approach involves conducting case studies at multiple inland terminals to assess the maturity of each company and provide valuable suggestions for enhancing their functionalities. To ensure the integrity and reliability of this research, rigorous measures have been implemented to meet the demands of good research practices. The model will undergo verification by experts and subsequently be applied to two case studies to establish its validity.

1.7. Research structure

The structure of the thesis report is shown in the Figure 1.2 and will be described as follows. The first chapter of the report is the introduction, in which the research problem, research objective, research scope, research questions, and research methods are explained. In the second chapter, literature review will be performed on dryports and maturity models. Then the chapter three will discuss the functions of dryports which is followed by identifying requirements that are needed for inland terminals to convert into dryports and developing morphological chart along with using Best-Worst method to rank the functions in the fourth chapter. Maturity model will be developed and verified in the fifth chapter. Once the model is developed

and verified, it is finally applied to a use case to find it's applicability to real world scenario. Finally, the last three chapters will include a conclusion, limitations and recommendations in which potential future research topics are suggested.

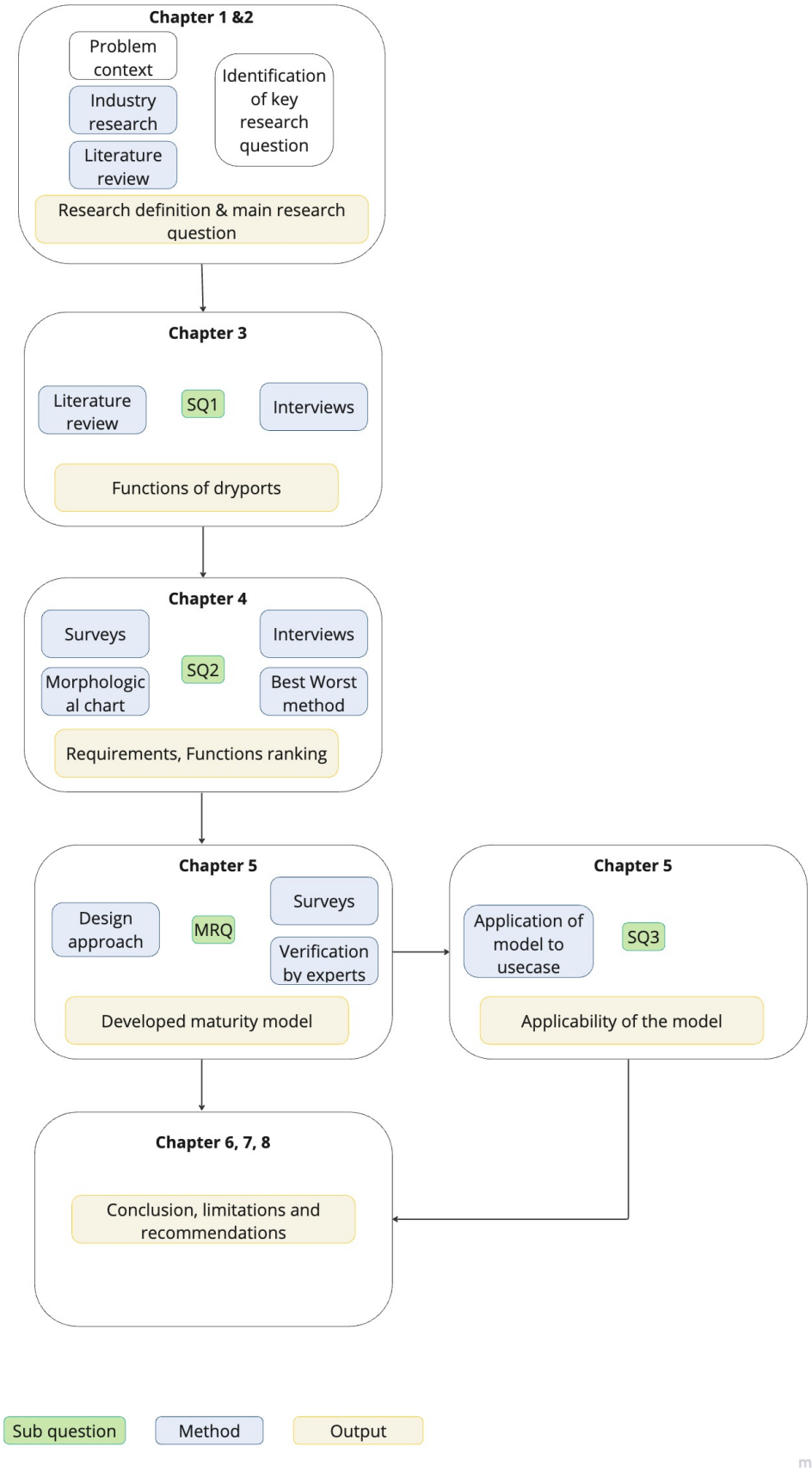

Figure 1.2: Report outline

2

LITERATURE REVIEW

In this chapter the literature review is discussed, which has been used to find an appropriate research gap that will be answered by the presented research questions in the previous chapter. This chapter starts with an explanation on dryports. Then, an overview of the literature that is already known combined with several search terms, which results in a research gap table is presented. This is followed by some information on morphological chart. Then, the final section gives details on the maturity model.

2.1. DRYPORTS

Dry ports have become increasingly popular in recent years as a means of improving the efficiency of global supply chains. Sea ports face pressure to enhance their competitiveness in order to retain or expand their market share. By adopting the dry port concept, sea ports can improve their service levels, capacities, and storage facilities by establishing intermodal terminals located inland, which are linked to the sea ports by rail/water. In recent years, there has been significant research interest in dry ports, as they are seen as a potential solution to improve the efficiency of hinterland transport. According to (Roso et al., 2009), dryport is defined as "an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport". The phrase "as if directly to a seaport" in the definition of a dryport implies that customers have the convenience of handling their standardised cargo units, such as containers, in a manner similar to how they would do so at a seaport. In other words, the dryport functions as an extension of the seaport, offering the same level of efficiency, connectivity, and services for cargo handling and movement. When cargo arrives at a dryport, it undergoes similar processes and procedures as it would at a seaport. Customers can leave their cargo units at the dryport for onward transportation to the seaport for export or collect cargo from the dryport after import in a streamlined manner. This direct connection to the seaport(s) and high-capacity transport means ensures smooth and seamless transfer of goods between the dryport and the seaport. This emphasizes the integrated nature of dryports with seaports and the ability to offer seaport-like services and facilities inland.

Benefits of dryports:
Dry ports offer numerous benefits for global supply chains. According to the (Roso and Lumsden, 2010), the benefits of dry ports include: 1) reducing congestion and delays at seaports, 2) improving the efficiency of the supply chain, 3) reducing transportation costs and carbon emissions, 4) enabling cargo consolidation, 5) enhancing regional competitiveness, and 6) promoting economic development. Dry ports also facilitate the integration of different modes of transportation, such as rail and trucking, which reduces the reliance on long-distance trucking and improves the overall efficiency of the supply chain.

Challenges of dryports:
Despite the benefits of dry ports, there are also several challenges that must be overcome. According to (Notteboom and Rodrigue, 2005), the challenges of dry ports include: 1) high capital costs and long lead times for investment, 2) coordination and governance issues among different stakeholders, such as shipping lines, trucking companies, and customs authorities, 3) regulatory and legal issues related to tariffs, customs procedures, and border crossings, and 4) environmental and social impacts related to the construction and operation of dry ports.

2.2. Previous research on Dryports

This section provides an overview of the existing research and literature on the topic of dryports. It aims to establish a comprehensive understanding of the current state of knowledge and identify any research gaps that exist. The section begins by outlining the research methodology employed, which guides the selection and analysis of relevant study papers. The selected study papers include both qualitative and quantitative analyses, offering a multidimensional view of dryports. Through these papers, various aspects of dryport development, operations, and management are explored.

2.2.1. Research Methodology

In order to find a research gap in the literature on dryports, certain terms are used in the search engine Google Scholar. Only the literature with the criteria mentioned in the Table 2.1 is considered. Literature research is mainly based on the snow balling technique. At first the citation function in the google scholar and scopus is used to find relevant literature using the keywords mentioned above. TU Delft repository has also been used to find some interesting thesis done by students done on the topic of Synchromodality. After obtaining the papers from above processes, they are given a 'light' read: abstract, literature review, introduction, discussion/conclusion and recommendations chapters only. Articles that are less relevant have been removed from the Literature selection. When new relevant articles were found while doing the previous step, they were also given a light read and added to the collection and this process was done iteratively until no more sources appeared. In total 51 papers were found to be relevant.

Table 2.1: Relevant articles of used search terms

Concept groups	Concept; Parameters; Location				
Keywords	Concept	Dry ports	Inland Terminals		
	Parameters	Supply chain	Cost reduction	Congestion	
	Location	Asia	America	Europe	The Netherlands
Truncation	(Concept) OR (Parameters) OR (Location)				

2.2.2. Study of papers

After carefully reading the papers resulted from the search above, methods used in the studies have been clearly stated in the Table 2.2. It is interesting to know that both qualitative and quantitative analyses have been performed for understanding the functioning and performance of dry ports.

Qualitative analysis

Qualitative analysis involves collecting and analyzing non-numerical data such as interviews, surveys, and observations. It can be observed that many studies (Khaslavskaya and Roso, 2019), (Rodrigues et al., 2021), (Khaslavskaya and Roso, 2020), (Roso and Lumsden, 2010), (Rodrigue and Notteboom, 2012), (Veenstra et al., 2012b), (Roso et al., 2009) and (Monios et al., 2016) have their main methodology as literature review. (Khaslavskaya and Roso, 2019) has studied the concept of dryports and applied it to a case study in Sweden to find the means to enhance supply chain optimization through the integration of dryports. Similarly, (Rodrigues et al., 2021) performed a literature review to find the main objectives of dryports in Brazil and later analysed the achievement of those objectives by conducting value-focused thinking approach on the case studies. Few studies performed litearture review alone to know the trends and outcomes of dryports. Based on the study from (Khaslavskaya and Roso, 2020), it was found that dry ports exhibit variation worldwide in terms of their location, functions, services, ownership, and level of development. Despite being a relatively new and distinct research domain, five key themes have emerged: conceptual discourse, environmental effects, economic implications, performance outcomes, and dry ports viewed from a network perspective. (Roso and Lumsden, 2010) and (Monios et al., 2016) show the advantages and disadvantages of a dryport and how dryports act as complementary to seaports. On the other hand, the research conducted by (Rožić et al., 2016) focuses on reviewing the existing literature concerning the development, classification, technological processes, and location of inland terminals.

Qualitative analysis is often used to explore complex phenomena, understand the experiences and perceptions of stakeholders, and identify critical issues that require further investigation. In the case of dry ports, qualitative analysis can be used to examine the factors that affect the operations and performance of the facility, including the policies, regulations, and infrastructure. For instance, qualitative analysis can help identify the bottlenecks in the supply chain, such as customs procedures or port congestion, which can negatively affect the efficiency and effectiveness of the dry port. (Jeevan et al., 2018) has conducted an online questionnaire survey and found that there are 12 important factors that are required for the efficient dry-port operations. Similarly, (Jaržemskis and Vasiliauskas, 2007) conducted a survey to gather insights from transport operator companies regarding the concept of dry ports. Questionnaires were sent out and the findings from the survey were used to validate and reinforce the concept of dry ports. (Nguyen et al., 2021) and (Dooms and Macharis, 2003) have both performed Multi-criteria and stakeholder analyses in order to develop a conceptual framework. The framework facilitates a better understanding of how various stakeholder groups may perceive the significance of dry ports and illustrates how the characteristics of dry ports can significantly influence their perceived roles among these groups. (Notteboom et al., 2017) developed a conceptual model to to tackle the current vagueness and lack of a well-defined conceptualization of logistics centers. (Awad-Núñez et al., 2016) has performed multi-criteria decision analysis and bayesian networks in order to find the sustainability of the location of the dryports. This helps in identifying the factors influencing the location of dryports. Many studies like (Gonzalez-Aregall and Bergqvist, 2019), (Hanaoka and Regmi, 2011), (Beresford et al., 2012), Black et al. (2012), Werikhe and Zhihong (2016) and Rodrigue et al. (2010) have case studies as their main methodology. All the case studies have been performed in different parts of the world such as China, India, Myanmar, Vietnam, Africa, North America and Europe. These studies revealed the factors influencing the development of dryports along with the potential challenges.

Benchmarking approach has been followed by two studies (Werikhe and Zhihong, 2016) and (Oláh et al., 2018) for dry ports because it allows them to compare their performance with other similar facilities, identify areas for improvement, and learn best practices from other successful dry ports. Benchmarking involves measuring performance against established standards or industry norms and identifying areas for improvement. By using benchmarking, dry ports can gain insights into their strengths and weaknesses, determine their competitive position in the market, and identify opportunities for growth and development. Additionally, benchmarking can help dry ports to set realistic goals and objectives, allocate resources effectively, and monitor their performance over time. Overall, benchmarking is an effective tool for dry ports to improve their performance, enhance their competitiveness, and deliver value to their stakeholders. (Werikhe and Zhihong, 2016) set Europe as a benchmark and compared the developments of dry ports in East Africa with Europe. An extensive stakeholder analysis is done by (Zain et al., 2022) and (Jeevan et al., 2015) by conducting interviews with stakeholders and gathering information on the importance of the development of the dryports. The dry port network development in Vietnam is analyzed using a SWOT analysis framework by (NGUYEN and NOTTEBOOM, 2016). The results show that the formation of most inland container depots (ICDs) in Vietnam lacked macro planning, resulting in poor location selection, overdependence on road transport, outdated facilities, and low management efficiency. Additionally, issues such as limited financial resources, excessive bureaucracy, and a lack of research to support inland transport planning further compounded the situation.

A study conducted by (Hui et al., 2019), concentrates on selecting KPIs for dryports. They are used to measure and evaluate the performance of dryports. These indicators are essential for monitoring the efficiency and effectiveness of operations, as well as for identifying areas that require improvement. By tracking KPIs, dryports can assess how well they are meeting their objectives and goals, such as reducing cargo transit time, increasing throughput capacity, or improving customer satisfaction. KPIs can also provide insights into areas that require attention, such as infrastructure maintenance, supply chain optimization, or staff training and development. The study highlights the importance of involving stakeholders in the development of KPIs for dry ports, given that each facility has unique requirements and limitations. The final qualitative method that has been used in the literature is comparative analysis. A comparative analysis of dry ports can provide valuable insights into the strengths and weaknesses of different facilities, as well as opportunities

for improvement and growth. By leveraging this information, dry ports can enhance their competitiveness, attract new business, and contribute to the development of regional and global supply chains. (Rodrigue and Notteboom, 2012) compared dry ports in intermodal rail systems of Europe and North America and concluded that although they have similarities in functionality, they play distinct roles within their respective transport and supply chains. Whereas, the primary objective of (Roso et al., 2009) is to expand on the dry port concept and classify dry ports into three categories based on their proximity to seaports: close, mid-range, and distant.

Few studies have combined different methodologies in order to obtain their results. For instance, (Dadvar et al., 2011) aimed to explore the advantages and obstacles of introducing dry ports in Iran. They conducted a literature review, followed by a questionnaire survey and a SWOT analysis, to assess the feasibility of implementing the dry port concept in the country. The research sought to determine whether it would be viable to adopt dry ports in Iran. Similarly, (Zeng et al., 2013b) utilizes a combination of industry interviews, publicly available data, and existing research to provide a comprehensive analysis of the current dry port network in China. It explores the motivations behind dry port development and identifies the challenges and opportunities associated with its further expansion.

Quantitative analysis

Quantitative analysis can provide a more objective and precise understanding of the performance of the dry port, including key performance indicators such as throughput, capacity utilization, and dwell time. These indicators can be measured using various data sources, including customs declarations, bills of lading, and terminal operating systems. Furthermore, quantitative analysis can help identify trends and patterns in the performance of the dry port over time, allowing managers to make informed decisions on resource allocation and capacity planning. From the study mainly three methods namely simulation, linear integer programming and statistical analysis have been identified. (Carboni and Orsini, 2020) developed a simulation model to assess the potential environmental advantages of implementing a dry port in terms of reducing emissions. The approach consists of three components: (i) analysis of traffic demand, (ii) traffic supply modeling, and (iii) assignment and emission modeling. According to the model, the implementation of a dry port is expected to lead to a reduction of 17% of CO_2 per year. However, this research has been extended by (Kurtulus and Cetin, 2019) by examining the impact of dry port usage not just on environmental benefits, but also on train capacity utilization, while considering empty container movements.

Integer linear programming (ILP) is a useful tool for dry ports because it allows for the optimization of complex logistical processes, resource allocation, and decision-making under various constraints. Dry ports often involve multiple modes of transportation, multiple service providers, and various regulatory and operational requirements. ILP can help dry ports to optimize their operations by formulating mathematical models that represent these logistical processes and constraints as linear equations. By solving these models, dry ports can identify the best possible solutions for various logistical scenarios, such as the allocation of storage space, the scheduling of transportation modes, and the optimization of service levels. (Li et al., 2019) developed a hypothetical country level container transportation model concerning 51 cities. The results show that there is a significant reduction in carbon emissions by developing dry ports. Moreover, (Ziar et al., 2023) also shows that implementing the proposed rail-road and p-hub median model can result in a decrease in overall transportation costs, as well as a significant reduction in air pollution. To address the problem, a matheuristic approach using the Genetic Algorithm (GA) is suggested. (Facchini et al., 2020) developed a mathematical model that enables the determination of the optimal number of containers to be stored in the port and/or dry port, taking into account both intra- and inter-terminal handling, to minimize overall operational costs and carbon footprint. The implementation of the model led to a 7% reduction in operational costs and an 11% decrease in the carbon footprint. Additionally, (Chang et al., 2015) proposes a linear programming solution for cost minimization, aided by a genetic algorithm, to determine the optimal location and capacity level among several candidate inland cities. Finally, statistical analysis is done by (Nguyen and Notteboom, 2019) to determine the correlations between dry ports and the seaports they are linked to, the transportation connection, and the terminal setup. The results emphasize the significance of

Table 2.2: Methods used in the previous studies on Dryports

	Literature review	Survey	Conceptual framework	Multi-criteria analysis	Case study	Benchmarking approach	Stakeholder analysis	SWOT analysis	KPI	Simulation	Linear integer programming	Statistical analysis	Comparative analysis
Hui et al. (2019)									★				
Khaslavskaya and Roso (2019)	★				★								
Gonzalez-Aregall and Bergqvist (2019)					★								
Carboni and Orsini (2020)										★			
Nguyen et al. (2021)			★	★			★						
Li et al. (2019)											★		
Rodrigues et al. (2021)	★				★								
Ziar et al. (2023)											★		
Hanaoka and Regmi (2011)					★								
Khaslavskaya and Roso (2020)	★												
Awad-Núñez et al. (2016)				★									
Beresford et al. (2012)					★								
Zain et al. (2022)							★						
Black et al. (2012)					★								
Dooms and Macharis (2003)			★	★			★						
Werikhe and Zhihong (2016)					★	★							
Jeevan et al. (2015)							★						
Kurtulus and Cetin (2019)										★			
NGUYEN and NOTTEBOOM (2016)								★					
Roso and Lumsden (2010)	★												
Facchini et al. (2020)											★		
Oláh et al. (2018)						★							
Nguyen and Notteboom (2019)												★	
Rodrigue and Notteboom (2012)	★												★
Veenstra et al. (2012b)	★												
Jeevan et al. (2018)		★											
Roso et al. (2009)	★												★
Notteboom et al. (2017)			★										
Chang et al. (2015)											★		
Monios et al. (2016)	★												
Rodrigue et al. (2010)					★								
Dadvar et al. (2011)	★	★						★					
Jaržemskis and Vasiliauskas (2007)		★											
Rožić et al. (2016)	★												
Zeng et al. (2013b)	★	★											

intermodality in the development of a dry port system.

It is interesting to observe that, despite the growing importance of dry ports in global logistics, there is a research gap in the literature regarding the development of a maturity model for these facilities. As the existing inland terminals are not efficient and there is need for converting them to dryports, maturity models can be used to improve the efficiency of inland terminals and help them in converting into dryports. Maturity models can help to assess the current state and progress of a dry port in terms of its organizational and operational capabilities, as well as its level of integration with the broader logistics network. However, few studies have focused on developing such models for dry ports. The absence of a maturity model hinders the ability of stakeholders to evaluate and compare the performance of different dry ports and identify areas for improvement. Therefore, there is a need for further research in this area. Additionally, a morphological chart can be used to develop the maturity model. The morphological chart can be used to identify the most promising design options, while the maturity model can be used to evaluate the organization's readiness to implement those options. Functions in a morphological chart can be used in a maturity model by mapping the potential solutions identified in the chart to the various stages or levels of the maturity model. This can help identify which solutions are most appropriate for organizations at different stages of maturity. Another way that functions in a morphological chart can be used in a maturity model is by identifying the key functions or components that are essential for organizations to achieve higher levels of maturity. This can help organizations focus their efforts on developing those functions or components that are most critical for success.

2.2.3. Different research aspects

While the previous section provided a clear understanding of the methods used in previous research, the following section will provide insights into the aspects of dryports that have been studied thus far. By understanding what has already been studied, areas where further research is needed can be identified, while policymakers and practitioners can make informed decisions about the design, management, and regulation of these facilities. Additionally, by building on existing knowledge, researchers can avoid duplicating previous research efforts and produce more efficient, effective, and impactful findings. Based on the research papers found from the research methodology described in the Subsection 2.2.1, six different research aspects have been identified. Research papers along with their corresponding research aspects are shown in the Table 2.3.

Location

One key research aspect of dry ports is their location. Researchers have studied the factors that influence the choice of dry port locations, such as proximity to seaports, access to transportation infrastructure, and regional economic development objectives. Location planning is a critical issue in the development of dry ports in developing economies. While reducing setup costs and overall logistics costs are important considerations in dry port location analysis, there are also other qualitative location factors that are influenced by multiple stakeholders, including operators, users, and the local community. The process of deciding on the location of a dry port requires careful consideration, as it can be very expensive to relocate the facility in the short term. Many models used for facility location take into account transportation costs as a significant factor in determining the optimal location (Nguyen and Notteboom, 2016). Determining the location of a dry port within a transportation network is a crucial factor in its construction. This decision is strategic and requires careful consideration before making any investment commitments. Various aspects come into play, such as establishing the dry port as a central hub connected to different cities. Optimizing the location involves allocating cities as nodes, taking into account cargo traffic volume between these nodes, time constraints for cargo delivery, and the overall transportation costs within the network. This location decision is a long-term consideration that aims to address the optimization problem involved in the efficient functioning of the dry port and its integration with the transportation network (Ziar et al., 2023). The study by (Awad-Núñez et al., 2016) demonstrates that identifying the most suitable location for dry ports is a complex task due to various factors such as environmental, economic, social, accessibility, and location considerations. Despite traditional theories of industrial location emphasizing accessibility to rail

Table 2.3: Different research aspects on Dryports

	Location	Governance and management	Economic impacts	Environmental impacts	Policy and planning
Ng et al. (2013)		★			
Ng and Cetin (2012)	★				
Ng and Gujar (2009)					★
Varese et al. (2020)					
Iannone (2013)		★			
Khaslavskaya et al. (2021)		★			
Flämig and Hesse (2011)	★	★			
Henttu and Hilmola (2011)			★	★	
Lättilä et al. (2013)			★	★	
Jeevan and Roso (2019)					
Carboni and Orsini (2020)				★	
Nguyen et al. (2021)		★			
Li et al. (2019)				★	
Ziar et al. (2023)	★			★	
Hanaoka and Regmi (2011)				★	
Awad-Núñez et al. (2016)	★				
Kurtulus and Cetin (2019)				★	
Facchini et al. (2020)			★	★	
Rodrigue et al. (2010)		★			
Chang et al. (2015)	★				
Notteboom et al. (2017)					★
Nguyen and Notteboom (2016)	★				

networks, high-capacity main roads, and seaports, the research reveals that environmental variables have the most significant impact on location decisions. The study also concludes that Bayesian Networks and Multicriteria Decision Analysis are reliable techniques for assessing dry port locations and can mitigate any inconsistencies in weightings.

Deciding on the most suitable location for a dry port entails weighing installation, storage, and transportation costs against one another. Location models must not solely concentrate on macroeconomic aspects, but must also take into account microeconomic goals and the perspectives of various stakeholders (Chang et al., 2015). The study proposes a two-stage framework for determining the best location for dry ports. The first stage uses an evaluation indicator system to identify candidate cities based on several factors and Fuzzy c-means (FCM) clustering to classify them. The second stage uses a linear location model to select optimal locations based on installation, storage, and transportation costs. The findings of (Ng and Cetin, 2012) suggest that dry ports near industrial clusters are favored by users, even though they may not always be the optimal location. This is different from Western economies, where dry ports are typically located at intermediate points along transport corridors rather than central locations. (Flämig and Hesse, 2011) identified potential dryport locations in Germany which are close to motorway intersections in order to reduce the travel time to/from the seaport.

Governance and Management

The second subject of research on dryports is Governance and management. It focuses on understanding the structures, processes, and mechanisms involved in the effective governance and management of these inland port facilities. It explores the relationships, roles, and responsibilities of various stakeholders, including public authorities, private operators, shipping lines, rail operators, and logistics companies. The research in this area aims to address questions related to the governance models, institutional arrangements, and decision-making processes that govern the operations of dryports. It examines the dynam-

ics of public-private partnerships, regulatory frameworks, and the involvement of multiple stakeholders in decision-making. Furthermore, it explores issues of accountability, transparency, and cooperation among stakeholders.

Throughout the study conducted by (Ng et al., 2013), it was discovered that the absence of a well-established legal framework resulted in limited confidence among dry ports to invest in infrastructure and facilities. A significant finding was that the institutional status quo had varying effects on operators who owned both sea and dry ports, as this arrangement provided them with greater control over the supply chain and market power. In regions with high demand for dry port services, inadequate planning, the absence of high-capacity corridors, and a bias towards road transportation created a situation where numerous small-sized dry ports with limited market scopes existed instead of large dry ports strategically located along high-capacity rail corridors. This paper highlights the importance of comprehending how institutions in specific countries interact to influence reforms and the development of transportation infrastructures. When institutions operate efficiently and bureaucracy does not hinder cargo flows, dry ports can become vital logistical components. Ultimately, the long-term viability of dry ports heavily relies on their capacity to adapt to market forces and enhance supply chain value. Iannone (2013) argue that port-hinterland container networks involve various inland transport modes and nodes, posing numerous challenges for both public and private stakeholders across different timeframes. The utilization of mathematical programming models to comprehensively support shippers' logistics planning for port-hinterland operations is still in its early stages. This paper identifies several limitations and research opportunities in the existing models, emphasizing the need for new mathematical models that address all aspects of the problem. Currently, many models make simplifying assumptions that do not meet the evolving needs of the industry. Shippers assess different hinterland logistics solutions by considering trade-offs, and there is a demand for new analytical tools that incorporate realistic features such as regulatory environments, uncertain information, risk analysis, logistical integration, and the environmental and social impacts of container distribution operations. Incorporating all these elements into network programming models adds complexity, but it is important to strike a balance between realism and solvability by utilizing practical data available in real-world contexts. The research by (Khaslavskaya et al., 2021) emphasizes the significance of taking into account the objectives of diverse stakeholders when developing a dryport. This study's primary contributions lie in the profiling of dry port services from a stakeholder involvement perspective. It translates stakeholder objectives regarding dry ports into essential criteria and indicators used by stakeholders in their selection or utilization of dry port services. Moreover, the study demonstrates how a multi-criteria decision-making approach can be adopted to facilitate stakeholder-engaged service design and development in dry ports or comparable organizational contexts like seaports or distribution centers. Similarly, Nguyen et al. (2021) argue that different stakeholder groups may perceive the value of dry ports based on their respective perspectives. This paper aims to develop a conceptual framework for evaluating the role of dry ports in port-hinterland settings. The framework integrates multi-criteria and multi-stakeholder approaches to assess the performance of dry ports from the perspectives of three primary stakeholder groups: dry port users, seaport-based players, and the community. One of the main findings is that dry ports, situated further inland and closer to distant economic zones, with high capacity and intermodal connections to seaports, are likely to contribute significantly to the logistical performance of their users. Seaports, on the other hand, benefit from collaboration with dry ports located near large customer regions, facilitated by dedicated connections.

However, main argument of (Flämig and Hesse, 2011) is that port regionalization presents distinct planning challenges that differ from those in core port areas. These challenges arise from the specific land demand and accessibility requirements associated with dryports and DC-clusters. Furthermore, the institutional framework for addressing these issues is less developed in suburban areas of the region compared to the well-established setting in the main port city. A specific perspective of regional governance is used to examine the policy and planning issues related to dryports and port regionalization. Finally, Rodrigue et al. (2010) argue that inland ports play a vital role in performing essential functions, but their establishment, management, and operations involve multiple actors. Despite sharing similar functions, the specific goals, means, and strategies employed by these actors result in diverse types of inland ports. This creates an opportunity for entities like port authorities, rail operators, logistics service providers, and economic development

boards to capitalize on their roles and boost revenue generation. However, conflicts of interest may arise, leading to an inland port system that doesn't align optimally with the regional freight distribution system in terms of location, quantity, and operational approach.

Economic impacts

Another research subject has explored the economic impacts of dryports, including their effects on trade flows, supply chain efficiency, regional development, and job creation. These findings provide insights into the overall contribution of dryports to the economy, helping policymakers, investors, and stakeholders make informed decisions about their development, expansion, and integration into regional and national transport networks. This study by (Facchini et al., 2020) emphasizes the need for resources and investments in container transportation between the port and the dry port. To determine the optimal strategy, a mathematical model is developed, which calculates the ideal number of containers to be stored in both the port and the dry port. The model takes into account the handling of containers within and between terminals, aiming to minimize overall operating costs and carbon footprint. The Port of Bari in Italy is used as a case study. The model's findings indicate that, based on the total number of containers and the distance between the port and dry port, a specific configuration can reduce running costs by 7% and carbon footprint by 11% compared to the scenario where all containers are stored in the port.

The analytical model developed by (Henttu and Hilmola, 2011) supports implementing dry ports for inland distribution, reducing emissions and transportation costs. It is found that Finland's optimal number of dry ports is between four and six based on transport costs. On the other hand, the model assessing environmental impact suggests that having more dry ports could result in a further decrease in external costs related to transportation. The study highlights the importance of tailoring the network to a country's transportation system, with more seaports enhancing cost-efficiency and inland transportation in Finland. In the study Lättilä et al. (2013), a simulation model is created to compare two transportation scenarios in Finland. The first scenario relies solely on road transportation, while the second scenario incorporates the use of dry ports and hinterland rail transport. According to a simulation model, 30-41% of inland transportation in Finland should be carried out through dry ports to minimize overall transportation costs. However, 59-70% of inland transportation is more cost-effective to be transported solely by road. Implementing a dry port network in Finland would reduce CO2 emissions compared to a road-only transportation network, potentially decreasing emissions by up to 45%.

Environmental impacts

Scholars have analyzed the environmental impacts of dryports, including their contribution to carbon emissions, noise pollution, and land use change, as well as the potential for sustainable practices. The findings by (Carboni and Orsini, 2020), suggest that the introduction of a dry port would bring about substantial positive environmental outcomes. The case study application reveals that the establishment of a new railway link connecting Venice Port and Interporto of Padua could result in a noteworthy 17% decrease in key pollutants, thereby benefiting the environment. The research by (Li et al., 2019) asserts the significance of implementing dry ports on a large scale in China to achieve low carbon objectives. However, it emphasizes that an equally important avenue for reducing emissions lies in the utilization of various container sea ports. While the locations examined in the study already have existing dry ports, their scale is not sufficient in terms of handling millions of TEUs (twenty-foot equivalent units) per year. It emphasizes that for environmental sustainability, it is crucial to have dry ports of a more significant scale. Furthermore, the study suggests that the primary mode of transportation between a dry port and a sea port should be rail, although waterway transports could also be a viable option.

Ziar et al. (2023) proposes bi-level programming approach for locating a dryport which tackles the conflict between the interests of the government (less flow on roads) and freight forwarders (direct transportation in order to reduce travel time). The suggested transportation network has the potential to substantially decrease the volume of traffic passing through direct connections, resulting in a notable reduction in air

pollution. Hanaoka and Regmi (2011) examines the emergence of intermodal transport in Asia and the potential environmental benefits of integrating dry ports. Case studies demonstrate the role of governments, markets, and the private sector in successful dry port development. Railway connections to dry ports can reduce CO2 emissions and local air pollution through modal shifts. Infrastructure investment and modernization, along with the use of cleaner fuels and ICT technology, are important for operational efficiency and environmental improvements. Coordination among government agencies and collaboration between the public and private sectors are crucial for the development of environmentally friendly intermodal transport in Asia. Similarly, Kurtulus and Cetin (2019) emphasize on the modal shift towards imtermodal transport in order to reduce carbon emissions in Turkey. The existing utilization of dry port-based intermodal transportation leads to a 5.79% reduction in greenhouse gas (GHG) emissions.

POLICY AND PLANNING

Studies have evaluated the role of government policies and planning in the development and operation of dryports, including funding mechanisms, regulatory frameworks, and planning processes. Notteboom et al. (2017) refers to logistic centers which could be dryports, inland terminals, extended gates, etc,. The conceptual model presented in this study offers valuable insights for researchers, policymakers, and practitioners, and serves as a foundation for advancing the theory on logistics centres. By incorporating multiple classification criteria, the model provides a comprehensive taxonomy that addresses the existing ambiguity in terminology related to logistics centres. This taxonomy captures the key dimensions of logistics centres, including their function, size, market coverage, position in transport and commodity chains, strategy, organization, technology, and governance. It also highlights how each dimension contributes to the positioning and competitiveness of different types of logistics centres, contributing to a better understanding of these infrastructures.The findings of (Ng and Gujar, 2009) reveal that the competitive dynamics of the Indian dry port industry encompass both economic and political dimensions. The Indian government plays a dual role by allowing and even encouraging foreign investments in dry ports to drive improvements in industry factors. Simultaneously, the government intervenes to impede the pressure on state-owned corporations to enhance their factor conditions while maintaining their dominant position in the market. These measures serve to prevent foreign investors from gaining opportunities to establish and exploit market concentration power. The study by Jeevan and Roso (2019) analyzes the effects of larger vessels on seaport competitiveness and examines the interaction between seaports and dry ports in the Malaysian context. It employs mixed-methods, highlighting challenges such as reduced efficiency, congestion, and infrastructure limitations. Integrating dry ports is identified as a viable solution to enhance accessibility, infrastructure, capacity, and overall efficiency in seaports.

While the mentioned research aspects cover important dimensions of dryports, there are several additional aspects that may be missing or underrepresented in the literature. These include social impacts, technological advancements, risk and resilience, cross-border cooperation, and long-term sustainability. Research exploring the social implications of dryports can shed light on the effects on local communities and labor conditions. Examining how emerging technologies are transforming dryport operations can provide insights into the role of automation and artificial intelligence. Investigating risks, vulnerabilities, and strategies for enhancing resilience can contribute to mitigating disruptions. Cross-border cooperation research can explore harmonization of policies and challenges in seamless transportation across countries. Additionally, studying the long-term sustainability of dryports can help in adapting to changing economic, environmental, and social conditions. Addressing these aspects would provide a more comprehensive understanding of dryports, supporting informed decision-making and policy development in the field.

2.3. MATURITY MODELS

A maturity model is a structured framework used to assess the level of maturity of an organization or system in achieving specific objectives (Henshall, 2019). It consists of a set of defined stages or levels, each representing a specific level of maturity in terms of process capability, organizational structure, and perfor-

mance. Maturity models have been widely used in various industries, including information technology, manufacturing, and supply chain management, to evaluate organizational and operational performance. "A maturity model depicts an entity's evolution across time. This entity could be a person, an organizational function, or something else entirely" (Wibowo and Waluyo, 2015). (Pullen, 2007) states that "A maturity model is a set of structured features that describe effective processes at various stages of development. It also includes the cut-off points for each stage as well as the mechanism for moving from one to the next". All in all, a MM is a tool that is used to measure, compare, describe, or determine a path or roadmap (Proença and Borbinha, 2016).

2.3.1. Components of Maturity models

According to (Ifenthaler and Egloffstein, 2020), Maturity models consist of major components such as:

- Maturity level or stage
- Descriptor for each maturity level (e.g., initial, managed, etc.)
- A generic description of each level
- Dimension(s) and perspectives
- Maturity items linked to corresponding dimensions
- A description of each element for each level of maturity

All in all, a maturity model consists of dimensions and criteria, which describe the areas of action. The levels of maturity are as follows (Facchini et al., 2019):

1. Initial: In certain situations, processes may lack rules and grow in a seemingly chaotic manner. Only a limited number of processes are properly defined, and the success of the project relies on human initiative.
2. Managed: The primary processes are typically defined with great care to ensure that costs, time, and functionality are well-managed. The output of these processes is reproducible.
3. Defined: Software processes are standardized and documented to cover organizational and production aspects. All software development and maintenance projects are governed by the company's processes and standards.
4. Quantitatively Managed: Detailed measurements are collected and analyzed for each software process, and both processes and products are subjected to scrutiny and control.
5. Optimizing: Continuous improvement of processes is achieved through the implementation of new ideas and procedures, as well as the utilization of measurement outcomes.

2.4. Conclusion

Based on the extensive literature review conducted, it is evident that dry ports have emerged as key strategic components in the global logistics and supply chain networks. They serve as critical nodes for facilitating the seamless movement of goods and enhancing the efficiency of transportation systems. The literature review has highlighted the significance of dry ports in improving connectivity, reducing congestion, optimizing logistics operations, and promoting sustainable transportation practices. However, a notable research gap exists in the absence of a dedicated maturity model specifically tailored for dry ports. Maturity models have proven to be valuable tools in assessing the level of development and maturity of various industries and processes. By providing a structured framework and benchmarks, maturity models enable organizations to evaluate their performance, identify areas for improvement, and guide their strategic decision-making.

The subsequent chapters of this thesis will delve into the defining functions of a dryport and framing requirements, developing morphological chart, maturity model and recommendations, ultimately contributing to the advancement of the dry port industry and enhancing the overall efficiency and sustainability of global supply chains.

3

FUNCTIONS

In this chapter, the focus is on addressing sub-research question one, which pertains to the identification of the functions associated with a dryport.

3.1. LIST OF FUNCTIONS

Functions refer to the various activities and services provided by a facility. According to (Rodrigue and Notteboom, 2011), the most important functions of dryports are load center and Transshipment. A study by (Rodrigue et al., 2010) defined the supply chain functions of inland port as Consolidation/deconsolidation, postponement and light transformation. Whereas, (MADAN B., 2012) considers Value-added services and information management to be the functions of a dryport. (Zeng et al., 2013a) emphasises that customs clearance is an integral function of a dryport. In addition to these functions, (Rodrigue et al., 2010) states that dryport should perform empty container management and container maintenance.

TRANSSHIPMENT

Transshipment refers to the process of transferring goods from one mode of transportation to another at a dryport or inland terminal. It involves the handling and transfer of cargo containers between different vessels, such as ships, trucks, or trains. The scope of transshipment encompasses activities such as container loading, unloading, storage, and documentation associated with the transfer process. Transshipment plays a crucial role in facilitating the seamless movement of goods between different transportation modes, enabling efficient logistics operations and optimizing supply chain networks.

CONSOLIDATION/DECONSOLIDATION

It involves the aggregation or disaggregation of cargo shipments at a dryport or inland terminal. It refers to the process of combining smaller shipments into larger, more cost-effective units for transportation or vice versa. Consolidation involves assembling multiple shipments into a single container or transport unit, while deconsolidation involves breaking down larger shipments into smaller units for distribution. This function streamlines logistics operations, improves cargo handling efficiency, and enables economies of scale in transportation, benefiting both shippers and carriers.

LOAD CENTER

The load center function involves the consolidation and distribution of cargo shipments within a dryport or inland terminal. It encompasses activities such as cargo receiving, sorting, cross-docking, and final delivery coordination. Load centers act as intermediaries between shippers and consignees, facilitating the efficient flow of goods and providing value-added services, such as order fulfillment, labeling, and packaging customization. It provides entry to distinct regional markets featuring both production and consumption functions. This typically encompasses a metropolitan region, where multiple terminals simultaneously fulfill intermodal, warehousing, distribution, and logistics operations. Load centers play a vital role in optimizing cargo handling processes, reducing transportation costs, and improving delivery reliability and speed.

Customs clearance

It refers to the formalities and procedures involved in the legal and regulatory compliance of goods passing through a dryport or inland terminal's customs jurisdiction. It encompasses activities such as customs documentation, import/export declarations, duty payments, inspection, and release of goods. Customs clearance functions ensure compliance with international trade regulations, facilitate smooth cargo flow, and prevent delays or penalties associated with customs procedures. Efficient customs clearance processes contribute to trade facilitation, supply chain security, and international trade competitiveness.

Additional service offerings

In addition to the core functions and processes, dryports or inland terminals often provide a range of additional service offerings to enhance their value proposition and meet the diverse needs of their customers. These additional services go beyond the traditional handling and storage of goods and containers, adding value and convenience to the overall logistics operations. Some common examples of additional service offerings in a dryport or inland terminal include packaging and labelling, fumigation, handling reefer containers, quality control and inspection, etc. These additional service offerings not only differentiate the dryport from its competitors but also contribute to the overall efficiency, convenience, and customer satisfaction within the logistics ecosystem. By providing a comprehensive range of services, the dryport aims to become a one-stop solution for its customers, offering end-to-end logistics support and value-added services that go beyond basic cargo handling and storage.

Light transformations

Light transformation involves value-added activities related to the modification or customization of goods within a dryport or inland terminal. It can improve supply chain management flexibility by being closer to final customers and allowing for various product and package transformations and customization to national, cultural, or linguistic market characteristics. Light transformation services enable customers to modify or tailor products closer to the market, reduce lead times, and meet specific customer demands. Dryports provide light transformation services to enhance supply chain flexibility, reduce logistics costs, and cater to the evolving needs of customers.

Buffer function

The Buffer function within a dryport or inland terminal assumes a pivotal role by offering customers buffer time to store their containers before onward dispatch. This strategic delay, synonymous with postponement, introduces heightened adaptability and responsiveness to dynamic market demands and customer needs. Inland terminals provide a chance for managing inventory through the duration of time they hold cargo, making it possible to consider last-minute and last-mile routing options for freight. This creates a buffer within the supply chain and is known as "warehousing-based terminalization". This method is commonly used by large retailers who have multiple stores and utilize inland ports to refine their distribution process.

Information management

It involves the collection, processing, storage, and dissemination of data and information within dryports or inland terminals. It encompasses activities such as data capture, analysis, integration, and sharing across various stakeholders in the supply chain. Effective information management enables real-time visibility, collaboration, and decision-making, leading to improved operational efficiency and customer service. Dryports invest in information management systems, technologies, and infrastructure to ensure seamless information flow, enhance supply chain visibility, and enable data-driven decision-making. This links customs/sea ports/customers/service providers to facilitate transport.

Empty container management

Empty container management focuses on the effective handling and storage of empty shipping containers at a dryport or inland terminal. Proper empty container management is essential to ensure optimal container availability, minimize container imbalances, and facilitate efficient container utilization within the supply chain. By effectively managing empty containers, dryports can contribute to reducing operational costs, minimizing container idle time, and enhancing overall logistics efficiency. This is one of the main functions of dryports in Vietnam and Sweden (Gonzalez-Aregall and Bergqvist, 2019), (Nguyen et al., 2021).

Container maintenance

Container maintenance encompasses a series of activities aimed at inspecting, maintaining, and ensuring the proper functioning of equipment within a container terminal. This comprehensive process involves the meticulous inspection, thorough testing, meticulous cleaning, and necessary repairs of container equipment. Furthermore, container maintenance places significant emphasis on implementing safety protocols to prevent accidents and safeguard the well-being of workers involved in these operations (Roso, 2007), (Beresford et al., 2012) and (Jaržemskis and Vasiliauskas, 2007). A terminal in Venlo has container maintenance as one of their functions (Rodrigue et al., 2010).

Freight forwarding

Freight forwarding involves the efficient coordination and management of transportation activities. This essential service aids in the smooth shipment of goods from their origin to destination using either a single or multiple carriers. The process of freight forwarding encompasses the utilization of various transportation modes such as air, sea, land, or rail to facilitate the movement of cargo (Inbound Logistics, 2022). Freight forwarding services provided at dryports or inland terminals ensure the smooth movement of goods, optimize transportation routes, and facilitate international trade. Freight forwarders play a crucial role in managing logistics operations and ensuring the timely delivery of goods.

Storage and warehousing

This function is derived from the requirements in Subsection 4.2.4. Storage and warehousing functions within a dryport or inland terminal involve the temporary storage, inventory management, and handling of goods. This includes the provision of storage facilities, inventory tracking systems, and value-added services such as order picking, packing, and labeling. The concept of a bonded warehouse can be integrated, allowing the temporary storage of containers with deferred duties or taxes, providing cost savings and flexibility. Storage and warehousing functions contribute to efficient supply chain management by ensuring the availability of goods when needed, reducing inventory holding costs, and enabling timely order fulfillment. Effective storage and warehousing practices are essential for optimizing space utilization, ensuring product integrity, and enhancing customer satisfaction.

Environmental sustainability

Similar to the previous function, this function is also derived from the interviews conducted and requirements formulated Subsection 4.2.4, Subsection 1.6.3. Environment sustainability focuses on promoting and implementing environmentally friendly practices within dryports or inland terminals. It involves initiatives to reduce carbon emissions, energy consumption, waste generation, and promote sustainable transportation modes. Environmentally sustainable practices can include the use of renewable energy sources, implementation of green technologies, waste management systems, and adherence to environmental regulations. Dryports and inland terminals strive to minimize their environmental impact, contribute to sustainable development, and meet the expectations of eco-conscious customers and stakeholders.

3.2. PROCESS FLOW

A process flow diagram helps in understanding all the steps involved in the whole process. These steps are shown sequentially with input and output of each and every step. An IDEF-0 scheme has been used to represent the process flow. Each box represents an activity or a sub-process and all the horizontal arrows would show the logical flow of activities, indicating how inputs from one process become the outputs of another. The arrow that comes from below represents the mechanisms that are the physical aspects of the activity in each block. The arrow coming from above represents controls that constrain and direct the activity or sub-processes (Presley and Liles, 1998). It allows stakeholders to understand the overall flow of activities at the dryport, identify dependencies and potential bottlenecks, and analyze the efficiency and effectiveness of the processes. The chart can serve as a basis for process improvement, optimization, and documentation of the dryport operations.

IDEF-0 process chart at A1 chart can be seen at Figure 3.1. This process flow chart represents the sequence of activities involved in the operations of a dryport. It starts with cargo arrival, where incoming shipments are received and documented. The cargo then moves to the cargo handling stage, where it is unloaded, sorted, and prepared for further processing.

Next, the cargo proceeds to customs clearance, where necessary customs procedures and inspections take place to ensure compliance with regulations. After customs clearance, the cargo is directed to storage, where it is securely stored until further processing.

From storage, the flow diverges into two paths. One path leads to transshipment, which involves transferring the cargo to another transportation mode or destination for onward delivery. The other path leads to value-added services, where additional services offerings and light transformation processes such as labeling, kitting, reworking, packaging, or assembly may be performed to enhance the value of the cargo. This depends on the client's requirements.

From value-added services, the flow further diverges into two options. One option is store the freight during the buffer period, where the cargo is held in storage until there is a specific demand or customization request. The other option is outbound distribution, which involves preparing the cargo for final delivery to its intended destination. Both transshipment and buffer processes are also connected to the outbound distribution stage, as they can directly influence the final delivery process.

It is important to not that Information management and Environmental sustainability are overarching aspects that are relevant to all the steps in the dryport operations. They are cross-cutting functions that influence and support the execution of various activities throughout the entire process. While they may not have specific dedicated steps, they permeate the operations and require continuous attention and management throughout the entire dryport workflow. Information management involves the effective flow of data and information related to cargo, logistics, documentation, and communication among stakeholders. It ensures transparency, coordination, and timely decision-making through tracking, recording, and sharing systems. Environmental sustainability focuses on minimizing ecological impact. It includes energy conservation, waste management, water conservation, emissions reduction, and the use of eco-friendly technologies and materials.

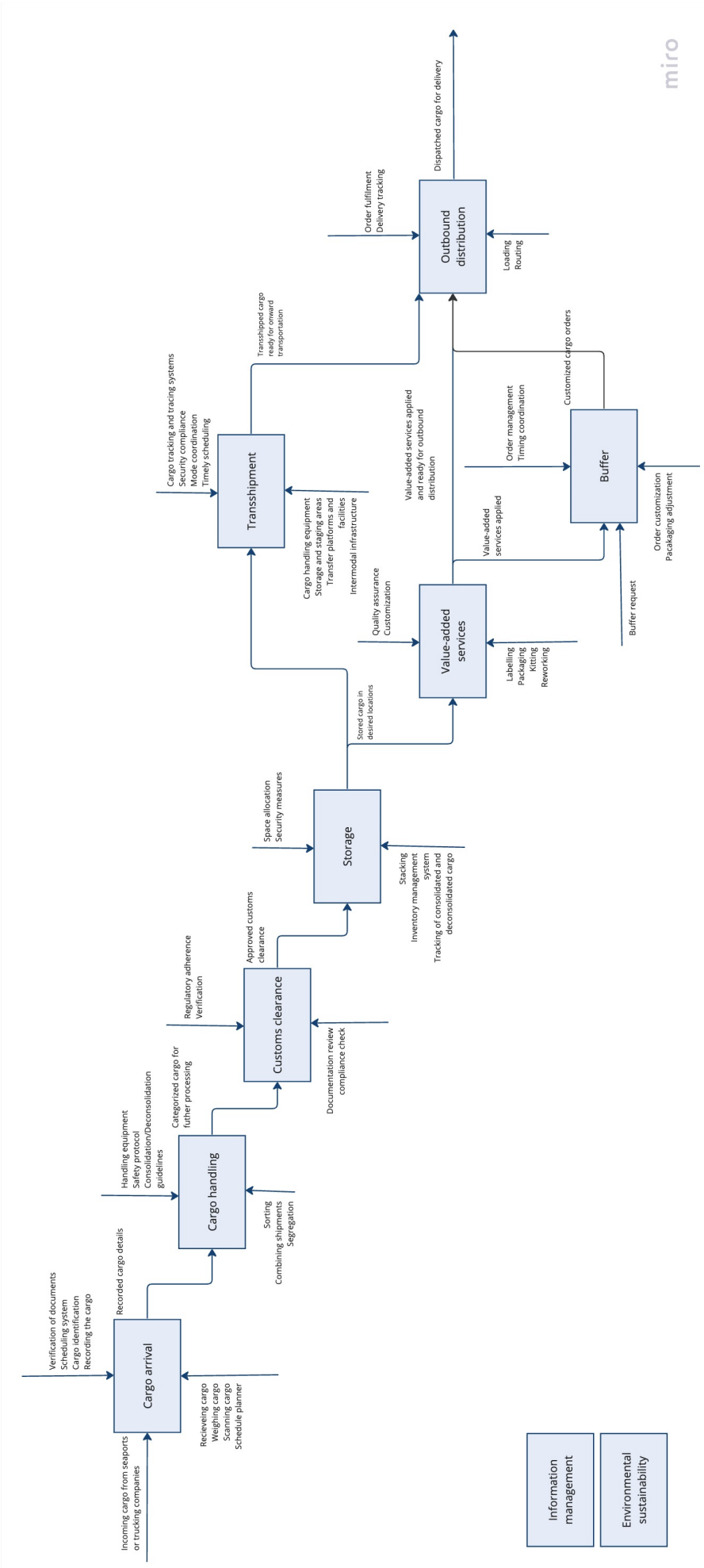

Figure 3.1: IDEF-0 process at A1 chart

3.3. CONCLUSION

In conclusion, the functions chapter has focused on identifying and understanding the key functions involved in dryport operations. Through a comprehensive literature review and analysis, a set of functions specific to dryports has been identified and categorized. These functions encompass various aspects of the supply chain. The chapter has also presented a process flow diagram that visually represents the sequence and interaction of these functions within a dryport. This diagram provides a clear overview of the operational processes and highlights the interconnectedness of the different functions.

By identifying and understanding the functions involved in dryport operations, stakeholders can gain valuable insights into the specific activities and tasks that need to be managed and optimized. This understanding is crucial for effective planning, resource allocation, and process improvement within dryports. The process flow diagram serves as a visual aid in illustrating the sequence of activities and the interdependencies between functions. It provides a holistic view of the overall operational flow within a dryport, facilitating better coordination, efficiency, and performance. This chapter sets the foundation for the subsequent development of the morphological chart.

4

DEVELOPMENT STEPS

The transformation of an intermodal terminal into a dryport is a significant undertaking that requires careful planning, coordination, and adherence to specific requirements. Understanding the development steps involved in this transformation process is crucial for stakeholders seeking to optimize terminal operations, enhance logistics efficiency, and unlock the economic benefits associated with dryports. This chapter aims to answer sub research question 2 by providing a comprehensive analysis of the development steps necessary for transforming an intermodal terminal into a fully functional dryport, considering the requirements and processes involved.

4.1. CONCEPTUAL UNDERSTANDING OF INTERMODAL TERMINALS AND DRYPORTS

Intermodal terminals serve as pivotal nodes in the transportation network, facilitating the seamless transfer of goods between different modes of transport, such as rail, road, and maritime. These terminals typically handle containers and play a vital role in connecting supply chains. However, transforming an intermodal terminal into a dryport involves additional considerations and requirements.

Dryports, or inland ports, are specialized terminals located away from traditional port areas, providing seamless connectivity to maritime ports and serving as hubs for intermodal freight transport and logistics activities. In addition to providing seamless connectivity, dryports also offer high-frequency services, making them even more attractive and efficient for freight transportation and logistics operations. The availability of frequent and regular services at dryports ensures that cargo can be moved swiftly and reliably between different modes of transportation. Moreover, dryports contribute to environmental sustainability by promoting modal shift to more eco-friendly transport modes, optimizing energy use, and implementing green infrastructure practices. Unlike intermodal terminals, dryports offer extended services, such as customs clearance, consolidation, deconsolidation, warehousing, managing empty containers and value-added logistics services. These additional functionalities require specific development steps to ensure the successful transformation of an intermodal terminal into a fully operational dryport.

4.2. IDENTIFICATION OF REQUIREMENTS FOR DRYPORTS

Transforming an intermodal terminal into a dryport requires careful evaluation and identification of specific requirements. These requirements encompass various aspects, including infrastructure, connectivity, technology, customs procedures, security, and operational capabilities. Understanding and fulfilling these requirements is essential to ensure that the transformed facility can effectively handle the diverse needs of its users and support seamless logistics operations. Requirements are essential for ensuring that a system or product meets the needs and expectations of its stakeholders and achieves its intended purpose or objective. This process of clearly defining the functional, infrastructural, and operational needs of a dry port results in optimized dry port operations, fostering regional connectivity, and driving economic growth.

4.2.1. METHODOLOGY

Requirements can be gathered through various techniques, such as interviews, surveys, workshops, or focus groups, and can be documented in a variety of formats, such as requirement specifications, use cases, user stories, or acceptance criteria. As part of this research, semi structured expert interviews with the below stakeholders mentioned in the Subsection 1.6.2 were conducted. The reason for choosing semi struc-

tured interviews is that it possess a flexible structure, allowing researchers to present a set of questions they desire answers to, while also allowing room for exploration of related subjects based on the interviewee's responses.

1. Inland terminal operators
2. Government agencies
3. Port authorities
4. Freight forwarders
5. Customers

Inland terminal operators play a crucial role in efficient operation of terminals and handling of cargo. Their input is valuable for understanding operational requirements, infrastructure needs, and identifying opportunities for collaboration between with seaports and converting into dryports. However, Government officials involved in transport, trade, and economic development can provide insights into the policy framework, regulations, and government initiatives related to dry ports. They can shed light on the strategic importance of dry ports and their impact on regional development. Port authorities manage seaports and play a crucial role in the establishment and operation of dry ports. Interviewing port authorities can provide valuable insights into the collaboration between seaports and dry ports, port-related challenges, and opportunities for integration. Freight forwarders are key players in the logistics industry, responsible for managing the transportation and distribution of goods. Their insights help identify the specific needs and challenges faced by freight forwarders, ensuring that dry ports can effectively support their operations and optimize supply chain efficiency. Customers on the other hand are also important stakeholders in the dryport development. Their perspective is crucial for understanding their specific requirements, expectations, and challenges. By involving customers, dry ports can better tailor their services, enhance customer satisfaction, and improve overall operational efficiency. Although residents are integral stakeholders in the dryport development process, they have not been interviewed or included in this thesis project. This omission is primarily due to the focus of the research, which centers on the internal aspects of dryport operations and their maturity model. As such, the primary aim was to explore functions, strategies, and operational dimensions within the dryport context. While residents' perspectives are important and could provide valuable insights into the broader impact of dryports on local communities, their inclusion would require a more extensive study specifically focused on understanding community perceptions and concerns. While shipping lines were not interviewed as part of this thesis project due to time constraints, their incentive can be understood to align with that of providers.

By conducting interviews with these stakeholders, comprehensive understanding of the requirements for a terminal to become a dryport, as well as the challenges and opportunities associated with developing and operating a dryport will be obtained. This information can be used to develop a set of guidelines or best practices for the development of dryports. While conducting interviews, the main focus will be on the requirements of infrastructure, service, regulatory, equipment and information technology and performance metrics to know throughput, productivity and customer satisfaction of dryports. Table 4.1 provides an overview of the companies involved in the interviews and the respective designations of the interviewees. A brief introduction of all these companies are given below.

Port of Rotterdam: It is one of the largest and busiest ports in the world, located in the city of Rotterdam, Netherlands. It is strategically positioned on the Rhine-Meuse-Scheldt delta, making it an ideal gateway to Europe. The port handles a diverse range of goods, including containers, oil, chemicals, and bulk cargo, serving as a crucial hub for international trade.

With its extensive infrastructure and advanced facilities, the Port of Rotterdam plays a vital role in the global supply chain. It boasts state-of-the-art terminals, efficient logistics systems, and innovative technologies that enable smooth and seamless operations. The port's deepwater access allows it to accommodate large vessels, contributing to its reputation as a major maritime hub. The Port of Rotterdam also prioritizes sustainability and environmental responsibility. It has implemented various initiatives to reduce emissions, promote renewable energy sources, and enhance energy efficiency. These efforts align with the port's commitment to becoming a carbon-neutral hub and a leader in the transition to a more sustainable future.

The Port of Rotterdam Authority and Rotterdam World Gateway (RWG) have expressed satisfaction with the expansion project taking place in the Princess Amaliahaven. The container terminal, RWG, has made the decision to expand the current terminal, adding approximately 45 hectares of terminal grounds and 920 meters of quay wall. This expansion will enable RWG to gradually increase its capacity by 1.8 million TEU, using fully automatic and CO2-neutral processes. The first phase of the expansion is scheduled to be operational by the end of 2025, and preparations are underway to introduce shore power and establish a connection to the Container Exchange Route (CER). (Port of Rotterdam, 2023).

BCTN Terminals: They are an important part of the container transport infrastructure in the Netherlands. BCTN operates several inland container terminals strategically located along the major rivers and waterways in the country. These terminals provide efficient and sustainable solutions for the transport of containers by barge. BCTN terminals are equipped with modern facilities and offer a range of services, including container handling, storage, and onward distribution. They serve as important logistics hubs, connecting the inland regions of the Netherlands to major seaports such as Rotterdam and Antwerp.

The terminals are known for their focus on sustainability, aiming to reduce the environmental impact of container transport. BCTN promotes the use of inland shipping, which is a greener alternative to road transport, and actively invests in energy-efficient equipment and infrastructure. Through their strategic locations and commitment to sustainability, BCTN terminals play a vital role in optimizing the container supply chain, offering efficient and eco-friendly solutions for inland transportation of goods.

CTD Terminals: Container Terminal Doesburg (CTD) is a significant container terminal located in Doesburg, Netherlands. It serves as a crucial transportation hub for containerized goods in the region. CTD offers comprehensive container handling services, including loading, unloading, storage, and logistics support. The terminal is well-equipped with modern infrastructure and advanced facilities to ensure efficient operations and smooth cargo flow.

Situated in the Netherlands, CTD benefits from the country's excellent transportation network, including access to major waterways and road networks. This strategic location enables seamless connectivity to other ports and inland destinations, facilitating the distribution of goods across Europe. As with many modern terminals, CTD prioritizes sustainability and environmental responsibility. It employs eco-friendly practices to minimize its carbon footprint, such as energy-efficient operations and the promotion of greener transport alternatives.

Aviko: It is a renowned international food company based in the Netherlands, specializing in the production and distribution of potato-based products. With a rich history dating back to 1962, Aviko has become a leading global brand in the potato processing industry. Aviko offers a wide range of potato products, including fries, hash browns, mashed potatoes, and specialties like potato gratin. Their products cater to both retail consumers and the foodservice industry, serving restaurants, fast-food chains, and other food establishments worldwide.

Quality and sustainability are at the core of Aviko's operations. They work closely with farmers to ensure a reliable and sustainable potato supply chain, prioritizing responsible farming practices and environmental stewardship. With a global presence in over 110 countries, Aviko has established itself as a trusted supplier of potato products. Their commitment to innovation and continuous improvement allows them to adapt to changing consumer demands and preferences, consistently delivering high-quality and convenient potato solutions.

VIM: It is a full-service logistics service provider specializing in the fashion, sports, and lifestyle sectors. Their mission is to completely unburden customers by providing comprehensive logistics solutions. VIM values personal attention, unburdening, pragmatism, customization, worldwide reach, and end-to-end logistics from production to the consumer. VIM offers customized services tailored to the specific needs of each client. They prioritize personal attention and establish sustainable partnerships with customers and

partners. By outsourcing logistics to VIM, they become an extension of the client's company.

VIM actively participates in initiatives aimed at consolidating transport flows in the fashion and lifestyle industry. These initiatives contribute to reducing kilometers traveled, CO2 emissions, and transport costs. VIM collaborates with Greenway Logistics, industry organizations such as Modint and FGHS, and logistics knowledge centers like TKI Dinalog and Connekt. With their own warehouses in multiple countries, totaling over 50,000 m² of warehouse space, VIM serves national and international customers. They prioritize efficiency, reliability, and sustainability in their operations.

Province Gelderland: The government of the Province of Gelderland plays an active role in promoting and supporting logistics and sustainability initiatives within the region. For logistics, the government works to improve transportation infrastructure, including road networks, waterways, and rail connections. They collaborate with relevant stakeholders to enhance the efficiency and accessibility of logistics routes, facilitating the smooth flow of goods and services. The government also encourages the use of sustainable transportation modes, such as promoting inland shipping and supporting initiatives for electric and hybrid vehicles. In terms of sustainability, the government of Gelderland is committed to environmental conservation and the transition to a more sustainable economy. They implement policies and programs to reduce carbon emissions, promote renewable energy sources, and support sustainable business practices. The government provides incentives and grants for businesses and organizations that adopt sustainable practices, such as energy-efficient technologies, waste reduction, and circular economy initiatives.

Table 4.1: List of interviews

Company	Designation
Port of Rotterdam	Program Manager Business Accounts
BCTN Terminals	Regional Sales Manager
CTD Terminals	Branch Manager
Aviko	Supply Chain Manager
VIM	Logistics Manager
Province Gelderland	Coordinator for logistics and freight transportation

4.2.2. Interview questions

Many scholars have examined and discussed the various roles played by different stakeholders in the transportation system of dry ports. As with any transportation network, the number of stakeholders involved in dry ports can be substantial, and their numbers tend to increase as sea ports expand into hinterland areas (Flämig and Hesse, 2011). Consequently, effective communication between local and global stakeholders becomes increasingly important. In addition, the significant financial investments required for dry port investments and maintenance operations means that public-private partnerships play a significant role (Haralambides and Gujar, 2011). With the expansion of the hinterland and the growing number of stakeholders involved in the system, the quality of the hinterland strategy adopted by both the sea port and the dry port becomes increasingly critical (Van den Berg and De Langen, 2011). Due to the above reasons, it is important to know the relationship with other stakeholders and the strategies they use to maintain and improve the relationships. According to (Haralambides and Gujar, 2011), the public sector continues to dominate the development and operations of dry ports, primarily due to factors such as pricing policies, capacity limitations, and land acquisition policies. These conditions create an environment in which private sector involvement is deemed risky and comparatively unappealing. Hence, it is important to know the policies related to the development of the dryports.

Numerous studies have explored the potential of dry ports to reduce transportation costs, with a focus on comparing costs before and after implementation (Henttu and Hilmola, 2011), (Flämig and Hesse, 2011). However, estimating costs for dry ports is more complex than for unimodal road transport due to a greater number of variables (Cullinane and Wilmsmeier, 2011). Without a clear reduction in transportation costs, investing in a dry port may not be financially viable. Although dry ports also offer environmental bene-

fits, these benefits alone are often not enough to justify their creation without significant cost savings in transportation. Hence, it is important to know the availability of the existing infrastructure and the costs associated with different types of modes. Many research studies on dry ports are dedicated to identifying the optimal geographic location for inland intermodal terminals. Utilizing a dry port offers several cost-saving opportunities beyond transportation expenses. These include reduced inventory costs through optimized storage and warehousing, streamlined handling and customs clearance processes, minimized packaging and repackaging expenses, time-related cost reductions due to efficient cargo transfer, decreased risk and insurance costs with enhanced security measures, and potential environmental cost savings by promoting greener transportation modes. These various cost reductions contribute to improved operational efficiency and overall competitiveness for businesses integrating dry ports into their supply chains. (Rahimi et al., 2008) developed a model that aims to minimize daily vehicle-miles to determine the best locations for inland ports. The addition of more inland ports to the model results in a significant reduction in vehicle-miles, which helps alleviate congestion and reduce air pollution.Careful consideration should be given to the location of a dry port, highlighting the importance of understanding land use policies and real estate development.

As dry ports are a key component of intermodal transportation, the management of containers plays a crucial role. (Choong et al., 2002) have emphasized the importance of considering empty containers when managing container flows, as neglecting them can render transportation business unprofitable. The authors recommend a longer planning horizon to facilitate the use of slower, less expensive transport modes such as barges, while a shorter planning horizon necessitates faster and more expensive delivery options. Additionally, the amount and location of container storage areas have a significant impact on the choice of transport mode. Hence, it is important to know how empty containers are managed currently in ports and inland terminals.

Intermodal transport can provide environmental benefits, as demonstrated by (Liao et al., 2009). The study compared CO2 emissions in two scenarios: one involving truck-only transportation for hinterland transportation, and the other involving intermodal coastal shipping for long haulage and road transport for the final transportation leg. The results revealed that substituting road transport with intermodal transport can significantly reduce CO2 emissions. In order to attain the maximum benefits from developing dryports, it is important to know current strategies followed by terminal operators from the environmental perspective.

The knowledge of current infrastructure is crucial for developing a maturity model for a dryport because it helps in understanding the existing capabilities and limitations of the dryport. (Hanaoka and Regmi, 2011) Investing in railway infrastructure and modern ICT technology is crucial for the development of a functional dryport. Hence, it is necessary to assess the level of digitalization and existing infrastructure in both ports and inland terminals. In addition, policies concerning the investment in new infrastructure must be considered.

Drawing from the research and insights obtained through the literature review, interview questions have been formulated. Interview questions are divided according to the different stakeholders. They are for inland terminal operators, providers, port authorities, government and users. During stakeholder interviews, it is crucial to ensure that participants have a clear understanding of the definition and significance of dryports before proceeding with the discussion. This foundational knowledge provides a common understanding and enables more informed and meaningful responses to subsequent questions. By establishing a shared understanding of dryports, stakeholders can provide valuable insights into their experiences, challenges, and perceptions, allowing for a comprehensive exploration of the topic and its implications for logistics, supply chain management, and regional development.

Inland terminal operators: This is for terminal operators who offer services to shipping lines and logistic providers. Interview questions are listed as:

- What is a dryport according to you?
- What are the functions of their current terminal and what are they planning to expand?

- How do you compare inland terminals to sea ports?
- What infrastructure and equipment are required to support terminal operations? Would there be any change if it is converted into a dryport?
- What role does digitalization play in operations, and how do you use technology to improve efficiency and visibility?
- How do you compete with other terminal operators?
- What strategies do you use to attract and retain shipping lines and other customers?
- How do you measure and evaluate the performance of your terminal, and what key performance indicators do you use to track progress over time?
- How do you collaborate with other actors in the logistics ecosystem, such as freight forwarders, trucking companies, barge operators, and rail operators, to create a seamless end-to-end supply chain?
- How do you deal with empty container management?
- How do you manage the interface between the inland terminal and seaport, and what strategies do you use to optimize container flows and reduce congestion?
- What strategies do you employ to address environmental challenges and comply with regulatory requirements?
- How would the quality of service differ if they convert it into a dryport?
- What modes of transportation are available for accessing your terminal?
- Do you think dryports are useful for imports or exports or both? And why?

Providers: This group of questions is focused on freight forwarders and shipping lines. Questions to be asked in interviews are listed below:

- What is a dryport according to you?
- What are the main factors that you strive for improvement?
- Do you support the concept of dryport or not? And why?
- What role do sustainability and environmental considerations play in your logistics operations, and how do you address these issues in the context of dryports?
- What is the accessibility of infrastructure and associated travel times and costs?
- How do you evaluate the suitability of a dryport for your logistics needs, and what factors do you consider when selecting a specific dryport?
- What are the cost elements in general that you take into consideration and how would they change if dryport concept is implemented?
- Do you think dryports are useful for imports or exports or both? And why?

Port authorities: This is mainly focused on the port operations and development. Interview questions are listed as:

- What role do dryports play in your overall port strategy, and how do you see them evolving in the years to come?
- What steps do you take to ensure the safety and security of cargo at the port, and how do you manage risk in your operations?
- Are there delays in the customs clearance?
- What are the incentives from port authorities and economic development agencies for shipping companies?
- What are strategies employed at the port for managing empty containers?
- Can you describe any tools or techniques you use to stay aware of potential hazards and risks?
- What do you see as the future of dryports, and how are you preparing for changes in the industry and global supply chain?
- What are the biggest challenges faced by ports?
- Do you see dryports as complementary to seaports?
- How do you build and maintain relationships with terminal operators and other supply chain partners, and what strategies do you use to manage these interactions effectively?
- What are the cost elements involved and how would they change if dryport concept is implemented?
- Do you think dryports are useful for imports or exports or both? And why?

Government: Interviews with Government will give insights on the policies related to the sustainable and economic port development. Interview questions are listed as:

- What is a dryport according to you?
- What is the Province of Gelderland's overall vision and strategy regarding the development of dryports within the region?
- How does it perceive the role of dryports in enhancing regional economic development, trade and logistics connectivity?
- What are the key criteria or factors in considering suitable locations for dryports?
- What would residents think about the dryport concept?
- What types of collaborations or partnerships exist between the government, terminal operators, logistics companies, and other stakeholders to support the growth and operations of dryports?
- What is the structure of the government with respect to port-hinterland relations?
- What are the incentives offered for the use of certain infrastructures like railways and barges?
- What are the key challenges and opportunities the Netherlands faces in the development and expansion of dryports, and how are these being addressed at the national level?

Users: Customers of ports/dryports will be interviewed to know their needs and expectations from a dryport. Questions are listed below:

- How does the implementation of dryport concept affect the supply chain of your business?
- How do you take environmental factors into consideration while transporting the goods?
- What opportunities are you looking for in dryports?
- What would be the main benefits to you from dryports?
- Do you think dryports are useful for imports or exports or both? And why?

4.2.3. KEY FINDINGS

This section presents the insights and findings obtained from interviews conducted with key stakeholders in the dryport industry. The direct questions and answers discussed during interviews are shown in the Appendix B.

Based on the response from the interview participants, dry ports are predominantly characterized as inland terminals situated in the hinterland, outside the city, and connected to seaports through intermodal transportation. According to the participants' feedback, the establishment of dry ports in the Netherlands aimed to support seaport activities and enable manufacturers to efficiently transport their containers to and from seaports, ensuring minimal time and cost. Dry ports, similar to seaports, are strategically located in the hinterland and facilitate the transportation of containers through various modes, particularly inland waterways. The interviews revealed distinct differentiators between dryports and traditional inland terminals. Dryports stand out due to their diverse service offerings, increased cargo handling capacity, and higher frequency of transport modes shuttling between seaports and dryports. Moreover, dryports play a pivotal role in advancing environmental sustainability by actively encouraging the adoption of greener transport options through modal shift initiatives.

The participants stressed that the effectiveness of dry ports is enhanced when they are situated near manufacturing areas or industrial parks, enabling smooth container movement and avoiding issues like traffic congestion or delays in clearance. Furthermore, the utilization of dry ports by manufacturers and other stakeholders helps alleviate capacity constraints at the Port of Rotterdam, easing the pressure on port facilities. Users perceive dry ports as instrumental in enhancing supply chain flexibility. By efficiently utilizing dry ports, waiting times for drivers, who are in high demand and scarce in the Netherlands, can be reduced, subsequently lowering transportation costs and time. Additionally, dry ports offer the advantage of leaving containers at the terminal and provide solutions for managing empty containers, alleviating the space constraints faced by seaports. These dry ports also deliver customized services to users, establishing and nurturing long-term relationships to cater to their specific needs. Consequently, the operation of the terminal is tailored based on the individual requirements of users, prioritizing sustained partnerships over

short-term benefits.

Inland terminals aim to complement seaport operations, considering trucking companies as their primary competitors. Inland terminals strive to compete and collaborate with each other, recognizing that greater volume and throughput are necessary to secure a slot in the Port of Rotterdam's terminals. Small inland terminals can leverage the services of dry ports when they do not possess sufficient volume to transport goods directly to seaports. The key factors driving their success include price competitiveness, strategic location, and the provision of value-added services. Inland terminals that hold a Dutch customs permit have the capability to conduct customs clearance procedures similar to seaports. As a result, users have the convenience of leaving or picking up their containers from these inland terminals, just as they would at seaports.

However, logistic providers express the perspective that dryports are not currently necessary, as their primary focus is on enhancing the efficiency and capacity of existing inland terminals. They emphasize the need for process improvements and increased capacity rather than the establishment of dryports. Additionally, they raise concerns about the high costs associated with setting up warehouses near dryports, which could make the surrounding land expensive. This warehouse can be used to temporarily store goods before they are loaded onto the next mode of transport. Additionally, it accommodates value-added services such as customs clearance, quality control, and packaging, making the dryport a one-stop solution for logistics and supply chain activities.

Furthermore, users contend that the utilization of dry ports is beneficial for their companies from a sustainability perspective. This is due to the adoption of intermodal transportation methods and the transportation of containers in significant volumes via waterways in the Netherlands. Interviewees from inland terminals shared their efforts towards sustainability, highlighting initiatives such as the introduction of hydrogen, electric, and hybrid ships, fully electric terminal trackers, and environmentally friendly trucks. However, the Port of Rotterdam faces a significant challenge in terms of energy transition, as many port activities still rely on fossil fuels. To address this, the port is investing in biofuels and hydrogen as alternative energy sources. Additionally, investments are being made in pipelines to facilitate the transportation of liquid bulk to the hinterland, further supporting sustainable practices.

To maintain terminal security, CCTV cameras are implemented at inland terminals. In their day-to-day operations, inland terminal operators rely on gantry cranes, reach stackers, trucks, empty handlers, and terminal trackers. Based on the interviews conducted with inland terminal operators, they offer a range of services including transshipment, storage, gas analysis, fumigation processes, customs clearance, road haulage, container maintenance, refer container handling, and forwarding. However, it should be noted that packaging and consolidation/deconsolidation services are not provided by these operators. Their primary focus is on transporting containers as a whole. Digitalization plays a pivotal role in all inland terminals, with the utilization of ERP and TOS systems to efficiently manage and monitor their business activities.

From the discussion with an employee from Province Gelderland, it was very clear Government was very much interested in the dryport concept and it has its main focus on sustainability. They mentioned measures such as greening transport, sustainable vans, reducing shipping, and implementing clean energy hubs. They collaborate with provinces and have a network covering the entire country. According to them, Dryports are seen as an interesting concept that can make the supply chain more robust and flexible. They offer advantages like reduced dependence on seaports for customs clearance, financial benefits, and enhanced reliability. The Province of Gelderland aims to make dryports more green and sustainable to attract shippers and businesses, working with partners like BCTN and zero-emission services. The Province of Gelderland has a long-term vision for dryports, focusing on attracting shippers and promoting cooperation.

4.2.4. Formulation of requirements

Based on the stakeholder interviews, following requirements of a dryport have been derived. To ensure clarity, after each requirement, relevant information about its derivation from specific stakeholders is provided

within brackets for transparency and context. Requirements can be categorised into two types: Constraints and objectives.

Constraints are the requirements that the project must comply to. A distinction is made between functional constraints, what the design must do, and non-functional constraints, what the design must have.

Objectives are the requirements that the design could preferably comply to. A distinction is made between functional objectives, what the design could preferably do, and non-functional objectives, what the design could preferably have.

Functional Constraints:

1. **The dryport must have the necessary capacity to handle a certain volume of cargo, including storage and handling facilities:** (Inland terminals and Port of Rotterdam)
   A dryport's capacity is essential to handle the required volume of cargo efficiently. It involves having adequate storage and handling facilities in place. Storage capacity ensures the proper management of incoming and outgoing goods, while efficient handling facilities enable smooth loading, unloading, and movement of cargo within the dryport. With the necessary capacity, a dryport can effectively meet stakeholders' needs, streamline supply chain operations and establish itself as a reliable and thriving logistics hub.
2. **The dryport must have the necessary equipment, such as cranes, forklifts, and trucks, to handle and transport cargo:** (Inland terminals and Port of Rotterdam)
   A well-equipped dryport requires essential machinery like cranes, forklifts, trucks, and specialized vehicles to handle and transport cargo efficiently. Cranes facilitate lifting and moving heavy containers, while forklifts ensure smooth internal cargo handling. Trucks connect the dryport to the broader supply chain, enabling seamless transportation. By meeting these equipment requirements, a dryport can optimize cargo operations, enhance logistics connectivity and contribute to overall trade success.
3. **The dryport must have good road and rail or barge access, as well as sufficient parking and waiting areas for trucks and other vehicles:** (Inland terminals and Port of Rotterdam)
   A successful dryport necessitates excellent road and rail or barge access, along with ample parking and waiting areas for trucks and other vehicles. Well-connected road and rail networks ensure efficient transportation links between the dryport and other parts of the logistics network. Barge access provides an additional mode of transportation for cargo movement, particularly for inland waterways. Sufficient parking and waiting areas cater to the needs of trucks and vehicles, allowing for smooth and organized traffic flow within the dryport premises. By meeting these requirements, a dryport can enhance accessibility, minimize congestion, and optimize the movement of goods, fostering efficient and effective logistics operations.
4. **The dryport must have effective security measures to ensure the safety of the cargo and the personnel working at the facility:** (Inland terminals and Port of Rotterdam)
   A secure dryport requires effective security measures to protect cargo and personnel. This includes surveillance systems, access control, perimeter fencing, and personnel training. These measures ensure continuous monitoring, authorized access, and a safe working environment. By implementing robust security measures, a dryport can safeguard cargo integrity and maintain a secure facility for its operations.
5. **The dryport must comply with relevant regulations and standards for transportation, security, and environmental protection:** (Inland terminals, Government and Port of Rotterdam)
   Compliance with applicable regulations and standards is essential for a dryport, covering transportation, security, and environmental protection. This entails adhering to transportation regulations to ensure safe and lawful cargo movement. Compliance with security standards involves implementing measures to protect assets, personnel, and data. Environmental compliance requires adherence to regulations aimed at minimizing the impact of operations on the environment. By meeting these requirements, a dryport can operate within legal frameworks, promote safety and security, and contribute to sustainable practices.
6. **The dryport must ensure a frequent and reliable rail/barge service connecting to the seaport:** (In-

land terminals)
A successful dryport must establish a frequent and reliable rail/barge service that effectively connects it to the seaport. This entails developing robust transportation infrastructure, coordinating schedules, and ensuring efficient operations. By providing regular and dependable rail/barge connections, the dryport can facilitate the seamless movement of cargo between the inland hub and the seaport, offering shippers and logistics providers a reliable and efficient logistics solution. This reliable service enhances supply chain connectivity, reduces transit times, and strengthens the overall competitiveness of the dryport as a pivotal link in the transportation network.

7. **The dryport must have enough capacity for the temporary storage of containers:** (Inland terminals and Port of Rotterdam)
A key requirement for a dryport is to have sufficient capacity for temporary container storage. This includes designated areas or facilities that can accommodate the storage of containers during transit or during periods when they are awaiting further transportation. Adequate container storage capacity ensures efficient handling and organization of containers, facilitating smooth cargo flow and reducing congestion. By having enough storage capacity, a dryport can effectively manage container inventory, optimize operations, and provide reliable storage services to support the logistics needs of shippers and transporters.

Non-Functional constraints:

1. **The dryport must be designed and operated to meet specific performance requirements, such as throughput, turnaround times, and reliability:** (Inland terminals)
A successful dryport must meet specific performance requirements, including throughput, turnaround times, and reliability. This entails efficient design, streamlined operations, and proactive maintenance. By optimizing processes and minimizing delays, the dryport can ensure efficient throughput, fast turnaround times, and reliable service delivery.
2. **The dryport must be designed and operated in an environmentally sustainable manner, with measures to reduce energy consumption, waste generation, and emissions:** (Inland terminals and Government)
An environmentally sustainable dryport must be designed and operated with a focus on reducing energy consumption, waste generation, and emissions. This involves implementing measures such as energy-efficient infrastructure, waste management systems, and emission reduction strategies. By integrating sustainable practices, the dryport can minimize its environmental footprint, contribute to climate change mitigation, and promote a greener logistics industry.
3. **The dryport must be designed and operated to minimize safety risks to personnel, cargo, and the environment:** (Inland terminals, Government and Port of Rotterdam)
Ensuring safety is a top priority in the design and operation of a dryport. It must be meticulously planned and executed to minimize risks to personnel, cargo and the environment. This includes implementing safety protocols, conducting regular inspections, providing proper training to personnel, and adhering to safety regulations and standards.
4. **The dryport must take into account cultural factors that may impact the design and operation of the facility, such as local labor practices and customs:** (Government)
In considering the design and operation of a dryport, it is crucial to take cultural factors into account, including local labor practices and customs. This entails understanding and respecting the cultural norms, values, and practices of the surrounding community. It involves engaging with local stakeholders, considering their input, and adapting operational strategies to align with cultural sensitivities. By integrating cultural factors, the dryport can foster positive relationships, promote social cohesion, and enhance community acceptance, ultimately contributing to the success and sustainability of the facility.
5. **The dryport must be designed and operated to be financially viable and sustainable over the long term:** (inland terminals)
A financially viable and sustainable dryport must be designed and operated with a long-term perspective in mind. This involves careful financial planning, cost-effective infrastructure design, and efficient operational strategies. The dryport should aim for a healthy balance between revenue gen-

eration and cost management to ensure financial viability. Sustainable practices, such as optimizing resource utilization, minimizing waste, and embracing technological advancements, contribute to long-term financial sustainability. By prioritizing financial viability and sustainability, the dryport can maintain its operations, attract investments, and support economic growth in the region.

Functional Objectives:

1. **Dryports shall facilitate efficient and effective transshipment of cargo between the seaport and the hinterland:** (Inland terminals)
   Dryports enable efficient transshipment of cargo between seaports and the hinterland, ensuring seamless connectivity and streamlined logistics operations. By strategically locating near seaports and optimizing cargo handling processes, dryports facilitate effective transfer between different modes of transportation. This enhances supply chain efficiency and reduces transit times for importers and exporters.
2. **Dryports shall provide fast and reliable access to international markets for regional industries and businesses:** Inland terminals and Government)
   Dryports serve as crucial gateways, providing regional industries and businesses with efficient and reliable access to international markets. By offering streamlined connections to seaports and global trade networks, dryports enable expedited trade and create opportunities for business growth. With their strategic positioning and seamless logistics operations, dryports play a vital role in facilitating regional industries' access to global markets, fostering economic development and enhancing international trade opportunities.
3. **Dryports should serve as strategic trade and investment hubs that actively contribute to the growth and development of regional economies:** (Government)
   Dryports play a pivotal role as strategic trade and investment hubs, actively contributing to the growth and development of regional economies. By attracting trade activities, fostering connectivity, and providing value-added services, dryports stimulate economic growth, generate employment opportunities, and attract investments. They serve as dynamic centers for commerce, innovation, and collaboration, promoting regional integration and driving economic diversification. Through their proactive role in facilitating trade and investment, dryports become catalysts for regional development, creating a favorable environment for businesses to thrive and economies to prosper.
4. **Dryports should enhance supply chain efficiency and reduce transportation costs:** (Inland terminals, users and Providers)
   Dryports are essential in enhancing supply chain efficiency and reducing transportation costs. By providing seamless connectivity between different transportation modes, dryports streamline the flow of goods and optimize logistics operations. This results in shorter transit times, minimized handling and transfer delays, and improved overall supply chain performance. Additionally, the consolidation of cargo at dryports enables economies of scale, leading to cost savings in transportation. By offering efficient operations and cost-effective solutions, dryports contribute to improved supply chain efficiency and reduced transportation costs for businesses and stakeholders.
5. **Dryports should streamline customs and border clearance procedures to facilitate international trade:** Inland terminals)
   One of the key roles of dryports is to streamline customs and border clearance procedures to facilitate smooth international trade. By implementing efficient customs processes, such as pre-clearance and electronic documentation, dryports reduce bureaucratic hurdles and minimize delays at border crossings. This helps expedite the movement of goods, enhances supply chain predictability, and improves overall trade efficiency.
6. **Dryports should offer a range of value-added services to enhance cargo handling and distribution operations:** (Inland terminals and users)
   Dryports are expected to offer a comprehensive range of value-added services to enhance cargo handling and distribution operations. These services can include consolidation, deconsolidation, sorting, labeling, packaging, and customization of goods based on customer requirements. Additionally, dryports can provide inventory management, order fulfillment, and last-mile delivery services to optimize the supply chain. By offering these value-added services, dryports add flexibility, efficiency,

and convenience to cargo operations, supporting businesses in meeting customer demands and improving overall logistics performance.

7. **The maintenance of containers at the dryport shall be conducted at regular intervals to ensure their optimal condition and functionality:** (Users and providers)
   Regular maintenance of containers at the dryport is crucial to ensure their optimal condition and functionality. This includes scheduled inspections, repairs, and cleaning to prevent damage, extend their lifespan, and maintain industry standards. By conducting regular maintenance, the dryport can ensure that containers are in proper working order, minimizing the risk of equipment failures and disruptions to cargo operations. This proactive approach to container maintenance enhances the overall reliability and efficiency of the dryport, allowing for the smooth movement of goods and supporting the seamless functioning of the supply chain.
8. **The dryport shall have an effective local communication system to enable seamless information exchange and collaboration among stakeholders:** (Inland terminals, users and providers)
   Local communication at a dryport also involves actively listening to clients and promptly addressing any issues or concerns that may arise. This client-centric approach ensures that clients are kept informed if any unexpected situations occur, allowing for timely resolution and mitigation of potential disruptions. Unlike some seaports that may not prioritize client communication, a dryport understands the importance of transparent and proactive communication with clients, building trust, and maintaining strong relationships. By prioritizing client satisfaction and open communication, the dryport establishes itself as a reliable and responsive partner, further enhancing its reputation and attracting continued business.
9. **Dryports shall have a systematic process that enable the reliable and timely provision of empty containers to customers:** (Inland terminals and (Rodrigue et al., 2010))
   Dryports must establish a systematic process to ensure the reliable and timely provision of empty containers to customers. This entails effective container tracking and management systems, proactive communication with shipping lines, and efficient coordination of container availability. By maintaining accurate inventory records, forecasting demand, and promptly replenishing empty containers, dryports can meet customer needs and minimize delays in container supply.

Non-Functional objectives:

1. **Dryports shall promote environmental sustainability by reducing energy consumption, waste generation, and emissions:** (Inalnd terminals, Government, users and providers)
   Dryports have a responsibility to promote environmental sustainability by actively reducing energy consumption, waste generation, and emissions. This includes implementing energy-efficient infrastructure, adopting renewable energy sources, and optimizing resource utilization. By embracing sustainable practices, such as waste reduction, recycling, and eco-friendly technologies, dryports can minimize their environmental footprint. Additionally, the promotion of modal shift towards greener transportation modes, such as rail or barge, helps to reduce carbon emissions. By prioritizing environmental sustainability, dryports contribute to a more sustainable logistics industry, support climate change mitigation, and help protect the environment for future generations.
2. **Dryports shall provide high levels of service quality and reliability to customers and stakeholders:** (Inland terminals)
   Dryports are expected to provide customers and stakeholders with high levels of service quality and reliability. This includes efficient cargo handling, accurate tracking and tracing systems, timely communication, and adherence to promised delivery schedules. By prioritizing service excellence, dryports can meet and exceed customer expectations, build trust, and foster long-term relationships. Reliable operations, such as consistent performance, minimal delays, and effective problem-solving, contribute to the overall satisfaction of customers and stakeholders. By consistently delivering on their commitments, dryports enhance their reputation as reliable and trusted partners in the logistics industry.
3. **Dryports shall minimize disruptions to the supply chain through effective risk management and contingency planning:** (Inland terminals, users and providers)
   Dryports are responsible for minimizing disruptions to the supply chain by implementing effective

risk management and contingency planning measures. This involves identifying potential risks, developing mitigation strategies, and establishing contingency plans to address unforeseen events or emergencies. By proactively managing risks and having robust contingency plans in place, dryports can swiftly respond to disruptions, minimize their impact on the supply chain, and ensure the continuity of operations.

4. **Dryports shall optimize resource utilization, including space, equipment, and personnel, to achieve operational efficiency and cost-effectiveness:** (Inland terminals)
   Dryports should optimize the utilization of resources, including space, equipment, and personnel, to achieve operational efficiency and cost-effectiveness. This involves strategic planning, efficient scheduling, and effective resource allocation. By maximizing the use of available space, ensuring the proper utilization of equipment, and optimizing the deployment of personnel, dryports can enhance operational efficiency, reduce unnecessary costs, and improve overall productivity. This resource optimization contributes to the competitiveness of the dryport, enabling it to deliver high-quality services while maintaining cost-effectiveness for customers and stakeholders.

4.3. Analysis of development steps

In the process of transforming an intermodal terminal into a dryport, careful assessment and prioritization of the functions required for its successful operation are essential. The functions performed by a dryport play a crucial role in facilitating efficient freight transportation, optimizing supply chain operations, and enhancing overall logistics connectivity. To effectively determine the functions that need to be incorporated into the dryport, as well as their relative importance, two valuable tools can aid in this analysis: a morphological chart and the best-worst method for ranking functions. Together, the morphological chart and the best-worst method offer a powerful analytical approach to identify, evaluate and prioritize the functions needed for a successful transformation from an intermodal terminal to a fully functional dryport. This ranking will help in placing functions in different maturity levels in the dryport maturity model.

4.3.1. Morphological chart

Dryports play a crucial role in facilitating efficient and seamless intermodal transportation and logistics operations. As these complex logistical hubs continue to evolve and face evolving challenges, it becomes essential to employ effective problem-solving methodologies to identify and explore suitable solutions. The morphological chart, a systematic tool for problem-solving and solution generation, offers a structured approach to address the multifaceted requirements and complexities of dryports. By breaking down the functions and potential solutions, the morphological chart provides a comprehensive framework for analyzing and evaluating various solutions that can contribute to the improvement and optimization of dryport operations.

This section will discuss the step-by-step process of developing the chart, along with the analysis of functions identified in Chapter 3 and identifying potential solutions for each function. This section provides valuable insights and directions for enhancing the efficiency and effectiveness of dryport systems, ultimately contributing to the overarching goal of optimizing intermodal logistics and transportation. The morphological chart draws from principles of systems thinking, problem-solving methodologies, and decision analysis. It leverages concepts from fields like operations research, logistics management, and engineering, providing a solid theoretical foundation for its application in the dryport context. Overall, the morphological chart enables structured problem-solving, comprehensive exploration and effective decision-making, making it a valuable tool in various domains, including optimizing dryport operations.

A morphological chart, also referred to as concept-combination tables or function-means table, is a problem-solving tool that facilitates the systematic combination of solutions to address a design problem (Richardson III et al., 2011). The functions and solutions within the context of dryports are integral components of an efficient logistics system. These functions represent key activities involved in the handling, processing, and distribution of cargo, while the solutions or means are the specific strategies and tools employed to accomplish these functions effectively. The chapter begins with a discussion on the functions and potential

solutions of dryports, followed by an evaluation of these functions and solutions. The subsequent section outlines the process flow within dryports, highlighting the sequential steps involved. The chapter concludes with a summary of the key findings and insights gathered throughout the chapter.

The morphological chart with the functions of a dryport is be presented in the Table 4.2. All the functions of a dryport and potential means are discussed below.

Table 4.2: Morphological Chart

Functions	Means/solutions				
Transshipment	Dedicated transshipment terminals	Cross-Docking facilities	Automated handling systems		
Consolidation/ Deconsolidation	Sorting area	Storage space	Sorting equipment		
Load center	Centralized distribution hubs	Cargo consolidation area	Inventory management systems	Efficient material handling systems	
Customs clearance	Customs inspection facilities	Documentation area	Customs compliance systems	Customs agent services	Integration with customs authorities' systems
Additional service offerings	Labelling and branding facilities	Product testing and certification space	Repackaging and relabelling stations	Product quality control systems	
Light transformation	Assembly and kitting center	Rework center	Configuration center	Contract packaging facility	
Buffer function	Agile supply chain networks	Advanced inventory management systems	Collaborative planning and forecasting	Flexible storage and warehousing	
Information management	Cargo tracking systems	Electronic data interchange capabilities	Integration with supply chain partners	Real-time visibility and reporting	Document management systems
Environmental sustainability	Renewable energy utilization	Waste management systems	Water conservation measures	Green building design and materials	Emissions reduction initiatives
Storage and warehousing	Warehouse space	Racking systems	Warehouse management systems	Climate-controlled storage areas	Security measures
Empty container management	Container repositioning optimization algorithms	Collaboration with sea carriers	Demand driven container forecasting	Container leasing	Collaborative empty container management system
Container maintenance	Container inspection and repair facility	Maintenance and cleaning services	Container tracking and monitoring system	Spare parts inventory management	Collaboration with container maintenance service providers
Freight forwarding	In-house freight forwarding department	Partnership with freight forwarding companies	Digital freight forwarding platform	Integrated supply chain management	

TRANSSHIPMENT

Transshipment involves the transfer of cargo between different modes of transportation, such as from ships to trucks or from trains to trucks. It plays a crucial role in connecting different transportation networks and facilitating the smooth movement of goods. Efficient transshipment operations ensure timely delivery, reduced handling costs, and improved supply chain connectivity (Filina-Dawidowicz and Kostrzewski, 2022). This can be achieved by different means as discussed below.

Dedicated Transshipment terminal: Dryports can have dedicated terminals equipped with the necessary infrastructure and equipment for efficient transshipment operations. These terminals can have specialized handling equipment, such as cranes and forklifts, to transfer cargo between different modes of transportation, ensuring smooth and swift transfers (Filina-Dawidowicz and Kostrzewski, 2022).

Cross-Docking facilities: Cross-docking facilities in dryports provide a streamlined process where incoming shipments are unloaded from one mode of transport and directly loaded onto another without the need for storage. This reduces handling time, minimizes storage costs, and enhances overall operational efficiency (TUP, 2022).

Automated handling systems: Dryports can leverage automation technologies, such as conveyor systems, automated guided vehicles (AGVs), and robotic arms, for the handling and transfer of cargo. Automated handling systems enhance speed, accuracy, and safety, reducing reliance on manual labor and improving

overall productivity(Kim et al., 2012).

CONSOLIDATION/DECONSOLIDATION

This function refers to the process of combining or breaking down shipments for efficient distribution. It involves sorting and organizing incoming shipments based on their destinations or other criteria. This function is essential for optimizing transportation efficiency, reducing costs, and improving delivery accuracy. Adequate storage space and sorting equipment are key elements in achieving effective consolidation and deconsolidation operations.

Sorting area: A dedicated space within the dryport facility where incoming shipments are sorted based on their destinations or other relevant criteria. This area can have designated sections or zones for different destinations or specific handling requirements. Sorting areas can include conveyor systems, sorting bins, or manual sorting stations to facilitate efficient organization and grouping of shipments (Theophilus et al., 2019).

Storage space: Sufficient storage facilities within the dryport to temporarily hold and consolidate incoming shipments. The storage space should be designed to accommodate different types and sizes of cargo. This may include racks, shelves, or pallet storage systems to optimize space utilization and accessibility. Efficient storage space allows for proper organization of goods, reducing the risk of damage and ensuring easy retrieval when needed.

Sorting equipment: The use of appropriate sorting equipment to streamline the consolidation and deconsolidation processes. This can include conveyor belts, automated sorting systems, or manual sorting stations. Advanced technologies such as barcode scanners, RFID systems, or automated identification systems can be employed to improve accuracy and efficiency during sorting operations. The selection of suitable sorting equipment depends on the volume and nature of the cargo handled within the dryport.

LOAD CENTER

Load centers, also known as centralized distribution hubs, serve as strategic locations for cargo consolidation and distribution. They act as central points for collecting and combining shipments from multiple sources before further distribution to their final destinations. They provide a central location for efficient material handling, inventory consolidation, and streamlined distribution processes.

Centralized distribution hubs: Load centers serve as centralized distribution hubs where cargo from various sources is collected and consolidated before further distribution. These hubs act as strategic locations within the dryport, strategically positioned to efficiently reach multiple destinations. They provide a central point for receiving, organizing, and dispatching shipments, streamlining the distribution process and reducing transportation costs.

Cargo consolidation area: Within the load center, there should be a designated area specifically for cargo consolidation. This area allows for the combining and grouping of shipments based on their destinations or specific requirements. It includes facilities such as sorting areas, storage space, and efficient material handling equipment to facilitate the consolidation process. The cargo consolidation area ensures optimal utilization of space, reduces handling times, and improves the overall efficiency of distribution operations (NOTTEBOOM and RODRIGUE, 2004).

Inventory management systems: Effective inventory management systems are crucial for load centers. These systems provide real-time visibility and control over the inventory within the dryport. They track incoming and outgoing shipments, monitor stock levels, and facilitate accurate inventory replenishment. Inventory management systems enable efficient demand forecasting, optimal stock positioning, and timely replenishment, ensuring the availability of goods when needed and minimizing inventory holding costs

(NOTTEBOOM and RODRIGUE, 2004).

Efficient material handling systems: Load centers require efficient material handling systems to handle the incoming and outgoing cargo. This includes equipment such as forklifts, pallet jacks, conveyor systems, or automated guided vehicles (AGVs). These systems streamline the movement of goods within the load center, enabling quick and accurate loading and unloading operations. Efficient material handling systems contribute to reducing handling times, minimizing errors, and optimizing the overall flow of goods in the dryport.

CUSTOMS CLEARANCE:

This function refers to the process of fulfilling legal and regulatory requirements imposed by customs authorities for the import and export of goods. It involves complying with customs procedures, documentation, inspections, and payment of duties or taxes. The customs clearance function is of utmost importance in the smooth flow of goods through the dryport, ensuring compliance with customs regulations and facilitating international trade.

Customs inspection facilities: These are designated areas within the dryport where customs officials carry out inspections of incoming and outgoing shipments. These facilities may include inspection stations, examination rooms, or specialized equipment for thorough examination of goods. Customs inspection facilities enable the verification of cargo contents, compliance with regulations, and identification of any discrepancies or security risks.

Documentation area: A dedicated space within the dryport where all the necessary customs documentation is processed and managed. This area involves activities such as preparing, reviewing, and submitting customs declarations, invoices, permits, and other required documents. It may also include electronic systems or software for efficient document management and submission to customs authorities.

Customs compliance systems: These systems involve the implementation of processes and technologies to ensure compliance with customs regulations and requirements. This may include automated customs compliance software, electronic data interchange (EDI) capabilities, or integration with customs authorities' systems. Customs compliance systems help streamline the customs clearance process, reduce errors, and ensure adherence to customs procedures (Monios et al., 2016).

Customs agent services: Engaging the services of customs agents or brokers who have expertise in navigating customs regulations and procedures. Customs agents assist in preparing and submitting the necessary documentation, coordinating with customs authorities, and ensuring compliance with customs requirements. Their knowledge and experience in customs processes can expedite clearance and help avoid delays or penalties.

Integration with customs authorities' systems: Establishing electronic connections and integration with customs authorities' systems, such as customs clearance portals or online platforms. This enables the exchange of information, submission of electronic documents, and real-time communication with customs authorities. Integration with customs systems enhances efficiency, reduces paperwork, and facilitates faster clearance of goods (Boschian et al., 2010).

ADDITIONAL SERVICE OFFERINGS

Value-added services refer to a range of additional activities and enhancements provided by dryports to meet specific customer requirements and add value to the logistics process. These services go beyond the basic transportation and storage functions and aim to offer customized solutions, improve product quality, and enhance the overall customer experience.

Labeling and branding facilities: Dryports can offer dedicated areas or facilities for labeling and branding activities. This includes applying labels, barcodes, or RFID tags to products for better tracking and identification. Additionally, branding facilities allow for customizing packaging or product labeling to align with specific customer or market requirements (Rivera et al., 2016).

Product testing and certification space: Value-added services can include the provision of testing and certification facilities within the dryport. This enables customers to ensure product quality, compliance with standards, and adherence to regulatory requirements. These facilities may include laboratories or testing centers equipped with necessary equipment and expertise to perform quality tests and certifications.

Repackaging and relabeling stations: Dryports may provide repackaging and relabeling stations where products can be repackaged into different sizes or configurations, or existing packaging can be rebranded or modified. This allows for more efficient handling, customization, or compliance with specific market or customer requirements.

Product quality control systems: Value-added services can involve the implementation of quality control systems within the dryport. These systems may include quality inspections, audits, or quality assurance processes to ensure that products meet specified standards and customer expectations. Quality control measures may include visual inspections, sample testing, or compliance checks.

Light transformation

This function specifically refers to the physical modification or enhancement of products at the dryport facility. It involves activities such as product assembly, kitting, configuration, rework, and contract packaging. The emphasis is on transforming products to meet specific customer needs, adapt to market demands, or optimize product configurations. Light transformation activities typically involve customization, personalization, and the preparation of products for distribution or retail purposes.

Assembly and kitting center: Dryports can provide dedicated areas or facilities for product assembly and kitting. This involves combining various components or parts to create a finished product or assembling kits for specific purposes. These centers are equipped with the necessary tools, equipment, and skilled personnel to efficiently perform assembly tasks (Tetik et al., 2021).

Rework center: Rework centers within the dryport allow for modifications or repairs to be made to products before they are distributed or delivered to customers. This may involve fixing cosmetic defects, addressing quality issues, or making adjustments to meet specific requirements. Rework centers ensure that products are in optimal condition and meet customer expectations.

Configuration center: Dryports may have configuration centers where products can be customized or configured according to individual customer specifications. This includes adjusting product settings, adding or removing features, or personalizing products to suit specific needs. Configuration centers enable flexibility and customization, allowing customers to receive tailored products.

Contract packaging facility: These facilities handle the packaging of products according to specific requirements or regulations. This may involve re-packaging products into different sizes, packaging types, or formats. Contract packaging facilities ensure that products are properly packaged and labeled for distribution or retail purposes (**?**).

Buffer function

The Buffer function in a dryport offers customers additional time to temporarily store their containers before onward transportation. This strategic delay enhances flexibility and responsiveness in catering to market changes and customer demands, contributing to effective cargo management and distribution optimization within the supply chain.

Agile Supply Chain Networks: This function relies on the establishment of agile supply chain networks that enable quick and efficient customization or finalization of products. These networks involve close collaboration with suppliers, manufacturers, and other supply chain partners to ensure timely availability of components or semi-finished products (Boone et al., 2007).

Advanced Inventory Management Systems: To effectively implement buffer strategies, robust inventory management systems are crucial. These systems help track and manage inventory levels of semi-finished or generic products, ensuring the availability of components or options for customization based on specific customer orders (Boone et al., 2007).

Collaborative Planning and Forecasting: Effective communication and collaboration between different stakeholders are essential for the successful implementation of buffer strategies. Collaborative planning and forecasting processes help align demand signals, customer orders, and production capabilities, enabling timely customization and reducing the risk of excess or obsolete inventory (Chaudhry and Hodge, 2012).

Flexible Storage and Warehousing: Buffer strategies necessitate appropriate storage and warehousing facilities capable of accommodating various configurations or alternatives of semi-finished products. Flexibility in storage space, layout, and handling equipment allows for efficient product customization and easy access to components during the finalization process.

Information Management

The Information Management function in the context of dryports pertains to the effective management, utilization, and exchange of information throughout the logistics operations. It involves the use of technology, systems, and processes to ensure real-time visibility, accurate data sharing, and efficient communication.

Cargo Tracking Systems: Information management includes the implementation of cargo tracking systems that enable the monitoring and tracing of shipments throughout the supply chain. These systems utilize technologies such as RFID (Radio Frequency Identification) tags, barcodes, or GPS (Global Positioning System) to provide real-time visibility of cargo location and status (Vaquero et al., 2016).

Electronic Data Interchange (EDI) Capabilities: EDI facilitates the electronic exchange of business documents, such as purchase orders, invoices, and shipping notices, between different stakeholders in the supply chain. It streamlines information flow, eliminates manual data entry errors, and enhances communication efficiency.

Integration with Supply Chain Partners: Effective information management involves integrating systems and processes with supply chain partners, including suppliers, carriers, customs authorities, and customers. Integration enables seamless data sharing, collaborative planning, and improved coordination, leading to better decision-making and enhanced supply chain visibility.

Real-time Visibility and Reporting: Information management systems enable real-time visibility of inventory levels, shipment status, and other key performance indicators. This allows for timely decision-making, proactive issue resolution, and accurate reporting to stakeholders, facilitating better control and optimization of logistics processes (M'hand et al., 2019).

Document Management Systems: Managing and organizing documents, such as shipping documents, customs declarations, and compliance certificates, is a critical aspect of information management. Document management systems help streamline document handling, improve accessibility, and ensure compliance with regulatory requirements (Antao et al., 2011).

Environmental Sustainability

The environmental sustainability function in the context of dryports focuses on incorporating environmentally friendly practices and initiatives to minimize the ecological impact of operations. It aims to reduce energy consumption, mitigate greenhouse gas emissions, promote waste management, and conserve natural resources.

Renewable Energy Utilization: Dryports can adopt renewable energy sources, such as solar panels, wind turbines, or geothermal systems, to power their operations. By transitioning to renewable energy, they can significantly reduce reliance on fossil fuels and decrease their carbon footprint (Kotowska et al., 2018).

Waste Management Systems: Implementing effective waste management systems is crucial for environmental sustainability. Dryports can implement recycling programs, composting facilities, and waste segregation practices to minimize waste generation and promote responsible disposal methods (Kotowska et al., 2018).

Water Conservation Measures: Dryports can implement water conservation measures to reduce water consumption. This can include the use of water-efficient technologies, rainwater harvesting systems, and water recycling processes to minimize water wastage and preserve this valuable resource (Varese et al., 2022).

Green Building Design and Materials: Dryport facilities can be constructed or retrofitted using sustainable building practices and materials. This includes using energy-efficient building designs, eco-friendly construction materials, and incorporating green infrastructure elements like green roofs or permeable pavements.

Emissions Reduction Initiatives: Dryports can implement initiatives to reduce emissions from transportation and other operational activities. This may involve optimizing logistics processes, promoting the use of electric or hybrid vehicles, and encouraging the adoption of eco-friendly transport modes.

Storage and Warehousing

The storage and warehousing function in the context of dryports refers to the management and organization of goods within the facility. It involves providing adequate storage space, implementing efficient inventory management systems, and ensuring the safe and secure handling of goods. Incorporating the concept of bonded warehouses can further optimize this function, enabling the deferral of duties and taxes on stored goods. This not only enhances financial flexibility but also contributes to overall operational efficiency.

Warehouse Space: The storage and warehousing function necessitates sufficient warehouse space to accommodate various types of cargo. This includes storage areas for different sizes and categories of goods, such as palletized items, bulk commodities, or temperature-controlled storage for perishable goods.

Racking Systems: To maximize storage capacity and facilitate organized inventory management, dryports employ racking systems. These systems consist of shelves, pallet racks, or mezzanine structures that allow for efficient stacking and retrieval of goods (Park, 2012).

Warehouse Management Systems: Effective inventory management is crucial for storage and warehousing operations. Dryports utilize warehouse management systems, which can be technology-based solutions or manual processes, to accurately track stock levels, monitor inventory movement, and enable timely replen-

ishment (Park, 2012).

Climate-Controlled Storage Areas: Certain goods, such as pharmaceuticals, perishable goods, or sensitive materials, require specific temperature and humidity conditions. Dryports may have dedicated climate-controlled storage areas to cater to these specialized storage needs and ensure product integrity (Goetschalckx, 2012).

Security Measures: To safeguard stored goods from theft, damage, or unauthorized access, dryports implement robust security measures. This may include surveillance systems, access control systems, security personnel, and inventory tracking technologies to ensure the integrity and safety of stored goods.

Empty Container Management

Dryports play a crucial role in consolidating, storing, and efficiently managing empty containers. By centrally managing the inventory of empty containers, dryports ensure their availability for exporters and importers in the hinterland. They optimize container utilization, reduce repositioning costs, and minimize unnecessary container movements.

Container repositioning optimization algorithms: These algorithms utilize data and advanced optimization techniques to determine the most efficient ways to reposition empty containers. By analyzing factors such as demand patterns, container availability, and transportation costs, these algorithms help minimize empty container movements, reduce costs, and optimize container utilization (Hosseini and Sahlin, 2019).

Collaboration with sea carriers: By establishing strong partnerships and communication channels with sea carriers, the dryport can proactively manage the flow of empty containers, reducing the accumulation of empty containers and optimizing container utilization. It can gain valuable insights into the sea carriers' container demand and supply patterns, allowing for better planning and coordination of empty container movements. Additionally, this can lead to more efficient container repositioning, ensuring that containers are readily available at the right time and location for export shipments, minimizing delays and costs for shippers.(Song and Carter, 2009)

Demand driven container forecasting: This solution utilizes historical data, market trends, and demand forecasting models to predict the future demand for empty containers. By accurately forecasting demand, the dryport can proactively manage its container inventory, ensuring the availability of empty containers to meet the anticipated demand and avoiding shortages or excesses (Stahlbock and Voss, 2010).

Container leasing: By partnering with container leasing companies, the dryport can access a diverse fleet of containers without the need for significant upfront investments. Leasing containers provides flexibility and scalability, allowing the dryport to adjust its container inventory based on fluctuating demand. This solution enables the dryport to meet the specific needs of shippers, optimize container availability, and efficiently manage container flows while reducing the financial burden associated with container ownership (Abdelshafie et al., 2022).

Collaborative empty container management system: This solution involves implementing a collaborative system that facilitates communication and cooperation among stakeholders involved in managing empty containers. Through real-time data sharing, joint decision-making, and information exchange, this system optimizes container utilization, minimizes imbalances, and ensures efficient flow between inbound and outbound shipments. It enhances visibility, coordination, and resource allocation, leading to cost savings, streamlined operations, and improved customer service (Abdelshafie et al., 2022).

Container Maintenance

By offering container maintenance services, dryports can help improve the quality and reliability of containers, enhance their lifespan, and ensure compliance with industry standards. This function adds value to the overall logistics operations by ensuring that containers are in proper working order, minimizing the risk of damage or delays during transportation, and supporting the efficient flow of goods.

Container Inspection and Repair Facility: Establish a dedicated facility within the dryport for inspecting and repairing containers. This facility would have specialized equipment, tools, and skilled personnel to assess the condition of containers, perform necessary repairs, and ensure they meet required standards (Kovalyov et al., 2023).

Maintenance and Cleaning Services: Provide regular maintenance and cleaning services for containers to keep them in optimal condition. This could include activities such as washing, sanitizing, and treating containers to prevent corrosion and damage.

Container Tracking and Monitoring System: Implement a tracking and monitoring system that allows for real-time visibility of container maintenance activities. This system can track container maintenance schedules, record maintenance history, and generate alerts for required maintenance tasks (Kavuri et al., 2020).

Spare Parts Inventory Management: Maintain an inventory of spare parts and components commonly used in container maintenance. This ensures quick access to replacement parts when needed, reducing downtime and delays in container maintenance activities (Zhu et al., 2020).

Collaboration with Container Maintenance Service Providers: Collaborate with external container maintenance service providers to enhance the range of maintenance services available at the dryport. This partnership can leverage specialized expertise and resources to ensure comprehensive container maintenance and repair capabilities.

Freight forwarding

The dryport facilitates efficient and reliable transportation logistics by offering comprehensive freight forwarding services. These services encompass the coordination, documentation, and management of shipments, ensuring smooth movement of goods between the dryport and various destinations.

In-house Freight Forwarding Department: Establishing an in-house freight forwarding department within the dryport facility, consisting of experienced professionals who can handle various aspects of transportation logistics, documentation, customs clearance, and coordination of shipments.

Partnership with Freight Forwarding Companies: Collaborating with external freight forwarding companies or agencies to provide comprehensive freight forwarding services to dryport users. This partnership can leverage the expertise and network of established freight forwarders to enhance the logistics capabilities of the dryport.

Digital Freight Forwarding Platform: Developing a digital platform that connects shippers, carriers, and freight forwarders to streamline the freight forwarding process. The platform can automate documentation, track shipments in real-time, facilitate communication, and provide transparency throughout the transportation logistics.

Integrated Supply Chain Management System: Implementing an integrated supply chain management system that encompasses freight forwarding functionalities. This system can automate and optimize various aspects of freight forwarding, including route planning, load consolidation, documentation management, and customs compliance.

While the morphological chart provides a comprehensive set of potential solutions based on existing literature, it is essential to validate these solutions by incorporating practical experiences and insights from industry experts. Real-world scenarios may present unique challenges and opportunities that cannot be fully captured by academic sources alone.

4.3.2. BEST WORST METHOD

In this section, the focus will be on weighing the importance of each function in relation to the overall operation of the dryport. A comprehensive evaluation will be conducted to determine the significance of each function in meeting the objectives and requirements of the dryport. The assessment will consider various factors such as operational efficiency, customer satisfaction and strategic alignment. The evaluation process is done based on the requirements gathered in the Subsection 4.2.4 and expert ranking by using Best-Worst method. This will provide a clear understanding of the critical functions that drive the success of the dryport and those that contribute to its extended capabilities.

(Rezaei, 2015) states that, according to BWM, the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) criteria are identified first by the decision-maker. Pairwise comparisons are then performed between each of these two criteria and the remaining criteria. Next, a maximin problem is formulated and solved to determine the weights assigned to each criterion. Similarly, the weights of the alternatives are obtained using the same process. The final scores of the alternatives are calculated by aggregating the weights from different sets of criteria and alternatives, leading to the selection of the best alternative. In this study, the BWM was applied to evaluate the relative importance of functions within a dryport. The 13 functions were divided into four groups: three groups with three functions each, and one group with four functions. These groups are discussed in detail below.

1. Core operations:
This dimension represents the fundamental operational functions within a dryport. It includes activities such as transshipment, which involves the efficient transfer of goods between different modes of transportation, ensuring smooth cargo flow. Consolidation and deconsolidation processes are also essential, where shipments are combined or divided to optimize space and logistics. Additionally, load center management focuses on effective cargo loading and unloading operations, ensuring efficient handling and timely movement of goods.

2. Value-added services:
This dimension emphasizes the provision of additional services beyond basic operations to enhance customer satisfaction and create competitive advantages. Additional service offerings may include services such as customized packaging, labeling, or product assembly. Light transformation processes may also be offered, involving minor modifications or value-added activities to meet specific customer requirements. Furthermore, buffer strategies can be implemented, providing customers with additional time to store their containers before they are dispatched to their final destinations.

3. Administrative and Support Functions:
This dimension encompasses the essential administrative and support activities required for the smooth functioning of a dryport. It includes functions such as customs clearance, ensuring compliance with customs regulations and facilitating the efficient movement of goods across borders. Information management plays a crucial role, involving effective data collection, storage, and analysis to support decision-making processes. Additionally, environment sustainability practices are becoming increasingly important, focusing on adopting eco-friendly measures, reducing carbon footprint, and promoting sustainable operations.

4. Container Management and Logistics:
This dimension covers the efficient handling and management of containers within the dryport. It includes storage and warehousing functions, ensuring proper storage and inventory management of containers. Effective management of empty containers, including their handling, storage, and maintenance, is crucial for optimizing container availability and minimizing idle time. Freight forwarding services, involving the coor-

dination of transportation and logistics for shipments, are also part of this dimension.

Ranking the functions
To obtain data for the pairwise comparisons and weight assignments, a survey was conducted using a google form. Please refer to the Appendix C for a detailed overview of the survey questions. A total of 16 experts, representing relevant stakeholders in the dryport industry, participated in the survey. The survey was conducted with experts from various areas of expertise and departments, each providing their rating on their knowledge of inland terminals and dryports on a scale of 1 to 5, with 1 being the least and 5 being the highest. The experts represented different companies and educational institutions, and they held various functions and roles related to the logistics and transportation industry. The experts' ratings revealed a considerable level of knowledge and expertise in the field, with most of them scoring between 4 and 5, indicating a high level of familiarity with the subject matter. Their expertise covered a wide range of areas, including dry bulk terminals, sales management, sustainable logistics, logistics and ports, sustainable rail freight transportation, strategy/consultancy and more.

From academic researchers and professors to industry professionals and managers, the experts brought diverse perspectives and experiences to the survey. Detailed information about the experts is given in Appendix C. Their knowledge and insights were crucial for the successful assessment of the functions' importance for the development of the dryports maturity model. The combined expertise and feedback from these experts played a pivotal role in the research, offering a comprehensive and well-rounded understanding of the subject. Their valuable input will significantly contribute to the credibility and reliability of the maturity model developed for dryports.

The experts were provided with the pairwise comparison matrices for each group of functions and were asked to rank the functions based on their perceived importance or preference. Upon collecting the responses from the experts, the pairwise comparison data was compiled and analyzed. The BWM process was then implemented using Excel solver, taking into account the preferences and priorities indicated by the experts. Using the survey data and the BWM approach, weights were assigned to each function within its respective group. This reflected the aggregated expert opinions on the relative importance of the functions. Once the weights for each group were obtained, the results were aggregated to derive an overall assessment of the functions. This aggregation considered the weights from each group to determine the relative importance of each function across the entire set of 13 functions. Each participant's individual responses in the pairwise comparisons and weight assignments were used to calculate their respective weighted scores for each function. These weighted scores reflect the participant's preferences and priorities. Mean is calculated to obtain the average score for each function across all participants. Alongside the calculation of the mean for the weighted scores, an additional step was taken to enhance understanding and clarity by scaling the mean values to a ranking of 1 to 5. To achieve this, the calculated mean values for each function were rescaled proportionally within the range of 1 to 5. This rescaling ensured that the relative importance of the functions could be easily interpreted on a standardized scale, where 1 represents the lowest importance and 5 represents the highest importance.

To further understand the spread or dispersion of the data, the standard deviation was calculated. This measure quantifies the variability or deviation from the mean and provides insights into the consensus or divergence among the expert opinions. The coefficient of variation, which is the ratio of the standard deviation to the mean, was also computed. This measure allows for the comparison of relative variability across different groups or functions, accounting for differences in their mean values. Results can be seen in the Table 4.3. By considering these statistical measures, including the mean, standard deviation, and coefficient of variation, a more comprehensive analysis of the expert responses and their consistency or variability was conducted. These measures provide valuable insights into the level of agreement or disagreement among the experts regarding the relative importance of the functions within the dryport. The weights for core operations, value-added services, administrative and support functions and container management and logistics are determined to be 0.41, .11, 0.18 and 0.28 respectively.

Table 4.3: Importance of functions (N=16)

Functions	Mean	Rank	Standard deviation	Coefficient of variation
Transshipment	0.21	5.00	0.14	0.64
Consolidation/Deconsolidation	0.12	2.89	0.09	0.73
Empty container management	0.09	2.19	0.09	1.00
Load center	0.08	2.00	0.03	0.43
Storage and warehousing	0.07	1.77	0.06	0.82
Customs clearance	0.06	1.68	0.08	1.31
Freight forwarding	0.06	1.66	0.06	0.88
Environment sustainability	0.04	1.26	0.06	1.28
Additional service offerings	0.04	1.20	0.03	0.66
Buffer function	0.04	1.19	0.03	0.83
Information management	0.04	1.05	0.02	0.69
Container maintenance	0.03	1.02	0.03	0.83
Light transformation	0.03	1.00	0.04	1.10

Insights from the results

1. Transshipment function has the highest mean score of 0.21, indicating its perceived importance in the dryport.
2. Container maintenance and Light transformation functions have the lowest mean scores of 0.03, suggesting relatively lower importance compared to other functions.
3. Coefficient of variation of customs clearance, environment sustainability, light transformation and empty container management are equal to or greater than 1 indicating significant variation in responses and diverse opinions.
4. Load center, information management, Transshipment and additional service offerings have the lower values for coefficient of variation with 0.43, 0.69, 0.64 and 0.66 respectively suggesting a higher level of agreement among participants.

4.4. Conclusion

In this chapter, valuable perspectives have been gained through insightful interviews with stakeholders from diverse backgrounds. These perspectives have laid the groundwork for crafting a comprehensive morphological chart, mapping the identified functions from the previous chapter alongside potential solutions. This visual tool empowered a holistic view of the intricate web of intermodal operations within a dryport.

To further enhance the decision-making process, the Best-Worst method emerged as a powerful ranking mechanism. By leveraging the input garnered from stakeholders, the relative importance of each function has been ascertained, subsequently guiding the development of the maturity model in the forthcoming chapter.

Through this iterative and systematic approach, deeper insights have been obtained into the multifaceted development steps involved in transforming an intermodal terminal into a flourishing dryport. The convergence of stakeholder perspectives, the ingenuity of the morphological chart, and the data-driven rankings pave the way for the creation of a robust and tailored maturity model, promising to revolutionize the landscape of dryports and intermodal freight transport.

5

Maturity Model

The primary objective of this chapter is to answer sub research question 3 by developing, verifying and validating a maturity model for dryports, leveraging the functions identified in the previous chapter's morphological chart. These functions were generated through a rigorous analysis of dryport requirements and considerations, taking into account various operational aspects and stakeholder perspectives. Building upon this foundation, the Best Worst Method (BWM), a well-established decision-making technique, was employed to rank and prioritize these functions based on their relative importance.

By utilizing the BWM, the functions are assigned weighted scores that reflect their significance within the context of dryport operations. These scores serve as the foundation for the placement of functions within the maturity model, categorizing them into different levels that represent increasing levels of maturity. The resulting maturity model provides a structured framework for assessing and benchmarking the maturity levels of various functions and processes within the dryport environment.

The operationalization of the maturity model ensures its practical applicability in decision-making processes. By integrating the maturity model into strategic planning and decision frameworks, dryport managers and stakeholders can effectively utilize it as a decision support tool. The maturity model becomes an integral part of the decision-making process, providing valuable insights into the current state of dryport operations, identifying areas for improvement, and guiding resource allocation and performance management efforts.

This chapter begins by providing an understanding of the concept of maturity models and their relevance in the context of dryports. Following that, the chapter focuses on the development of a maturity model specifically tailored for dryports. The constructed maturity model is then presented, incorporating dimensions, levels of maturity, and mapping of functions. The chapter concludes by discussing the evaluation of the maturity model through interviews conducted with terminal operators to assess its applicability and effectiveness.

5.1. Concept Design

5.1.1. Definition of maturity and maturity model

In an organizational context, the term 'maturity' can be regarded "as the degree to which a process is defined, managed, measured, and continuously improved". Whereas, the Oxford English Dictionary identifies 'maturity' as "The state of being mature; fullness or perfection of development or growth". When applied to information systems, maturity is often assessed through capabilities, which represent the overall strength or capacity, both physical and mental, to perform tasks and accomplish goals (Simpson et al., 1989).

A standardized definition of a maturity model is "A maturity model depicts an entity's evolution across time. This entity could be a person, an organizational function, or something else entirely" (Wibowo and Waluyo, 2015).

5.1.2. Relevance of maturity models in the context of dryports

Maturity models are highly relevant in the context of dryports as they provide a structured framework for assessing and improving performance. In an ever-evolving industry, dryports face complex challenges related to logistics, operations, and stakeholder management. Maturity models offer a systematic approach to

evaluate the maturity levels of various functions and processes within a dryport, enabling a comprehensive understanding of strengths, weaknesses, and improvement areas.

By using maturity models, dryports can establish a benchmark for their current state and set realistic goals for future development. These models help identify gaps in capabilities and provide a roadmap for enhancing operational efficiency, streamlining processes, and optimizing resource utilization. Moreover, maturity models encourage knowledge sharing and collaboration among stakeholders, fostering a culture of continuous improvement and innovation.

The application of maturity models in the context of dryports enables decision-makers to make informed choices, prioritize initiatives and allocate resources effectively. It also facilitates benchmarking against industry standards and best practices, leading to enhanced competitiveness and sustainability. Ultimately, the utilization of maturity models empowers dryports to adapt to changing market dynamics, address emerging trends, and achieve their strategic objectives in a structured and systematic manner.

5.1.3. Challenges of developing maturity models for dryports

Developing a maturity model for dryports entails various challenges that need to be addressed. Firstly, understanding the complexities of dryports and their interconnected functions is crucial to ensure the model's accuracy and effectiveness. Defining the scope and boundaries of the model is essential for focusing the evaluation.

Moreover, aligning the maturity model with the strategic goals of the specific dryports being studied is vital to ensure its practical relevance and usefulness in decision-making processes. Engaging stakeholders, such as dryport operators, logistics providers, and government agencies, is essential for validating the model and ensuring its applicability in real-world scenarios. Additionally, the maturity model needs to be adaptable and flexible to accommodate technological advancements, changing regulations and market dynamics. These challenges require careful consideration and thoughtful approaches to overcome them and develop a robust and effective maturity model for dryports.

5.2. Development of maturity model

In the development of the maturity model for dryports, it is essential to begin by defining different maturity levels. Later, the dimensions that will serve as the basis for assessing the maturity of various aspects of dryport operations will be established along with the functions present in different maturity levels within each dimension. This is followed by constructing the maturity model framework. However, prior to initiating any of these steps, it is imperative to reevaluate and rearrange the functions according to their BWM rankings across distinct dimensions. This preliminary process is crucial for establishing a coherent overview.

5.2.1. Reordering BWM ranked functions

In this subsection, the focus shifts to the pivotal process of realigning the ranked functions from the Best-Worst Method analysis, under different dimensions. core operations, value-added services, administrative and support functions, and container management and logistics. These are already defined in the Subsection 4.3.2 as groups. This reordering effort is undertaken to establish a more systematic arrangement, which ultimately facilitates the seamless integration of these functions into the development of the maturity model. This reordering of functions is depicted in the Figure 5.1.

Functions	Mean	Rank	Standard Deviation	Coefficient of variation
Transshipment	0.21	5.00	0.14	0.64
Consolidation/Deconsolidation	0.12	2.89	0.09	0.73
Empty container management	0.09	2.19	0.09	1.00
Load center	0.08	2.00	0.03	0.43
Storage and warehousing	0.07	1.77	0.06	0.82
Customs clearance	0.06	1.68	0.08	1.31
Freight forwarding	0.06	1.66	0.06	0.88
Environment sustainability	0.04	1.26	0.06	1.28
Additional service offerings	0.04	1.20	0.03	0.66
Buffer function	0.04	1.19	0.03	0.83
Information management	0.04	1.05	0.02	0.69
Container maintenance	0.03	1.02	0.03	0.83
Light transformation	0.03	1.00	0.04	1.10

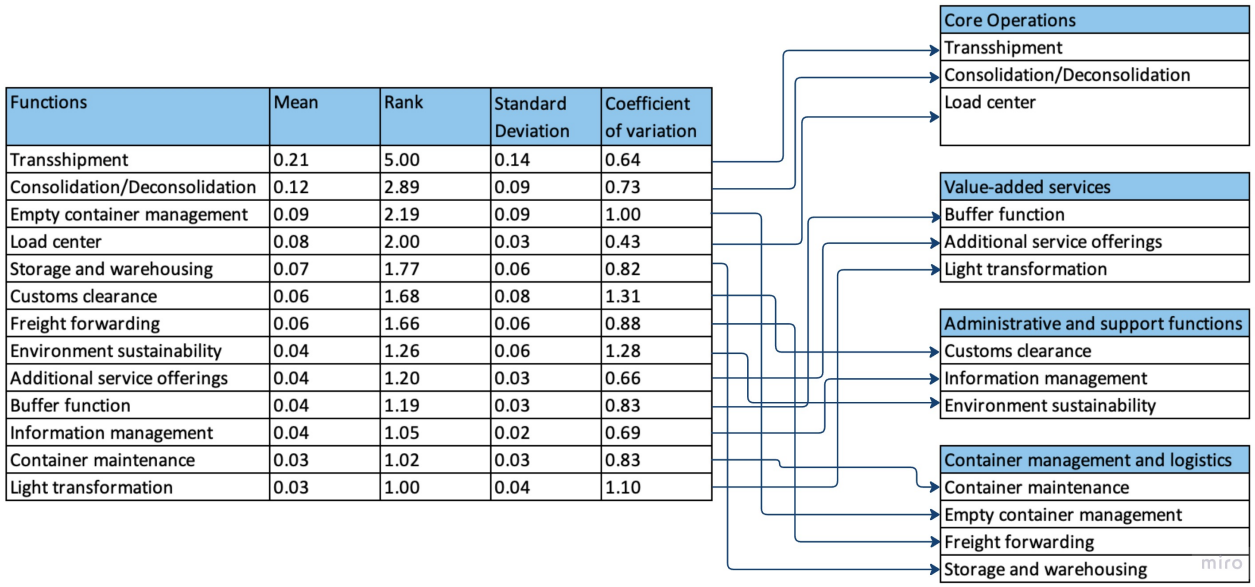

Figure 5.1: Reordering functions

Transshipment, identified as the most important function with a rank of 5 according to the Best-Worst Method ranking, is positioned in the first place. Consolidation/deconsolidation, ranked as the second highest important functionn with a rank of 2.89, is placed in the second place. Lastly, the load center function is placed in the third position under core operations.

Under the dimension of Value-added services, buffer function is placed in the first position even though additional service offerings have a higher ranking of 1.20 compared to that of buffer function which is 1.19. The reason for that is buffer function have coefficient of variation of 0.83 which indicates that responses were diverse and also the feasibility and ease of implementation of it. Additional service offering is placed second which is followed by light transformation which has the lowest ranking among all functions.

Administrative and service functions starts with customs clearance services as it ranked the highest of 1.68 in this dimension. Even though it has the highest coefficient of variation of 1.31, this is considered to be the most important function according to the Chapter 3. Information management is placed in the second position even though environmental sustainability ranked highest with 1.26 while information management has 1.05. One of the reasons is the high coefficient of variation of 1.28 which indicates that responses are not reliable and the other reason is that information management is regarded to be one of the critical functions as per Chapter 3, Subsection 4.2.4.

In the last dimension of container management and logistics, container maintenance is placed, despite having the lowest ranking of 1.02 among all the functions in this dimension. This function is relatively easier to realize compared to other functions, requiring less investment and infrastructure. Empty container management takes precedence even though it is the highest-ranked function in this dimension with a ranking of 2.19. This function is considered challenging to implement, as it requires significant space, optimization, and operational practices. Freight forwarding is positioned next, as it has the second lowest ranking of 1.66. In the last position, storage and warehousing function is positioned. It is placed in this stage due to the need for additional land and investments to establish warehouses. Considering the coefficient of variation, these four functions exhibit different levels of variability in the rankings. Container maintenance, freight forwarding, empty container management and storage and warehousing have a COV of 0.83, 0.88, 1 and 0.82 respectively suggesting greater variability in the importance assigned to these functions. Therefore, the placement of these functions is determined based on practical considerations derived from the interviews conducted Subsection 1.6.3, rather than solely relying on their rankings.

5.2.2. Different Maturity levels

The maturity model for dryports sets out five levels of maturity to facilitate administrations in assessing their current level of development and charting a pathway to higher levels. The decision to choose five levels is driven by the need to provide clear distinctions that aid in determining maturity, while ensuring the differences between levels are not too extreme. This approach facilitates a better understanding of the progression towards higher levels of maturity. The maturity model for dryports is designed with a progressive approach, comprising distinct levels that represent the evolution of inland terminals towards becoming fully functional dryports. The chosen levels aim to provide clear distinctions and aid administrations in assessing their current level of maturity while visualizing the pathway for further growth.

The model adopts the "Established" level as the anchor, representing the average maturity level. This level serves as a reference point for administrations to gauge their own maturity and progress. From this anchor level, the descriptions for the other maturity levels were developed, detailing the pathway from the "foundational" level to the "Established" level, and envisioning further possibilities for the future. They are listed as below:

1. Foundational: The focus of this level is on the development of inland terminals. These terminals are in the early stages of establishing their functions and infrastructure. While they may have some basic capabilities, they still have significant progress to make before being classified as dryports. This level represents the initial steps towards becoming a fully functional dryport.

2. Developing: This level marks the transition phase for inland terminals on their journey towards becoming dryports. At this stage, significant reforms and improvements are undertaken to enhance the terminal's functions and operations. This includes the implementation of advanced technology, optimization of logistics processes, and the establishment of stronger connections to transportation networks.

3. Established: This level designates the point at which inland terminals can be officially referred to as dryports. These dryports have achieved a high level of maturity in their functions, services, and connectivity. They exhibit efficient handling and transshipment capabilities, streamlined customs procedures, and strong integration with the regional and international logistics networks.

4. Advancing: This level represents dryports that have excelled in terms of their functions, services and overall performance. They go beyond the established standards and set new benchmarks for excellence in the industry. Advanced dryports leverage advanced technologies, implement innovative logistics solutions, and provide a wide range of value-added services to their customers. They play a crucial role in driving regional economic growth and serving as strategic trade hubs.

5. Leading: It represents the future vision for dryports. This level envisions highly advanced and integrated dryports that are at the forefront of global logistics and supply chain management. These leading dryports prioritize sustainability, utilize advanced technologies like IoT and AI, and provide seamless connectivity and services to facilitate efficient cargo movement and trade operations. They serve as models for the industry, continually striving for improvement and setting new standards.

5.2.3. Maturity model dimensions

Dimensions represent the key areas or domains that contribute to the overall maturity of a dryport. These are already defined in the Subsection 4.3.2 as groups. The order of the functions under different dimensions is already discussed in the Subsection 5.2.1. The maturity levels in which different functions are placed is discussed below.

1. Core operations:

In the context of core operations, the functions of transshipment, consolidation/deconsolidation, and load center play significant roles in the maturity levels of dryports. This dimension's weight of 0.41 in the BWM framework influences the initiation of function placement from the first level.

Transshipment is positioned in the foundational maturity level. This signifies that while transshipment is already in progress, there is ample room for further development and enhancement in terms of operational capabilities.

Consolidation/deconsolidation is placed in the developing maturity level. This indicates that inland terminals have made notable advancements and reforms in this area, working towards achieving the average level of advanced dryports. Efforts are focused on optimizing consolidation and deconsolidation processes to facilitate efficient cargo handling and streamlined logistics operations.

Lastly, the load center function is positioned in the established maturity level. This implies that dryports have achieved a high level of maturity in core operations, showcasing well-developed and optimized processes. Load centers within dryports have demonstrated efficiency, effectiveness and seamless coordination among different stakeholders, contributing to the overall growth and performance of the dryport.

In the higher levels of maturity, namely the advancing and leading levels, the focus shifts from core operations to other dimensions of dryports. It is important to note that the absence of specific core operations functions in these levels does not diminish their importance. Rather, it suggests that dryport development at these advanced stages transcends individual functions within core operations and expands into broader dimensions that contribute to the overall excellence, sustainability, and future potential of the dryport ecosystem.

2. Value-added services:
In the context of value-added services within the dryport framework, different functions like buffer, additional service offerings and light transformation occupy various maturity levels. The first two levels, namely foundational and developing, do not explicitly include functions in this dimension, indicating that value-added services are still in their early stages of development and require further progress. Moreover, with a BWM weightage of 0.11, this dimension holds the least influence.

In the established maturity level, buffer function is offered. The buffer function of dryports demonstrates its ability to accommodate customer requirements and provide tailored solutions.

Moving to the advancing level, additional service offerings come into focus. Dryports at the leading level excel in providing a diverse range of services beyond storage, which may include packaging, labeling, quality control, or other customized services to enhance the customer experience and meet specific requirements.

Finally, in the leading level, light transformation is placed. Although ranked with the lowest importance among the functions, light transformation represents a forward-thinking vision for dryports. This function envisions the dryport evolving into a hub for value-creation activities such as assembly, customization, or light manufacturing processes. While currently considered less important, light transformation signifies the potential for dryports to expand their scope of services and become comprehensive value-adding centers.

3. Administrative and Support Functions:
In the context of administrative and support functions within the dryport framework, customs clearance, environmental sustainability and information management are positioned in various maturity levels. The first level, foundational, does not include specific functions in this dimension, indicating that administrative and support functions are still in their initial stages of development. This dimension has a weight of 0.18.

In the developing maturity level, customs clearance services are offered. This function signifies the advancement of inland terminals in providing efficient and streamlined customs processes for cargo clearance. Customs clearance is considered a fundamental function for an inland terminal, and it is essential to incorporate this service to facilitate seamless trade operations. They have the flexibility to either handle customs clearance internally or establish partnerships with third-party service providers. This allows them

to meet customer expectations and align with the practices at seaports.

Moving to the established level, information management takes precedence. It shows the significance of efficient data handling, information exchange and digitalization in running dryport operations smoothly. Information management ensures the seamless flow of data, effective coordination among stakeholders, and enables real-time tracking and monitoring of cargo movements.

In the advancing level, environmental sustainability is emphasized. It reflects the growing importance of incorporating sustainable practices in every aspect of business operations, including dryports. Environmental sustainability encompasses various initiatives such as reducing energy consumption, minimizing waste generation and implementing eco-friendly policies. Dryports at the advancing level prioritize sustainability to comply with government regulations, meet customer expectations and contribute to a greener and more responsible supply chain.

While the leading level does not specify particular functions within the administrative and support dimension, it emphasizes the intrinsic and integrated nature of these functions within the long-term vision for dryports. The absence of explicit functions in this level underscores the understanding that administrative and support functions are fundamental and foundational elements that form the backbone of the dryport ecosystem.

4. Container Management and Logistics:
In the context of container management and logistics functions within the dryport framework, the functions are distributed across different maturity levels based on their rankings and implementation complexities. In the first level of emergence, there is no development observed in the container management and logistics dimension as it has a weight of 0.28 which is less than that of core operations. This suggests that container management and logistics are yet to be established or implemented at this early stage of dryport development.

In the developing maturity level, container maintenance is placed. Container maintenance focuses on ensuring the optimal condition and functionality of containers, contributing to the overall efficiency and reliability of cargo transportation.

Moving to the established level, empty container management takes precedence. Empty container management involves the efficient handling, storage, and positioning of empty containers, ensuring their availability and timely distribution for future use.

In the advancing level, freight forwarding is positioned. Freight forwarding involves the coordination and management of the transportation of goods, and its placement acknowledges its importance in the dryport's logistics operations.

In the leading level, storage and warehousing function is positioned. Storage and warehousing play a critical role in dryports by providing secure storage facilities for goods and supporting efficient inventory management.

The developed maturity model framework can be seen in the Figure 5.2.

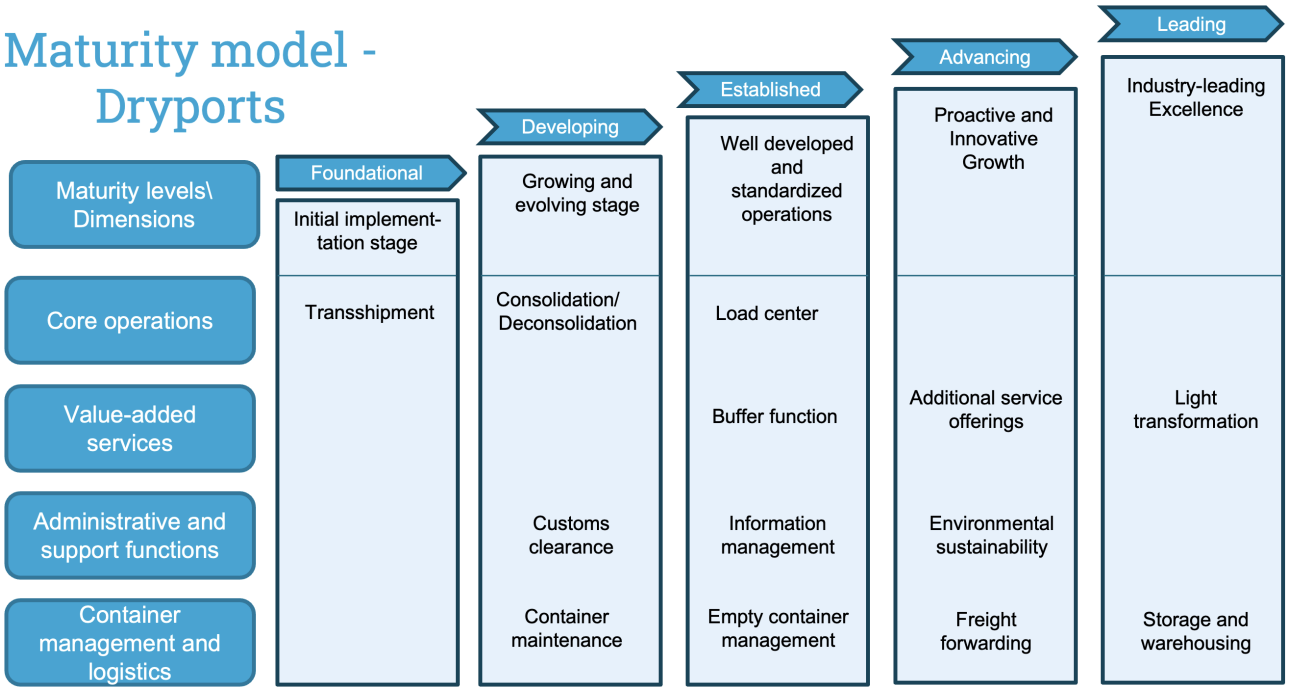

Figure 5.2: Maturity model of dryports

5.3. VERIFICATION OF THE MODEL

The verification of the maturity model is a critical step in assessing its accuracy and reliability in capturing the progression and characteristics of dryport development. To verify the maturity model, an important step involved soliciting the expertise and insights of industry professionals and experts in the field of dryports. To achieve this, a google form survey was created and distributed to a targeted group of respondents.

The survey questions were carefully designed based on (Salah et al., 2014), ensuring alignment with established frameworks and concepts in the field. The questions aimed to gather feedback and opinions on the different dimensions and maturity levels proposed in the model. The survey questions encompassed various aspects of the maturity model, including its taxonomy, description, and practical implications. In the survey form, experts were provided with a five-point Likert scale to evaluate the maturity model. The evaluation statements pertained to the sufficiency, comprehensiveness, accuracy, and practical relevance of the model. The survey included experts from varied domains: an academic adept in dry port location and GIS at Adani University, a Sales Manager from BCTN, an inland terminal organization, a Programme Manager at the Port of Rotterdam, specializing in ports and container logistics, and the Branch Manager of Container Terminal Doesburg B.V., offering supply chain management insights. Their collective expertise ensures a comprehensive evaluation of the maturity model for dryports. The average scores for all the questions can be seen in the Table 5.1.

Table 5.1: Verification of the maturity model (N=4)

	Average score
Maturity model taxonomy	
The maturity levels are sufficient to represent, all maturation stages of the domain (Sufficiency)	3.75
The maturity model domains are sufficient to represent all relevant domains for dryports (Sufficiency)	3.75
There is no overlap detected between descriptions of maturity levels (Accuracy)	3.25
Maturity model descriptions	
The provided descriptions for each maturity level are: Relevant to the domain (Relevance)	3.25
The provided descriptions for each maturity level are: Cover all aspects involved in the domain (Comprehensiveness)	3.25
The provided descriptions for each maturity level are: Are clearly distinct (Mutual exclusion)	4
The provided descriptions for each maturity levels are: Assigned to the correct maturity level (Accuracy)	3.25
Understandability and ease of use	
The maturity levels and domains are understandable	4.25
The self-assessment system is easy to use (Checking which functions a dryport/inland terminal perform)	4

The assessment criteria in the provided table offer insights into the effectiveness and comprehensiveness of the developed maturity model for dryports. Each aspect is evaluated on a scale, with the corresponding scores indicating the model's performance in those dimensions.

Regarding the maturity model taxonomy, both sufficiency aspects scored 3.75, indicating that the maturity levels and domains adequately cover the various stages and relevant domains within the dryport context. However, the accuracy dimension scored 3.25, suggesting the need for further refinement to ensure the precise alignment of descriptions with their intended maturity levels, preventing any potential overlap.

In terms of maturity model descriptions, relevance, comprehensiveness and accuracy each scored 3.25, implying that while the descriptions are generally aligned with the domain, there is an opportunity to enhance their comprehensiveness and accuracy. On a positive note, the mutual exclusion aspect scored a perfect 4, indicating that the descriptions are distinctly separate, which is essential for clearly delineating the stages of maturity.

Finally, for understandability and ease of use, both dimensions scored favorably. The maturity levels and domains received a score of 4.25, indicating that they are easily understood by users. Similarly, the self-assessment system's ease of use, rated at 4, reflects its user-friendly nature for assessing which functions a dryport or inland terminal performs.

The feedback by experts highlights concerns regarding potential overlaps among maturity levels in the context of dryports. The reviewer emphasizes the significance of how terminal actions are executed in determining maturity. They also point out the challenge of predicting maturity solely based on stated value-added contributions and suggest a potential misalignment in the sequence of maturity levels. The feedback envisions scenarios where terminal evaluation by customers might differ from a top-down assessment, leading the reviewer to assign a relatively lower rating due to these factors.

In conclusion, while the maturity model demonstrates strengths in representing different maturation stages and domains, there are opportunities for enhancement in terms of accuracy and comprehensiveness of descriptions. These insights provide a basis for further refining and optimizing the maturity model for enhanced usability and effectiveness in guiding dryport development. One limitation of the survey is the small sample size, with only four responses obtained. While these responses provide some insights into the evaluation of the maturity model, a larger sample size would have been preferable to enhance the reliability and generalizability of the findings. With a larger number of responses, a more comprehensive and representative assessment could have been conducted, capturing a broader range of perspectives from experts in the field.

5.4. Enhancements and adjustments to the model

Following the model verification and incorporating feedback, several refinements were introduced to enhance its effectiveness. The explanations clarifying the rationale behind function placements within specific maturity levels were improved. A minor adjustment involved relocating certain functions to their appropriate levels for improved coherence. Environmental sustainability and information functions have been swapped. In addition to that, empty container management and freight forwarding functions have also been swapped as a well established dryport should have empty container management as one of their functions. Particularly, the "Postponement" function was reformulated as the "Buffer" solution to provide a clearer and less ambiguous representation. These modifications contribute to the model's overall clarity and precision. Additionally, labels assigned to the maturity levels were revised to accurately reflect their intended significance. This alteration was implemented to ensure that each level's designation effectively communicates its specific meaning and purpose within the model.

5.5. Validation of the Model

In order to validate the practicality and effectiveness of the developed maturity model in aiding the development of dryports, two case studies were conducted with a focus on BCTN and CTU. These case studies served as valuable real-world examples, allowing for an in-depth exploration of the applicability of the maturity model in the specific context of these dryport projects. The objective of the validation process was to assess how well the maturity model could guide the transformation of an inland terminal and gather valuable insights from stakeholders involved in the development process. This validation process involved the utilization of semi-structured interviews. These interviews provided a flexible framework for gathering insights and feedback from stakeholders involved in the development of inland terminals into dryports. The interviews served as a valuable method for collecting qualitative data, capturing stakeholders' perceptions, challenges, and recommendations related to the application and practicality of the maturity model in the context of dryport development.

5.5.1. Use Case 1

The first use case in this study involves a collaboration with BCTN, a prominent company in the field of inland container terminals and logistics services which is clearly described in the item 4.2.1. Building upon the insights and expertise of BCTN, this use case aims to examine the application and validation of the developed maturity model within the specific context of BCTN's operations. Based on the insights shared during the discussion with the Regional Sales Manager at BCTN, the functions within the developed maturity model have been visually highlighted using different colors to denote their current status and future plans which can be seen in the Figure 5.3. This color-coded approach provides a clear distinction between the functions that BCTN currently performs, those they plan to expand in the future, and the functions they do not intend to implement in the foreseeable future.

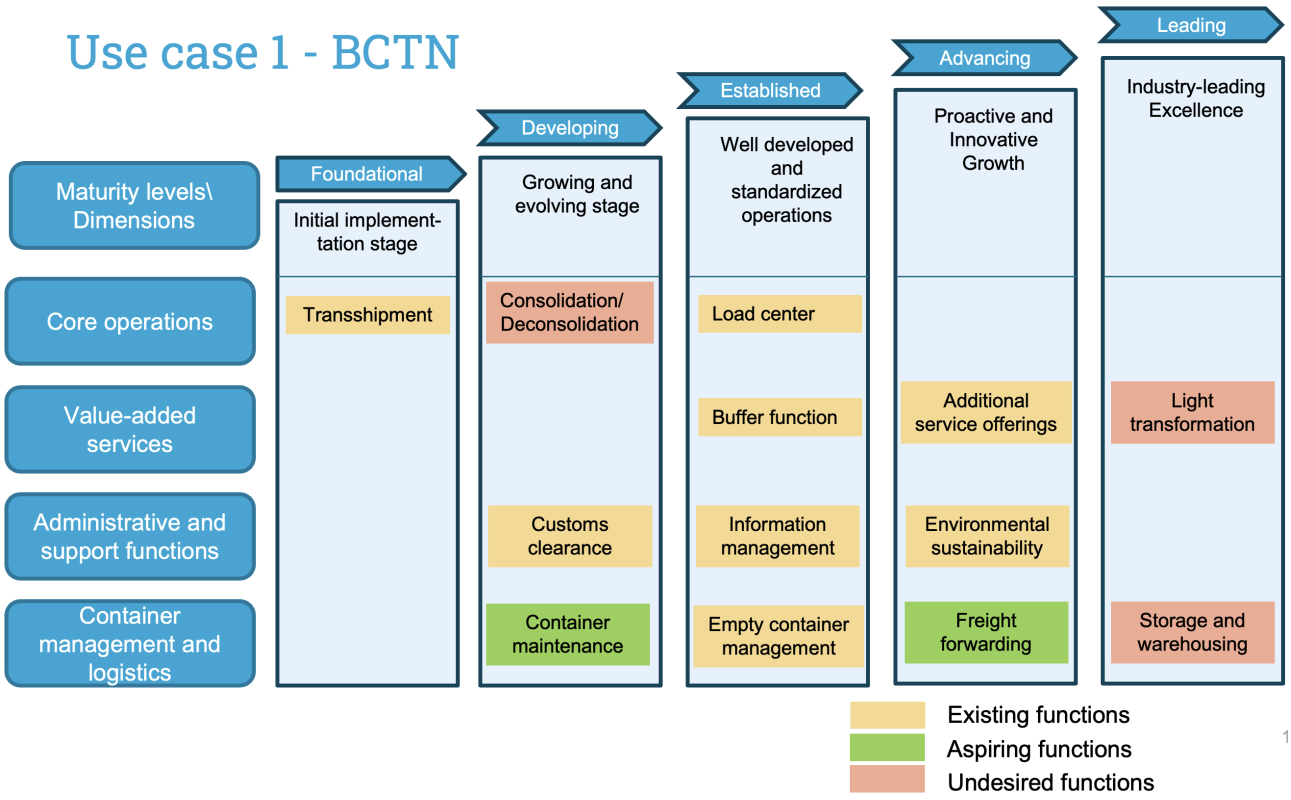

Figure 5.3: Validated by BCTN

Existing functions:

Functions that are currently performed by BCTN are highlighted in yellow, representing their existing capabilities and operational focus. These functions are already part of BCTN's operations and contribute to

their current service offerings. Transshipment stands as a crucial function within BCTN, given its role in facilitating the seamless transfer of containers between different modes of transport, such as barge and truck. BCTN also operates a load center, ensuring efficient loading and unloading operations, and offers customs clearance services to expedite the movement of goods across borders. Notably, BCTN incorporates buffer services to meet client requirements by providing buffer time for container storage.

Environmental sustainability is a key focus area for BCTN, evident through their adoption of hybrid, electric, and hydrogen-powered vessels, as well as investments in eco-friendly trucks and electric terminal trackers. Furthermore, BCTN has made notable strides in renewable energy by establishing windmills and solar panels. In terms of additional service offerings, BCTN provides diverse options such as labeling, fumigation, reefer container management and container cleaning.

Effective information management is a cornerstone of BCTN's operations, facilitated by their Terminal Operating System (TOS) software. The TOS enables container booking, tracking, and monitoring through an interactive map, enhancing transparency and providing real-time updates. BCTN ensures seamless coordination across its terminals by integrating them into a centralized system, enabling activities such as scheduling and barging to be efficiently managed.

Lastly, BCTN places great emphasis on providing a ready supply of empty containers to customers. By optimizing the use of empty containers within their terminal, BCTN contributes to supply chain efficiency and responsiveness. This proactive approach ensures that customers have access to empty containers whenever needed, enhancing overall logistics operations.

Aspired functions:
Functions that BCTN plans to expand in the future are highlighted in green, indicating their intention to invest resources and efforts in enhancing these areas. These functions represent the growth and development plans of BCTN, as they aim to expand their capabilities and meet evolving customer demands. At present, BCTN primarily focuses on container cleaning services, relying on the Port of Rotterdam for container repairs. Looking ahead, BCTN envisions expanding its operations and broadening its service offerings. One significant future plan involves taking on container maintenance in-house, allowing them to handle repairs and maintenance tasks independently, thus reducing reliance on external facilities. This strategic shift aims to enhance operational efficiency and provide a more comprehensive service to customers.

Currently, BCTN efficiently moves containers between the terminal and customer warehouses based on the customer requirements. However, BCTN does not handle bookings directly, operating as a service provider rather than a freight forwarder. Additionally, BCTN plans to venture into the domain of freight forwarding. By extending their scope to include freight forwarding services, BCTN aims to offer end-to-end logistics solutions, effectively managing the entire supply chain for their customers. This expansion into freight forwarding signifies BCTN's commitment to meeting evolving market demands and providing a seamless and integrated logistics experience.

Undesired functions:
Functions highlighted in salmon color signify that BCTN does not intend to implement them across their operations in the future. BCTN's operational strategy centers around full container loads, catering to a strong and consistent demand in this area. Given their focus on efficient container transport, BCTN does not foresee the need to consolidate shipments in the future. Consolidation/Deconsolidation function, which involves combining or separating shipments to optimize space and logistics, is not considered attractive to BCTN's business model.

Similarly, BCTN has decided against implementing the light transformation function in their operations. They recognize that light transformation, which involves altering or modifying goods within the supply chain, can introduce complexities that may hinder their primary objective of seamless container transport. BCTN prefers to maintain a streamlined and straightforward approach to their supply chain operations.

Furthermore, BCTN does not envision incorporating a storage and warehousing function within their op-

erations. Their primary focus remains on the efficient and reliable transportation of containers rather than long-term storage solutions. By concentrating their efforts on container transport, BCTN can maximize their operational efficiency and better meet the demands of their target market.

The determination of the maturity level of BCTN poses a challenge due to the presence of functions across different levels. While BCTN lacks certain functions typically associated with the second, fourth and fifth levels, it possesses all the functions attributed to the third level. The absence of consolidation/deconsolidation is understandable for larger terminal operators like BCTN, which primarily handle full container loads rather than smaller shipments.

The maturity level of BCTN may be best characterized as a combination of functions from different levels, reflecting its unique operational focus and specialization. It demonstrates a higher degree of maturity in areas such as transshipment, customs clearance, environmental sustainability, information management, and storage and warehousing. However, the absence of certain functions at lower maturity levels suggests that BCTN has chosen to prioritize and excel in specific areas that align with its operational strategies and customer demands.

It is important to recognize that maturity levels in the dryport context are not solely determined by the presence or absence of specific functions, but rather the overall alignment of functions with the strategic goals and operational capabilities of the terminal operator. BCTN's focus on specific functions and its success in those areas may indicate a strategic positioning within the dryport ecosystem, catering to specific market segments and fulfilling specific customer needs.

5.5.2. USE CASE 2

The second use case in this study entails a collaborative partnership with CTU, a renowned inland container terminal located in the Netherlands. Located in the heart of the Netherlands, CTU serves as a vital intermodal hub connecting the inland region with seaports and global trade networks. CTU operates as a comprehensive container terminal, offering a range of services to facilitate efficient and seamless logistics operations. With a strategic location and well-established infrastructure, CTU serves as a pivotal point for the transshipment of containers between various modes of transportation, including road and barge. This multimodal connectivity enhances supply chain efficiency and enables businesses in the region to access international markets.

Through an in-depth conversation with the Commercial Manager at CTU, valuable insights were gathered regarding the delineation of functions within the developed maturity model. Similar to the previous case study, clear and distinct color coding was employed to illustrate the categorization of functions into three distinct categories: existing functions, aspired functions, and undesirable functions. This comprehensive approach allowed for a visual representation of the desired direction for CTU's operations and facilitated a comprehensive understanding of their strategic goals and aspirations which can be observed in the Figure 5.4.

Existing functions:

The functions currently in operation at CTU are highlighted in yellow, representing their existing capabilities within the developed maturity model. Among these functions, transshipment emerges as a pivotal aspect of CTU's operations, as the terminal serves as an intermodal hub with convenient barge and road access. Additionally, CTU offers customs clearance services, although they rely on third-party expertise to facilitate this function. The terminal also provides buffer services, allowing customers to store their containers for extended periods, thereby accommodating their specific needs.

CTU demonstrates a strong commitment to environmental sustainability by incorporating all-electric machinery and promoting the use of barges for transportation. These initiatives help reduce congestion and emissions, contributing to a more eco-friendly logistics ecosystem. Furthermore, it is looking to invest in silent and emission free hydrogen terminal tracker. The effective management of information is another

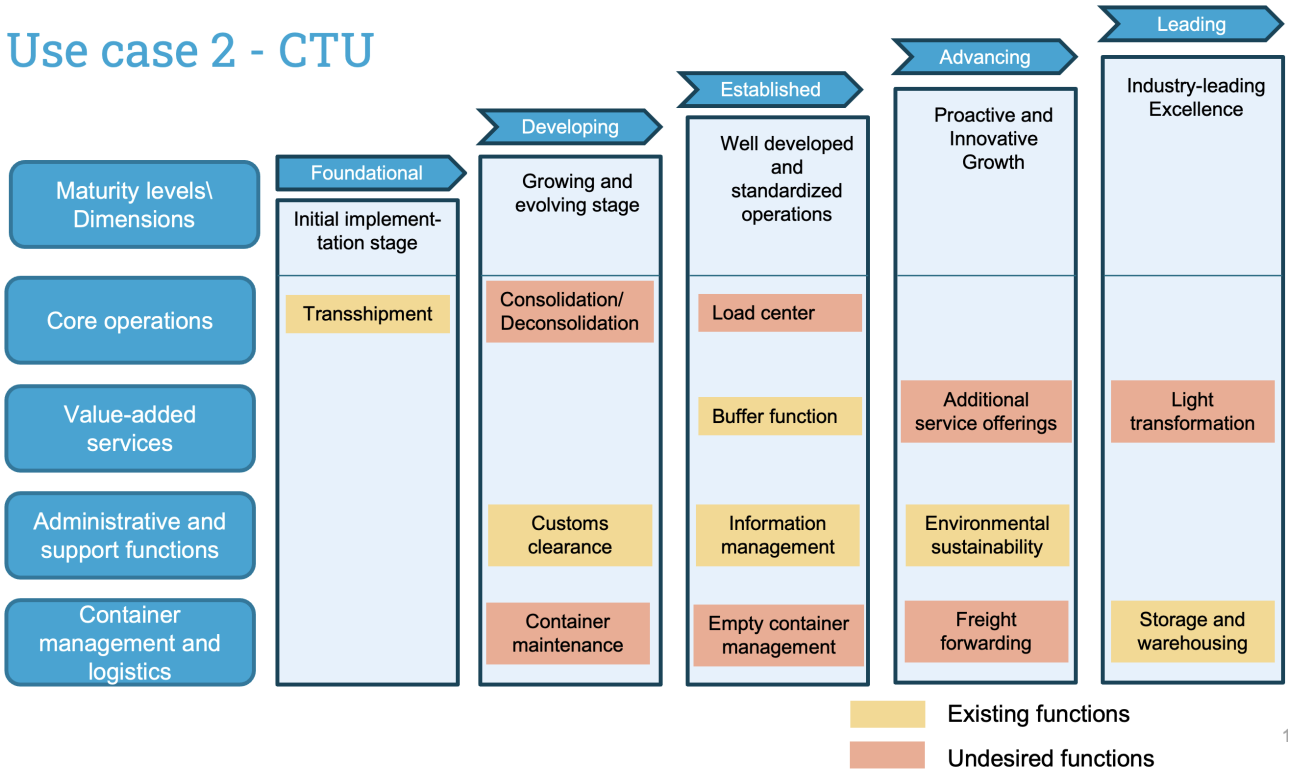

Figure 5.4: Validated by CTU

area of focus for CTU, employing advanced systems like Portbase to efficiently handle bookings, deliveries, estimated time of arrivals (ETAs), and customer-related information. Furthermore, CTU utilizes text messaging services to keep customers informed about their bookings.

While CTU does offer storage and warehousing functions, it is important to note that their warehouse capacity is relatively small, with an area of 4500m2. Consequently, storage and warehousing do not serve as their primary functions, but rather complement their broader service offerings.

Undesired functions:
CTU's strategic focus primarily revolves around the transportation of containers, rendering the remaining functions as undesired within their operational framework. The terminal's primary objective is to garner higher volumes and sustain their current operations without substantial diversification. CTU's expansion plans hinge upon the demands and preferences of their customers; if customers do not express a need for additional services, expansion is unlikely to occur. Given that their main clientele consists of freight forwarders, CTU deliberately refrains from offering freight forwarding services to avoid competing with their own customers.

CTU's scope of additional service offerings remains limited, encompassing functions such as container cleaning and weighing. However, the provision of these services is contingent upon customer requests, as CTU does not proactively engage in such activities. Furthermore, the terminal does not consistently offer empty containers to customers, as customers typically establish direct contracts with ocean carriers for this purpose. The expansion of services to encompass light transformation is also not within CTU's strategic trajectory, as their involvement primarily entails the transfer of goods from larger containers to smaller ones in select scenarios.

Determining the maturity level of CTU presents certain complexities as it demonstrates functions across different levels. The presence of functions on different levels showcases a diverse range of functions. Notably, the function of consolidation/deconsolidation is not applicable to CTU as it primarily deals with full container loads. CTU's maturity level can be characterized as a combination of functions spanning dif-

ferent levels, reflecting its progress in specific areas of operation. While CTU exhibits functions at various stages, the absence of certain functions in the earlier levels suggests areas for potential development and improvement.

Assessing the overall maturity level of CTU requires careful consideration of its specific operational context, strategic priorities and the extent to which it aligns with the functions outlined in the maturity model. While CTU may not fit neatly into a single maturity level, the presence of functions across multiple levels indicates a gradual progression toward higher maturity. It is important to note that maturity levels should not be viewed as static or definitive classifications, but rather as a means to assess and guide the development of dryports. The evaluation of CTU's maturity level provides insights into its current capabilities, areas of advancement, and potential future growth opportunities.

5.6. Conclusion

In this chapter, the development, verification and validation of a maturity model for dryports have been presented. The foundation of the maturity model was established by leveraging the outcomes of the Best-Worst method, which facilitated the prioritization and classification of pertinent functions to dryport operations. This systematic approach enabled the assessment of dryports' maturity levels, considering their respective functions and operational capabilities.

To ensure the robustness and trustworthiness of the maturity model, a meticulous verification process was conducted. Esteemed experts from the field were invited to meticulously evaluate the model's taxonomic structure, descriptive elements and practical implications. The valuable feedback and assessments provided by these experts offered profound insights into the adequacy, comprehensiveness, accuracy and pertinence of the maturity model. As a result, this verification phase significantly bolstered the overall effectiveness and usability of the model. Based on the feedback received by experts, few modifications have been made to the model to make it more efficient.

Moreover, to validate the maturity model's efficacy, it was practically applied to two real-world case studies, namely BCTN and CTU. These authentic case studies provided a pertinent context to gauge the model's applicability and practical viability within the operational dynamics of actual dryports. The in-depth analysis of the case studies yielded valuable observations on how well the maturity model aligned with the functions and operational practices observed in these specific dryport settings.

6

LIMITATIONS

While the research project has provided valuable insights into the development of a maturity model for dryports, it is important to acknowledge some limitations:

1. Geographical Limitation: The stakeholder interviews conducted for this research were primarily focused on the Netherlands. As a result, the perspectives, experiences and insights gathered from the stakeholders may be specific to the Dutch context. The findings may not fully represent the diverse range of perspectives and practices in other countries or regions with different socio-economic, cultural and regulatory contexts. Therefore, the generalizability of the findings to other geographical locations may be limited.

2. Sample Size: The research project involved a limited number of case studies and stakeholder interviews. The application of the best-worst method for ranking the functions of dryports relied on a small sample size of 16 participants. While efforts were made to include diverse stakeholders from the dryport industry, the limited sample size may affect the generalizability and robustness of the rankings. The verification of the developed maturity model for dryports involved a relatively small sample size of only 4 experts. While their expertise and insights are valuable, the small sample size limits the ability to generalize the findings to a broader population. A larger sample size of experts from different backgrounds and experiences could have provided more diverse perspectives and increased the reliability of the model verification results. A larger sample size and more extensive data collection could provide a more comprehensive understanding of the maturity model and its applicability across different dryport contexts.

3. Limited Research Duration: The research project operated within a specific timeframe, which may have imposed limitations on the depth and breadth of data collection and analysis. The complexity and dynamic nature of dryports require ongoing observation and data collection to capture changes and evolving trends over time. A longer research duration could provide a more nuanced understanding of the maturity model and its long-term effectiveness.

4. Subjectivity: The process of identifying functions, conducting stakeholder analysis and ranking functions using the best-worst method inherently involved subjective judgments and interpretations. Different researchers or stakeholders may have different perspectives, priorities and biases, which could influence the outcomes and results. Despite efforts to minimize subjectivity through rigorous expert validation, some level of subjectivity may still exist in the final maturity model.

5. External factors: The research primarily centered on exploring and analyzing internal aspects pertaining to the development and operations of dryports. While recognizing the significance of external factors like evolving regulations, economic fluctuations and geopolitical occurrences, it is important to acknowledge that these aspects were not comprehensively examined within the scope of this study. Nonetheless, understanding the potential impact of such external dynamics on the success and challenges of dryports could provide valuable insights for future research and industry practitioners.

7

CONCLUSION

Recent studies have revealed a gap in the development of maturity models specifically for the field of dryports. Therefore, the primary objective of this project is to address this research gap by developing a comprehensive and tailored maturity model specifically designed for dryports. Throughout this study three sub-research questions were formulated and answered to satisfy the design objective.

How to develop a maturity model for dryports?

The answers for all these sub-research questions are given below.
SRQ1: What are the key functions involved in the operations of dryports?
The first research question is addressed in chapter three of this thesis. The research commenced with an extensive literature review to comprehend the dryport concept fully. This literature review was instrumental in enhancing the understanding of the dryport concept and identifying the key functions associated with dryports. The functions are found to be Transshipment, Consolidation/Deconsolidation, Load center, postponement, customs clearance, container maintenance, environmental sustainability, freight forwarding, empty container managemnet, information management, additional service offereings, light transformation and storage and warehousing.

SRQ2: What are the development steps involved in transforming an intermodal terminal into a dryport, considering the requirements and the processes?
The transformation of intermodal terminals into dryports requires a well-defined roadmap which was discussed in chapter four. Stakeholder analysis through expert interviews further validated the identified functions from the previous steps and elucidated the requirements for successful dryport transformation. The morphological chart created as part of this study provided a visual representation of the functions and their potential solutions, enabling a holistic assessment of dryport requirements. Through the Best-Worst Method ranking, functions were effectively prioritized, forming the basis for establishing maturity levels within the proposed model.

SRQ3: How can the developed maturity model for dryports be effectively operationalized, ensuring its applicability and linkage to decision-making processes? This research question has been answered in the chapter five. To ensure the practical applicability of the developed maturity model, rigorous verification and validation processes were undertaken. Expert evaluations played a vital role in assessing the model's accuracy and effectiveness, while real-world case studies that are applied to BCTN and CTU validated its applicability to diverse dryport scenarios. This model can now serve as a valuable tool for industry practitioners, policymakers, and researchers to assess and optimize the development and progress of dryports effectively.

Despite the limitations in the Chapter 6, the thesis project has made significant strides in advancing the understanding of dryports and their development processes, offering valuable contributions to both research and practical applications. The comprehensive literature review, stakeholder analysis, morphological chart, and Best-Worst Method ranking have collectively contributed to the establishment of a robust maturity model. By embracing the limitations and acknowledging the dynamic nature of the logistics industry, future research can build upon this foundation, further refining and enhancing the model to address new challenges and opportunities.

Contribution to Research:
This thesis has made several significant contributions to the field of dryports and logistics research. Firstly, by identifying the research gap in the absence of a maturity model specifically tailored for dryports, this study addresses a critical knowledge deficit. The developed maturity model serves as a comprehensive and structured framework, enabling researchers to systematically analyze and assess the development and progress of dryports in different contexts. Moreover, the morphological chart and Best-Worst Method ranking add valuable methodological contributions to the field, offering novel approaches for assessing functions and their prioritization.

Furthermore, the comprehensive literature review sheds light on various research aspects and methodologies employed in similar studies, offering an essential resource for future researchers exploring dryport-related topics. The stakeholder analysis also contributes to understanding the requirements and perspectives of experts and professionals in the logistics industry, enhancing the quality and applicability of future research in this domain.

Contribution to Practice:
From a practical perspective, this research project offers significant contributions to the operationalization and development of dryports. The identification of key functions and their potential solutions in the morphological chart provides terminal operators and logistics practitioners with valuable insights into the necessary components for successful dryport operations. The proposed maturity model offers a structured tool for assessing a terminal's maturity level and identifying areas for improvement, facilitating informed decision-making and strategic planning for dryport development.

Additionally, the validation of the developed maturity model through case studies with BCTN and CTU demonstrates the model's real-world applicability and effectiveness. Terminal operators and policymakers can rely on this model to guide their efforts in transforming intermodal terminals into efficient and sustainable dryports, optimizing freight transportation and logistics activities.

In conclusion, this thesis project contributes significantly to both the academic research on dryports and their practical implementation. By providing a tailored maturity model and methodological advancements, this study advances the understanding of dryport development and lays the groundwork for more efficient, interconnected, and sustainable logistics networks. The insights gained from this research have the potential to foster positive impacts on the global supply chain, enhancing freight transport efficiency and driving economic growth in the Netherlands and beyond.

8

RECOMMENDATIONS

In this chapter, recommendations for further research that can contribute to the advancement of the field of dryport development will be presented. Building upon the findings and insights gained from the current study, these recommendations aim to address the identified research gaps and explore new avenues for enhancing the understanding and effectiveness of dryport operations. The research conducted thus far has shed light on the development steps involved in transforming an intermodal terminal into a dryport, as well as the identification of functions and their placement on different maturity levels. However, there are several areas that warrant further investigation and exploration to deepen our understanding and provide practical guidelines for dryport stakeholders.

One important area for future research is to explore the further integration of the morphological chart with the developed maturity model and function improvement strategies. This integration can provide valuable insights into how the existing functions in each maturity level can be improved by adapting solutions from the morphological chart. Understanding the factors that contribute to successful function improvement can guide stakeholders in their decision-making processes. For future research, it is crucial to validate and enrich the solutions identified in the morphological chart through practical implementation and real-world case studies. Collaborating with industry practitioners and stakeholders to gather insights and feedback on the feasibility and effectiveness of the proposed solutions will enhance the applicability and relevance of the maturity model. By incorporating practical experiences and empirical data into the morphological chart, the research can bridge the gap between theory and practice, resulting in a more robust and reliable tool for guiding the transformation of intermodal terminals into efficient and sustainable dryports.

To ensure the reliability and applicability of the developed maturity model for dryport development, further validation through collaboration with multiple dryports is recommended. This validation process involves applying the model to various dryport contexts, working closely with dryport operators and stakeholders to assess its effectiveness in capturing the maturity levels and functions specific to different regions.

By collaborating with diverse dryports across different regions and countries, the model's applicability and usefulness can be evaluated in real-world scenarios. Feedback from dryport operators and stakeholders will provide valuable insights into the model's relevance to their specific contexts and its ability to guide their growth strategies. This assessment will help refine and enhance the model, making it more comprehensive and adaptable to the varying needs of different dryports.

Moreover, conducting cross-country comparisons will offer valuable insights into variations in dryport development approaches and practices. By examining the maturity levels and functions of dryports in different contexts, similarities, differences, and best practices can be identified. This comparative analysis will facilitate knowledge sharing and enable the adoption of successful strategies across borders.

One valuable research recommendation for the Greening Corridors project is to investigate the potential for collaborative initiatives among a group of inland terminals to function as a unified dryport. By exploring the feasibility and benefits of integrating multiple terminals into a single, cohesive dryport entity, researchers can analyze how this approach contributes to reducing carbon emissions and optimizing the flow of goods within the logistics network. Additionally, the study could delve into the organizational, operational and environmental implications of such collaborations, thereby offering valuable insights to further enhance the sustainability and efficiency of the Green Corridor project.

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A

SCIENTIFIC ARTICLE

Development of maturity model for dryports in the Netherlands

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Abstract: This paper presents a comprehensive study on the development of a maturity model for dryports. Through an extensive literature review, key functions and requirements of dryports were identified, providing a foundational understanding for subsequent research. To validate and enhance the identified functions, a stakeholder analysis was conducted through interviews with field experts and professionals. The insights gained from these interviews shaped the requirements of a dryport. A morphological chart was created to systematically analyze functions and potential solutions. The Best-Worst Method prioritized functions which acted as an input for constructing a structured framework to evaluate dryport maturity based on capabilities. The developed maturity model was verified through expert engagement to assess its accuracy and effectiveness. Additionally, two case studies applied the model to BCTN and CTU terminals, validating practicality and applicability. While the research significantly contributed to understanding and developing maturity models for dryports, limitations were acknowledged, including reliance on literature-based solutions in the morphological chart and the need for further research to refine the model's maturity level sequence. This research provides a valuable maturity model aiding industry practitioners, policymakers and researchers in assessing and enhancing dryport development.

Keywords: Dryports, Maturity Model, Inland Intermodal Terminals, Best Worst Method, Morphological chart.

1. INTRODUCTION

The Netherlands holds a prominent position in the world of international trade due to its strategic location at the heart of Europe's transportation network. The country's extensive system of ports, waterways and highways has made it an attractive choice for companies seeking efficient access to European markets. Notably, the port of Rotterdam stands as one of the world's busiest and most crucial seaports, handling vast amounts of cargo each year. However, despite the success of major Dutch ports, the inland terminals face challenges in achieving optimal efficiency.

Problem statement: The development of dryports, also known as inland ports or intermodal terminals, has been less pronounced in the Netherlands compared to other countries, despite the country's strategic location and significance in international trade. The fragmented nature of the inland terminal sector, with numerous small operators managing terminals independently, poses challenges in coordination and standardization. Additionally, certain terminals face infrastructure inadequacies, hindering their overall efficiency. The lack of sufficient volume and imbalances in imports and exports further contribute to the inefficiencies. However, adopting the dryport concept could be a promising solution to address these challenges and enhance the efficiency and sustainability of the Dutch logistics sector. Therefore, the research problem revolves around understanding the barriers to dryport development in the Netherlands and exploring the potential benefits they offer to improve supply chain efficiency and reduce transportation costs.

State-of-the-art: Previous studies have extensively analyzed dryports worldwide, employing quantitative and qualitative methodologies which can be seen in the section 2. These studies have focused on comparing various dryports, using simulation models, linear programming and p-hub median models to evaluate cost and emission savings. Qualitative methods, such as SWOT analysis, case study analysis and stakeholder analysis, have explored the advantages of dryports. Despite these efforts, a notable research gap exists, specifically in the development of a

maturity model for dryports. Such a model would provide a standardized approach to assess dryports' development and maturity levels, evaluating infrastructure, processes and technology aspects.

Contribution: The primary objective of this research is to develop a comprehensive maturity model for dryports, facilitating their assessment and improvement for converting inland terminals into fully functional dryports. The model will identify the strengths and weaknesses of dryports, aiding stakeholders in making informed decisions and fostering benchmarking and knowledge sharing among different facilities. The research will contribute to the literature review by filling the gap in the development of maturity models for dryports. Additionally, the research will explore the functions involved in dryport operations, development steps to transform an intermodal terminal into a dryport and the effective operationalization of the developed maturity model, linking it to decision-making processes.

The remainder of this paper is organized in the following order: in the section 2, literature review on dryports is discussed which helps in identifying the functions of dryports. This is followed by defining the aim of the research with research questions. In the next section, Methodology is discussed which involves stakeholder analysis, morphological chart and Best-Worst method. Section 5 discusses the final results of the research. The second last part of this paper contains limitations and the final part of the paper discusses conclusions and recommendations.

2. LITERATURE REVIEW

This section offers an overview of existing research and literature on dryports. It seeks to comprehensively understand the current knowledge state and identify research gaps. According to [1], dryport is defined as "an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport". The phrase "as if directly to a seaport" in the definition of a dryport implies that customers have the convenience of handling their standardised cargo units, such as containers, in a manner similar to how they would do so at a seaport. The chosen papers encompass qualitative and quantitative analyses, providing a multifaceted dryport perspective. These papers explore diverse facets of dryport development, operations and management. Methods used in these studies have been shown in the Table 1.

Table 1. Methods used in the previous studies on Dryports

	Literature review	Survey	Conceptual framework	Multi-criteria analysis	Case study	Benchmarking approach	Stakeholder analysis	SWOT analysis	KPI	Simulation	Linear integer programming	Statistical analysis
Hui et al. (2019)[13]									⋆			
Khaslavskaya (2019)[2]	⋆				⋆							
Gonzalez (2019)[17]					⋆							
Carboni (2020)[18]										⋆		
Nguyen (2021)[10]			⋆	⋆			⋆					
Li et al. (2019)[19]											⋆	
Rodrigues (2021)[3]	⋆				⋆							
Ziar et al. (2023)[20]											⋆	
Hanaoka (2011)[21]					⋆							
Khaslavskaya (2020)[4]	⋆											
Awad-Nunez (2016)[22]				⋆								
Beresford (2012)[23]					⋆							
Zain et al. (2022)[24]							⋆					
Black (2012)[25]					⋆							
Dooms (2003)[26]			⋆	⋆			⋆					
Werikhe (2016)[11]					⋆	⋆						
Jeevan (20150[27]							⋆					
Krutulus (2019)[28]										⋆		
Nguyen (2016)[12]								⋆				
Roso (2010)[5]	⋆											
Facchini (2020)[29]											⋆	
Olah et al. (2018)[30]						⋆						
Nguyen (2019)[31]												⋆
Rodrigue (2012)[14]	⋆											
Veenstra (2012)[32]	⋆											
Jeevan (2018)[8]		⋆										
Roso et al. (2009)[1]	⋆											
Notteboom (2017)[33]			⋆									
Chang (2015)[34]											⋆	
Monios (2016)[6]	⋆											
Rodrigue (2010)[35]					⋆							
Dadvar (2011)[15]	⋆	⋆						⋆				
Jarzemskis (2007) [9]		⋆										
Rozic et al. (2016)[7]	⋆											
Zeng et al. (2013)[16]	⋆	⋆										

Qualitative analysis

Qualitative analysis involves non-numerical data collection and analysis, such as interviews, surveys and observations. Studies like [2], [3] and [4] utilize literature reviews as their main methodology. For example, [2] examines dryport integration's supply chain optimization in Sweden. [3] evaluates Brazilian dryport objectives through value-focused thinking. Themes like environmental effects, economic implications and performance outcomes emerge. [5] and [6] analyze dryport advantages and disadvantages. [7] reviews inland terminal development. Qualitative analysis helps identify supply chain bottlenecks, like customs issues or congestion, impacting dryport efficiency. Stakeholder surveys, e.g., [8] and [9], reveal operational factors. Frameworks like multi-criteria analysis by [10] assess stakeholder perspectives. Benchmarking studies, such as [11], compare dryport performance globally. SWOT analysis, like [12], assesses network development. [13] focuses on Key Performance Indicators (KPIs) for dryports to enhance efficiency. Comparative analyses like [14] compare dryports in transport systems. Studies like [15] combine literature review, surveys and SWOT analysis for comprehensive assessment. Similarly, [16] combine industry interviews, data analysis and existing research to understand China's dryport network.

Quantitative analysis

Quantitative analysis enhances dry port performance understanding, measuring indicators like throughput, capacity use and dwell time via customs data, bills of lading and terminal systems. It identifies trends, aiding resource allocation and capacity planning. Three main methods are highlighted: simulation, linear integer programming (ILP) and statistical analysis. [18] uses a simulation model, finding dry port implementation could cut CO2 by 17%. [28] expands this by considering train capacity and empty container impact. ILP optimizes complex logistics in dry ports with various constraints, aiding decisions like storage, transport and service levels. [19] reduces emissions

through dry port development. [20] suggests using the Genetic Algorithm (GA) for rail-road and p-hub median model to cut transport costs and air pollution. A model by [29] determines optimal container numbers, reducing costs and carbon footprint. [34] uses linear programming and GA for location and capacity optimization in candidate inland cities. Statistical analysis by [31] emphasizes intermodality's importance in dry port system development.

Despite dry ports' global significance, research gaps exist in maturity model development for efficient conversion of existing terminals. Few studies focus on such models for dry ports, impeding performance comparison and improvement. Morphological charts could aid maturity model creation, mapping solutions to different maturity levels. Identifying essential functions can guide efforts for successful dry port development.

Different research aspects

This part delves into various research aspects of dryports. Five research aspects are identified which are shown in the Table 2.

1. Location: Studies focus on identifying optimal dry port locations by considering factors like transportation costs, environmental variables and accessibility. Models emphasize the importance of transportation efficiency and connectivity within the network [36], [20]. Environmental considerations also play a significant role in location decisions [22].

2. Governance and Management: Research explores the governance and management structures of dry ports, highlighting the role of stakeholders like public authorities, private operators and logistics companies. Effective governance, public-private partnerships and streamlined regulations are crucial for dry port success [37], [38]. Stakeholder engagement and multi-criteria decision-making are seen as key for service design and development [39], [10].

3. Economic Impacts: Studies assess the economic effects of dry ports, including trade facilitation, supply chain efficiency and job creation. Mathematical models highlight the need for container transportation optimization to reduce costs and carbon emissions [29], [40]. Dry ports contribute to emission reduction and cost efficiency when integrated with rail transport [41].

4. Environmental Impacts: Research examines the environmental consequences of dryports, focusing on carbon emissions, noise pollution and land use. Dry port establishment, rail connections and scaled operations contribute to decreased pollution and enhanced sustainability [18], [19], [20], [21], [28].

5. Policy and Planning: Studies delve into government policies, funding mechanisms and planning processes that influence dry port development. Effective policy frameworks and private sector involvement are crucial for ensuring competitiveness and market efficiency [33], [42], [43].

These findings collectively provide insights into the optimal location of dry ports, the dynamics of their governance, the economic and environmental impacts they generate and the significance of appropriate policies for their successful implementation. Additional research areas, such as social impacts, technological advancements, risk management, cross-border cooperation and long-term sustainability, could further enrich the understanding of dry port systems.

Table 2. Different research aspects on Dryports

	Location	Governance and management	Economic impacts	Environmental impacts	Policy and planning
Ng et al. (2013)[37]		⋆			
Ng (2012)[44]	⋆				
Ng (2009)[42]					⋆
Varese (2020)[45]					
Iannone (2013)[38]		⋆			
Khaslavskaya (2021)[39]		⋆			
Flaming (2011)[46]	⋆	⋆			
Henttu (2011)[40]			⋆	⋆	
Lattila (2013)[41]			⋆	⋆	
Jeevan (2019)[43]					
Carboni (2020)[18]				⋆	
Nguyen (2021)[10]		⋆			
Li et al. (2019)[19]				⋆	
Ziar et al. (2023)[20]	⋆			⋆	
Hanaoka (2011)[21]				⋆	
Awad-nunez (2016)[22]	⋆				
Kurtulus (2019)[28]				⋆	
Facchini (2020)[29]			⋆	⋆	
Rodrigue (2010)[35]		⋆			
Chang et al. (2015)[34]	⋆				
Notteboom (2017)[33]					⋆
Nguyen (2016)[36]	⋆				

3. AIM OF THE RESEARCH

The aim of the research is to develop a comprehensive maturity model for dryports in order to fill the research gap that was found in section 2. The primary research question guiding the study is formulated as follows:

How to develop a maturity model for dryports?

The following sub-questions need to be clarified in order to answer the main research question:

(1) What are the key functions involved in the operations of dryports?
(2) What are the development steps involved in transforming an intermodal terminal into a dryport, considering the requirements and the processes?
(3) How can the developed maturity model for dryports be effectively operationalized, ensuring its applicability and linkage to decision-making processes?

4. METHODOLOGY

Various methodologies used in this study are discussed in detail below.

4.1 Stakeholder analysis

Stakeholder analysis is done in order to determine requirements needed for a successful function of a dryport. Semi-structured interviews are performed with the list given in the below Table 3.

Table 3. List of interviews

Company	Designation
Port of Rotterdam	Program Manager Business Accounts
BCTN Terminals	Regional Sales Manager
CTD Terminals	Branch Manager
Aviko	Supply Chain Manager
VIM	Logistics Manager
Province Gelderland	Coordinator for logistics and freight transportation

Formulation of requirements

The stakeholder interviews have yielded a set of requirements for dryports. These requirements distinguish between those applicable to both intermodal terminals and dryports and those exclusively emphasized for dryports (highlighted in yellow). These requisites can be divided into two categories: constraints and objectives.

Constraints are the requirements that the project must comply to. A distinction is made between functional constraints, what the design must do and non-functional constraints, what the design must have. These requirements can be seen in the Table 4.

Objectives are the requirements that the design could preferably comply to. A distinction is made between functional objectives, what the design could preferably do and non-functional objectives, what the design could preferably have. Objectives are shown in the Table 5.

Table 4. Constraints

	Functional Constraints	Non-Functional Constraints
1	The dryport must have the necessary capacity to handle a certain volume of cargo, including storage and handling facilities.	The dryport must be designed and operated to meet specific performance requirements, such as throughput, turnaround times, and reliability.
2	The dryport must have the necessary equipment, such as cranes, forklifts, and trucks, to handle and transport cargo.	The dryport must be designed and operated in an environmentally sustainable manner, with measures to reduce energy consumption, waste generation, and emissions.
3	The dryport must have good road and rail or barge access, as well as sufficient parking and waiting areas for trucks and other vehicles.	The dryport must be designed and operated to minimize safety risks to personnel, cargo, and the environment.
4	The dryport must have effective security measures to ensure the safety of the cargo and the personnel working at the facility.	The dryport must take into account cultural factors that may impact the design and operation of the facility, such as local labor practices and customs.
5	The dryport must comply with relevant regulations and standards for transportation, security, and environmental protection.	The dryport must be designed and operated to be financially viable and sustainable over the long term.
6	The dryport must ensure a frequent and reliable rail/barge service connecting to the seaport	
7	The dryport must have enough capacity for the temporary storage of containers	

4.2 Morphological chart

Dryports have a pivotal function in enabling smooth and effective intermodal transportation and logistics activities. With these intricate hubs constantly evolving and encountering new challenges, it becomes imperative to adopt proficient techniques for problem-solving to identify and investigate appropriate remedies. The morphological chart, serving as a methodical instrument for both problem-solving and devising solutions, presents a structured strategy to confront the intricate demands and intricacies associated with dryports. By dissecting the functions and prospective solutions, the morphological chart establishes a comprehensive structure for dissecting and assessing diverse approaches that have the potential to enhance and refine dryport operations. A morphological chart, also known as concept-combination or function-means table,

Table 5. Objectives

	Functional Objectives	Non-Functional Objectives
1	Dryports shall facilitate efficient and effective transshipment of cargo between the seaport and the hinterland.	Dryports shall promote environmental sustainability by reducing energy consumption, waste generation, and emissions.
2	Dryports shall provide fast and reliable access to international markets for regional industries and businesses.	Dryports shall provide high levels of service quality and reliability to customers and stakeholders.
3	Dryports should serve as strategic trade and investment hubs that actively contribute to the growth and development of regional economies.	Dryports shall minimize disruptions to the supply chain through effective risk management and contingency planning.
4	Dryports should enhance supply chain efficiency and reducing transportation costs.	Dryports shall optimize resource utilization, including space, equipment, and personnel, to achieve operational efficiency and cost-
5	Dryports should streamline customs and border clearance procedures to facilitate international trade.	
6	Dryports should offer a range of value-added services to enhance cargo handling and distribution operations	
7	The maintenance of containers at the dryport shall be conducted at regular intervals to ensure their optimal condition and functionality	
8	The dryport shall have an effective local communication system to enable seamless information exchange and collaboration among stakeholders	
9	Dryports shall have a systematic process that enable the reliable and timely provision of empty containers to customers	

is a problem-solving tool [47]. It systematically combines solutions to address design issues. In dryports, functions and solutions are vital for efficient logistics. Functions involve tasks like cargo handling, processing and distribution, while solutions are strategies and tools for effective execution. The developed morphological chart for can be seen in the Table 6.

According to [48], the most important functions of dryports are load center and Transshipment. A study by [35] defined the supply chain functions of inland port as Consolidation/deconsolidation, postponement and light transformation. Whereas, [49] considers Value-added services and information management to be the functions of a dryport. [50] emphasises that customs clearance is an integral function of a dryport. In addition to these functions, [35] states that dryport should perform empty container management and container maintenance. Based on the interviews, storage and warehousing, freight forwarding and environmental sustainability are also considered to be important functions of a dryport. These functions and their potential solutions are described in detail below:

Transshipment: It involves transferring cargo between different transportation modes at a dryport. It facilitates seamless movement of goods and optimizes supply chains.

In dryports, *dedicated transshipment terminals* offer specialized infrastructure and equipment for efficient cargo transfers between transportation modes. These terminals, equipped with cranes and forklifts, ensure swift operations [51]. *Cross-docking facilities* within dryports enable seamless transfer of shipments from one transport mode to another, eliminating storage needs, minimizing handling time and enhancing operational efficiency [52]. Additionally, *automation handling systems* like conveyor systems, automated guided vehicles (AGVs) and robotic arms are leveraged in dryports for cargo handling. These systems boost speed, accuracy and safety, reducing reliance on manual labor and ultimately enhancing overall productiv-

Table 6. Morphological Chart

Functions	Means/solutions				
Transshipment	Dedicated transshipment terminals	Cross-Docking facilities	Automated handling systems		
Consolidation/ Deconsolidation	Sorting area	Storage space	Sorting equipment		
Load center	Centralized distribution hubs	Cargo consolidation area	Inventory management systems	Efficient material handling systems	
Customs clearance	Customs inspection facilities	Documentation area	Customs compliance systems	Customs agent services	Integration with customs authorities' systems
Additional service offerings	Labelling and branding facilities	Product testing and certification space	Repackaging and relabelling stations	Product quality control systems	
Light transformation	Assembly and kitting center	Rework center	Configuration center	Contract packaging facility	
Buffer function	Agile supply chain networks	Advanced inventory management systems	Collaborative planning and forecasting	Flexible storage and warehousing	
Information management	Cargo tracking systems	Electronic data interchange capabilities	Integration with supply chain partners	Real-time visibility and reporting	Document management systems
Environmental sustainability	Renewable energy utilization	Waste management systems	Water conservation measures	Green building design and materials	Emissions reduction initiatives
Storage and warehousing	Warehouse space	Racking systems	Warehouse management systems	Climate-controlled storage areas	Security measures
Empty container management	Container repositioning optimization algorithms	Collaboration with sea carriers	Demand driven container forecasting	Container leasing	Collaborative empty container management system
Container maintenance	Container inspection and repair facility	Maintenance and cleaning services	Container tracking and monitoring system	Spare parts inventory management	Collaboration with container maintenance service providers
Freight forwarding	In-house freight forwarding department	Partnership with freight forwarding companies	Digital freight forwarding platform	Integrated supply chain management	

ity [53].

Consolidation/Deconsolidation: This function combines or breaks down cargo shipments to improve efficiency and achieve cost-effective transportation.

Within a dryport, a *sorting area* serves as a designated space to categorize incoming shipments based on destinations or specific criteria. This zone is equipped with features like conveyor systems, sorting bins and manual sorting stations to efficiently group shipments [54]. Adequate *storage facilities* are crucial in a dryport to temporarily accommodate and consolidate incoming shipments. These spaces are designed to suit various cargo types and sizes, potentially incorporating pallet storage systems, racks, or shelves for optimal organization and accessibility. Employing suitable *sorting equipment*, such as conveyor belts, automated sorting systems, or manual stations, is essential to streamline consolidation and deconsolidation processes. Advanced technologies like barcode scanners, RFID systems, or automated identification systems can enhance accuracy and efficiency during sorting operations, tailored to the cargo volume and characteristics handled within the dryport.

Load Center: They consolidate and distribute cargo, offering value-added services and enhancing logistics efficiency.

Load centers within a dryport function as *centralized distribution hubs*, collecting and consolidating cargo from various sources for efficient onward distribution. Positioned strategically, they minimize transportation costs by providing a central point for receiving, organizing and dispatching shipments. An essential feature of load centers is the *cargo consolidation area*, facilitating the combining of shipments through sorting areas, storage spaces and adept material handling equipment. This consolidation optimizes space usage, streamlines distribution and enhances operational efficiency [55]. Effective *inventory management systems* are imperative within load centers, offering real-time inventory visibility and control. Monitoring stock levels, tracking shipments and supporting accurate replenishment, these systems enable precise demand forecasting and inventory positioning, minimizing holding costs [55]. *Efficient material handling systems*, encompassing equipment like AGVs, forklifts and conveyor systems, are vital for load centers to ensure swift loading and unloading. These systems enhance accuracy, reduce handling times and optimize the overall cargo flow within the dryport.

Customs Clearance: It ensures compliance with trade regulations, facilitating smooth cargo flow and international trade competitiveness.

Within a dryport, *customs inspection facilities* are dedicated spaces for comprehensive inspection of shipments by customs officials, verifying contents, ensuring compliance and identifying security risks. The *documentation area* manages essential customs paperwork, involving tasks like preparing, reviewing and submitting customs declarations, permits and invoices, often utilizing electronic systems for efficient management and submission. *Customs compliance systems* employ technology and processes, such as automated compliance software or electronic data interchange (EDI), to streamline customs procedures, reduce

errors and ensure adherence to regulations [6]. *Customs agent services* involve hiring experts to navigate customs complexities, facilitating proper documentation and compliance while expediting clearance. *Integration with customs authorities' systems*, through electronic connections and portals, facilitates real-time information exchange and document submission, enhancing efficiency, reducing paperwork and expediting goods clearance [56].

Additional Service Offerings: Dryports offer services like packaging, quality control and labeling, adding value to logistics operations.

In dryports, *labeling and branding facilities* provide designated spaces for tasks like applying labels, barcodes, or RFID tags for tracking and customizing packaging to meet specific customer or market needs [57]. Value-added services can encompass *product testing and certification spaces* within the dryport, offering customers the means to verify product quality and compliance with standards. These facilities, equipped with necessary equipment and expertise, enable quality tests and certifications. *Repackaging and relabeling stations* are potential offerings where products can be repackaged or rebranded to suit different sizes or market requirements, enhancing efficiency and customization. This also include *product quality control systems*, implementing inspections, audits and assurance processes to ensure products meet standards and customer expectations through measures like visual inspections, sample testing and compliance checks.

Light Transformations: This customize goods closer to market demands, reducing lead times and meeting customer needs.

Dryports can offer *assembly and kitting centers*, designated spaces equipped with tools, equipment and skilled personnel to efficiently combine components or parts into finished products or kits for specific purposes [58]. Rework centers within dryports facilitate modifications or repairs to products before distribution, addressing defects, quality issues, or adjustments to meet requirements and ensure optimal condition. *Configuration centers* in dryports allow for customization of products based on individual customer specifications, enabling adjustments to settings, features, or personalization to meet unique needs. Additionally, *contract packaging facilities* handle product packaging according to specific regulations or requirements, which might involve repackaging products into different sizes, types, or formats for proper distribution or retail purposes.

Buffer function: The Buffer function within a dryport or inland terminal assumes a pivotal role by offering customers buffer time to store their containers before onward dispatch. This strategic delay, synonymous with postponement, introduces heightened adaptability and responsiveness to dynamic market demands and customer needs.

Buffer strategies rely on *agile supply chain networks*, involving close collaboration with partners to ensure quick customization through timely availability of components or semi-finished products [59]. *Advanced inventory management systems* are essential to implement this function effectively, tracking semi-finished or generic product levels for customization based on specific customer orders [59]. Successful implementation of buffer opportunities hinges on *collaborative planning and forecasting* processes that align demand signals, customer orders and production capabilities, reducing the risk of excess inventory [60]. *Flexible storage and warehousing facilities* accommodating various configurations of semi-finished products play a vital role in storage and warehousing, enabling efficient customization and easy component access during finalization.

Information Management: Efficient information management enhances visibility, collaboration and decision-making in the supply chain.

Information management entails *cargo tracking systems* employing RFID tags, barcodes, or GPS for real-time shipment visibility [61]. *Electronic Data Interchange (EDI)* streamlines business document exchange, reducing errors and enhancing communication efficiency. *Integration with supply chain partners*, including suppliers and customs authorities, improves coordination and decision-making. *Real-time visibility systems* facilitate informed decisions, issue resolution and reporting, enhancing logistics control [62]. *Document management systems* are crucial for handling shipping documents and ensuring regulatory compliance [63].

Environmental Sustainability: Dryports promote eco-friendly practices, including renewable energy use and waste management, to minimize environmental impact.

Dryports can enhance environmental sustainability through *renewable energy utilization*, like solar panels and wind turbines, reducing carbon footprint. *Waste management systems* with recycling, composting and waste segregation minimize waste generation [64]. *Water conservation measures*, like rainwater harvesting, reduce water usage [65]. Dryports can adopt *green building practices*, using eco-friendly materials and designs and *emission reduction initiatives* such as optimizing logistics and promoting eco-friendly transportation.

Storage and Warehousing: This helps in managing temporary storage, inventory and order fulfillment, enhancing supply chain efficiency. The concept of a bonded warehouse can be integrated, allowing the temporary storage of containers with deferred duties or taxes, providing cost savings and flexibility.

Dryports necessitate ample *warehouse space* accommodating diverse cargo types, including temperature-controlled storage for perishables. *Racking systems*, like shelves and pallet racks, enhance storage efficiency. *Warehouse management systems* ensure precise inventory tracking and replenishment [66]. *Climate-controlled areas* cater to specialized storage needs. Robust *security measures*, like surveillance and access control, safeguard stored goods [67].

Empty Container Management: This function optimizes handling and storage of empty containers, minimizing costs and improving logistics efficiency.

Container repositioning optimization algorithms employ data and advanced techniques to minimize empty container movements, reducing costs [68]. *Collaborating with sea carriers* optimizes container utilization and flow [69]. *Demand-driven container forecasting* uses historical data and models to anticipate container demand, ensuring availability [70]. *Container leasing* provides flexible access to containers, meeting fluctuating demand without high investments. *Collaborative empty container management systems* enhance coordination and efficiency through real-time data sharing.

Container Maintenance: It ensures proper equipment functioning through inspection, cleaning, repairs and safety protocols.

A dedicated *container inspection and repair facility* equipped with specialized tools and skilled staff ensures containers meet standards. Regular *maintenance and cleaning services* prevent damage, while a *container tracking and monitoring system* provides real-time maintenance visibility [71]. *Spare parts inventory management* reduces downtime [72]. *Partnering with maintenance service providers enhances capabilities* also could be a potential solution.

Freight Forwarding: This involves the efficient coordination and management of transportation activities. Additionally, this coordinates transportation activities, optimizing routes and ensuring timely delivery of goods.

Establish an *in-house freight forwarding department* with professionals handling logistics, customs and coordination. *Partnership with external forwarding companies* helps expanded services, leveraging their expertise. Develop a *digital freight forwarding platform* connecting stakeholders for streamlined processes, transparency and real-time tracking. Implement an *integrated supply chain management* system automating freight tasks, from planning to customs compliance.

4.3 Best-worst method

This section of the article focuses on assessing the significance of each function in the overall operation of the dryport. A comprehensive evaluation is conducted to determine the importance of each function in meeting dryport objectives, considering factors such as operational efficiency, customer satisfaction and strategic alignment. The assessment is based on requirements gathered in Table 4.1 and expert rankings using the Best-Worst method. This method evaluates the relative importance of functions within the dryport.

According to [73], the Best-Worst method involves identifying the best and worst criteria, performing pairwise comparisons, formulating a maximin problem to determine weights for each criterion and applying the same process to alternative weights. Final scores are calculated, leading to the selection of the best alternative. In this study, the Best-Worst method is used to evaluate the 13 functions within the dryport, grouped as follows:

1. Core Operations: This dimension encompasses fundamental operational functions, including transshipment, consolidation/deconsolidation and load center management. Transshipment ensures smooth cargo flow across different transportation modes. Consolidation and deconsolidation optimize space and logistics, while load center management handles cargo loading/unloading efficiently.

2. Value-added Services: This dimension focuses on additional services beyond basic operations to enhance customer satisfaction. It includes additional service offerings, light transformation processes for specific customer needs and buffer strategies can be implemented, providing customers with additional time to store their containers before they are dispatched to their final destinations.

3. Administrative and Support Functions: This dimension covers vital administrative and support activities. It includes customs clearance to facilitate cross-border movement, information management for effective decision-making and environment sustainability practices for eco-friendly operations.

4. Container Management and Logistics: This dimension involves efficient container handling and management. It includes container maintenance, storage and warehousing functions for proper container storage and inventory management, effective empty container management to minimize idle time and freight forwarding services to coordinate transportation and logistics.

Ranking of functions

A survey was conducted to gather data for pairwise comparisons and weight assignments. Sixteen experts, from academic researchers and professors to industry professionals and managers, the experts brought diverse perspectives and experiences to the survey. Their extensive expertise covered logistics, transportation, strategy and more. Their diverse perspectives enriched the assessment of functions' importance for the dryports' maturity model.

The experts ranked functions using pairwise comparison matrices. The resulting data was analyzed using the Best-Worst Method (BWM) with Excel solver, assigning weights to functions within each group. These weights reflected aggregated expert opinions on relative importance. Aggregating group weights produced an overall assessment of functions. Individual responses calculated participants' weighted scores, averaged for each function. Means were scaled from 1 to 5 for clarity, with 1 denoting low importance and 5 high importance.

To assess data dispersion, standard deviations and coefficients of variation were computed. These measures showcased consensus or divergence in expert opinions. The analysis of means, standard deviations and coefficients of variation provided a robust understanding of experts' agreement or disagreement regarding function importance within dryports. Results from the Best-Worst method are shown in the Table 7.

The analysis of the results revealed several key insights. Firstly, the Transshipment function garnered the highest mean score of 0.21, signifying its pronounced importance within the dryport context. Conversely, the Container Maintenance and Light Transformation functions exhib-

Table 7. Importance of functions (N=16)

Functions	Mean	Rank	Standard deviation	Coefficient of variation
Transshipment	0.21	5.00	0.14	0.64
Consolidation/ Deconsolidation	0.12	2.89	0.09	0.73
Empty container management	0.09	2.19	0.09	1.00
Load center	0.08	2.00	0.03	0.43
Storage and warehousing	0.07	1.77	0.06	0.82
Customs clearance	0.06	1.68	0.08	1.31
Freight forwarding	0.06	1.66	0.06	0.88
Environmental sustainability	0.04	1.26	0.06	1.28
Additional service offerings	0.04	1.20	0.03	0.66
Buffer function	0.04	1.19	0.03	0.83
Information management	0.04	1.05	0.02	0.69
Container maintenance	0.03	1.02	0.03	0.83
Light transformation	0.03	1.00	0.04	1.10

ited the lowest mean scores at 0.03, indicating comparatively diminished significance relative to other functions.

Furthermore, a noteworthy observation emerged from the coefficients of variation. Customs Clearance, Environment Sustainability, Light Transformation and Empty Container Management exhibited coefficients of variation equal to or exceeding 1, implying substantial divergence in responses and a wide spectrum of opinions among participants.

Conversely, the Load Center, Information Management, Transshipment and Additional Service Offerings functions displayed lower coefficients of variation, registering values of 0.43, 0.69, 0.64 and 0.66, respectively. These lower coefficients underscored a heightened level of consensus and agreement among participants regarding the importance of these functions.

The rankings from the Best-Worst method will be used as an input for developing maturity model in the next section.

5. RESULTS

This section aims to address the main research question and sub research question 3 by creating, verifying and validating a dryport maturity model using the functions identified in the previous chapter's morphological chart. The weighted scores derived from the BWM in the previous section reflects each function's significance within dryport operations. These scores underpin the maturity model, categorizing functions into maturity levels. This model offers a structured framework to assess and benchmark dryport function maturity. The model is constructed by establishing dimensions for assessment, determining function maturity levels and structuring the model. It provides a comprehensive framework for evaluating dryport maturity, aiding in goal-setting, enhancement and adaptability to industry changes.

5.1 Development of the maturity model

The dryport maturity model outlines five distinct levels of maturity to guide administrations in assessing their development progress and aiming for higher stages. The selection of five levels ensures clarity in differentiation while avoiding extreme variations. This approach aids in understanding the evolution toward enhanced maturity. The model is designed progressively, featuring levels that represent the transformation of inland terminals into fully operational dryports. The levels are as follows:

1. Foundational: In this stage, inland terminals establish initial functions and infrastructure, marking the initial steps toward becoming a complete dryport.

2. Developing: This phase signifies the transition of inland terminals toward dryport status. Significant en-

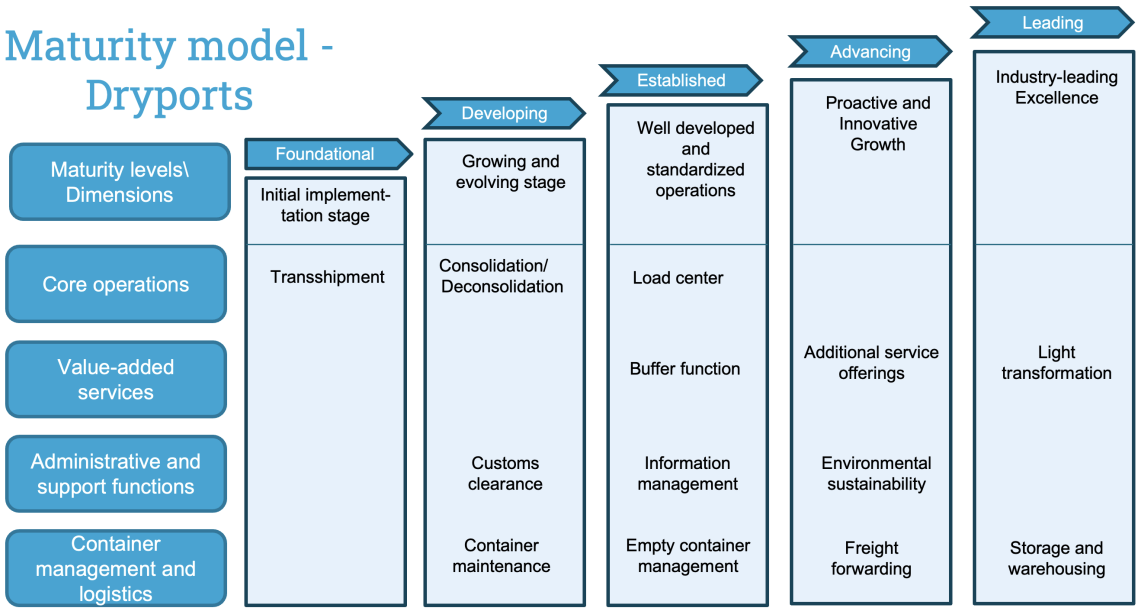

Fig. 1. Maturity model of dryports

hancements in functions, operations and technology are implemented, integrating with transportation networks.

3. Established: At this level, terminals are officially considered dryports, displaying mature functions, services and connectivity. They excel in handling, customs and regional logistics networks.

4. Advancing: These dryports exceed established norms, leveraging technology and innovation for enhanced services, contributing to regional growth and serving as trade hubs.

5. Leading: This visionary stage depicts advanced dryports, showcasing global logistics leadership. These exemplars prioritize sustainability, incorporate advanced technologies and offer seamless connectivity, setting industry benchmarks.

The four different dimensions of the maturity model are Core operations, value-added services, administrative and support functions and container management and logistics, which are mentioned as groups in the best-worst method subsection 4.3. The functions associated with distinct dimensions are distributed across various maturity levels according to their rankings as determined in the preceding section. Furthermore, practical implications are factored in, particularly when a high coefficient of variation suggests less reliable responses. In such instances, functions are allocated to distinct maturity levels based on the requirements derived in the previous sections. The developed maturity framework can be seen in the Figure 1.

5.2 Verification of the model

The verification of the maturity model is a crucial process to evaluate its accuracy and dependability in reflecting the advancement and attributes of dryport development. This verification phase entailed engaging industry specialists and experts in the dryport sector to contribute their insights. A google form survey was meticulously formulated and shared with a specific audience. The survey's structure was designed with reference to established frameworks and concepts in the field, as detailed in the [74]. The average scores for all the questions can be seen in the Table 8.

The maturity model exhibits strengths in representing diverse maturation stages and domains. However, refinement opportunities exist, particularly in terms of description accuracy and comprehensiveness. These insights offer a foundation for optimizing the maturity model's usability and effectiveness in guiding dryport development. A limitation of the survey is the small sample size, yielding only four responses. While these responses offer valuable insights, a larger sample size would enhance reliability and generalizability. A greater number of responses would enable a more comprehensive and representative assessment, encompassing a broader spectrum of expert perspectives.

5.3 Validation of the model

In order to validate the practicality and effectiveness of the developed maturity model in aiding the development of dryports, two case studies were conducted with a focus on BCTN and CTU. This validation process involved the utilization of semi-structured interviews. In both use cases, the functions outlined in the developed maturity model have been visually emphasized with distinct colors to indicate their present status and future intentions. Functions currently executed at the terminals are highlighted in yellow, aspired functions in green and undesired functions in salmon color.

1. Use case 1
The first use case in this study involves a collaboration with BCTN, a prominent company in the field of inland container terminals and logistics services in the Netherlands. The model based on BCTN can be seen in Figure 2. The assessment of BCTN's maturity level presents a challenge due to its functions spanning various levels. While it lacks certain functions typical of the second and third levels, it fully embodies the functions of the fourth level. The absence of consolidation/deconsolidation is logical given its focus on full container loads rather than smaller

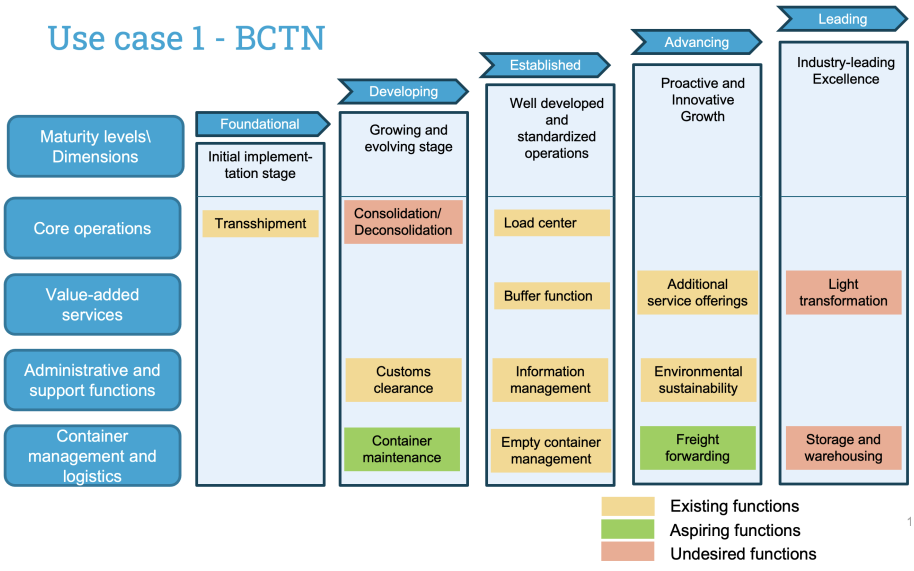

Fig. 2. Validated by BCTN

Table 8. Verification of the maturity model (N=4)

	Average score
Maturity model taxonomy	
The maturity levels are sufficient to represent, all maturation stages of the domain (Sufficiency)	3.75
The maturity model domains are sufficient to represent all relevant domains for dryports (Sufficiency)	3.75
There is no overlap detected between descriptions of maturity levels (Accuracy)	3.25
Maturity model descriptions	
The provided descriptions for each maturity level are: Relevant to the domain (Relevance)	3.25
The provided descriptions for each maturity level are: Cover all aspects involved in the domain (Comprehensiveness)	3.25
The provided descriptions for each maturity level are: Are clearly distinct (Mutual exclusion)	4
The provided descriptions for each maturity levels are: Assigned to the correct maturity level (Accuracy)	3.25
Understandability and ease of use	
The maturity levels and domains are understandable	4.25
The self-assessment system is easy to use (Checking which functions a dryport/inland terminal perform)	4

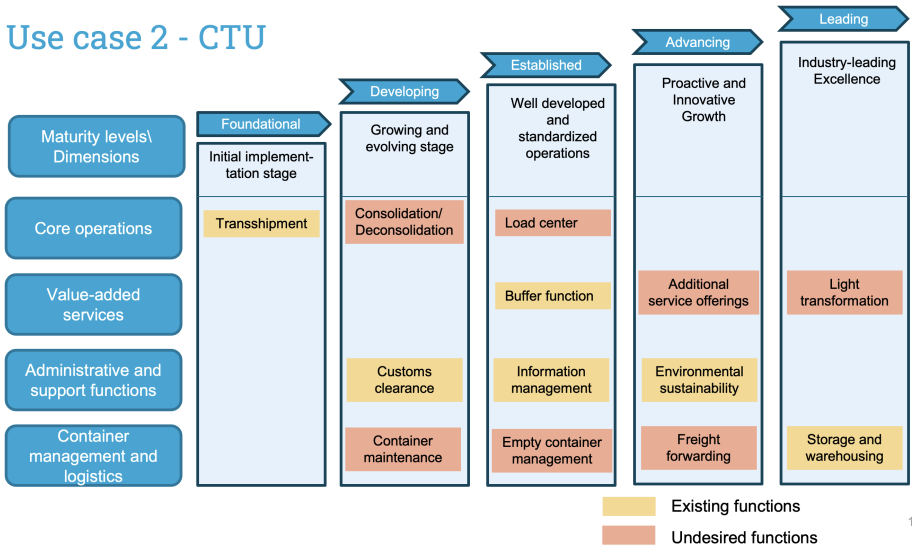

Fig. 3. Validated by CTU

shipments. BCTN's maturity level is a fusion of functions from different levels, reflecting its distinct specialization. Notably mature in transshipment, customs clearance, sustainability, information management and storage, BCTN prioritizes specific areas aligned with its strategy. Maturity in dryports isn't solely about function presence; BCTN's strategic focus and success signal tailored market positioning, addressing specific customer needs.

2. Use case 2

The second use case in this study entails a collaborative partnership with CTU, a renowned inland container terminal located in the Netherlands. The developed maturity model when applied to CTU looks like Figure 3. Evaluating CTU's maturity level is intricate due to its functions spanning various levels. The absence of consolidation/deconsolidation aligns with its focus on full container loads. CTU's maturity level reflects its multifaceted functions and shows progress in specific operational areas. While certain functions are present at different stages, the absence of functions at earlier levels suggests room for growth. CTU's overall maturity needs contextual consideration of its operations and alignment with the model. Its presence across levels signifies gradual advancement. Maturity levels are fluid and guide development. Assessing CTU highlights capabilities, progress and growth potential.

6. LIMITATIONS

Although the research endeavor has yielded valuable insights into formulating a maturity model for dryports, it is imperative to recognize certain limitations. Firstly, the stakeholder interviews were predominantly conducted in the Netherlands, potentially limiting the transferability of insights to diverse global contexts. Secondly, the reliance on a relatively small sample size (16 participants) for applying the best-worst method might impact the generalizability of function rankings. Similarly, the verification of the maturity model (4 experts) may constrain its broader applicability. Thirdly, the research was conducted within a specific timeframe, potentially limiting the depth and scope of data collection and analysis of dynamic dryport operations. Furthermore, the inherent subjectivity in identifying functions and ranking them using the best-worst method, despite expert validation, introduces an element of potential bias. Lastly, the study primarily explored internal aspects of dryport development and operations, leaving out comprehensive examination of external factors such as regulations, economic shifts and geopolitical events. Despite acknowledging the importance of external factors such as evolving regulations, economic shifts and geopolitical events, it's crucial to note that these elements weren't thoroughly investigated within this study's scope. Nevertheless, recognizing the potential influence of these external dynamics on dryports' successes and challenges

could offer valuable insights for subsequent research and industry practitioners.

7. CONCLUSION AND RECOMMENDATIONS

Recent studies have revealed a gap in the development of maturity models specifically for the field of dryports. Therefore, the primary objective of this project is to address this research gap by developing a comprehensive and tailored maturity model specifically designed for dryports. The project commenced with a comprehensive literature review to explore various research aspects and methodologies employed in similar studies. This literature review was instrumental in enhancing the understanding of the dryport concept and identifying the key functions associated with dryports.

To gain further insights and validate the identified functions, stakeholder analysis was conducted through interviews with experts and professionals from the field. These interviews provided valuable perspectives and helped in identifying the requirements necessary to convert an intermodal terminal into a fully functional dryport. In order to systematically analyze the functions and potential solutions, a morphological chart was created. This chart served as a visual tool to identify the different combinations of functions and their corresponding solutions. Furthermore, the functions were ranked using the Best-Worst Method, which facilitated the prioritization of functions based on their significance and impact on the development of dryports. This ranking process contributed to the establishment of maturity levels within the proposed model.

The developed maturity model was subjected to verification and validation processes. Expert evaluations and feedback were sought to ensure the model's accuracy and effectiveness. Additionally, two case studies involving BCTN and CTU, prominent terminal operators in the Netherlands, were conducted to validate and refine the model based on real-world scenarios.

Despite limitations, the project's contributions are substantial. Academically, it addresses the research gap, providing a structured framework, innovative methodological approaches and valuable insights for future studies. Practically, it guides terminal operators and policymakers in dryport development and optimization. The validated model holds promise for enhancing logistics networks and driving economic growth.

Based upon the current study's findings to address research gaps and enhance dryport operations, few recommendations are provided. Future research can focus on the integration of the morphological chart with the maturity model and validating function improvement strategies. Collaboration with industry practitioners can validate solutions and bridge theory with practice. Further validation of the maturity model across multiple dryports is crucial for applicability. Collaboration with diverse dryports will refine the model based on real-world scenarios and context-specific needs. Cross-country comparisons offer insights into development approaches. For the Green Corridor project, investigating collaborative initiatives among inland terminals to function as a unified dryport could enhance sustainability and efficiency, analyzing environmental implications and benefits. These recommendations collectively contribute to the advancement of dryport research and practice.

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B

INTERVIEW DISCUSSION

Table B.1: Discussion with Port of Rotterdam

Questions	**Answers**
What role do dryports play in your overall port strategy, and how do you see them evolving in the years to come?	The use of dryports can help alleviate issues such as space shortage and traffic congestion that arise from traditional ports being built near cities. This is particularly helpful when there is good connectivity between the dryport and the port.
What steps do you take to ensure the safety and security of cargo at the port, and how do you manage risk in your operations?	ISPS regulations, container scanning, more than 200 cameras installed
Are there delays in the customs clearance?	Dutch customs scan all the containers on board and sometimes X-ray if there is any change - it can take a few days and sometimes even more for very high risk containers.
What are the incentives from port authorities and economic development agencies for shipping companies?	Incentives for ships that exceed a certain percentage of their maximum dead weight during unloading and to large shipping lines that handle substantial volumes of goods.
What are strategies employed at the port for managing empty containers?	There are a lot of empty depots in the port where they can store empty containers.
Can you describe any tools or techniques you use to stay aware of potential hazards and risks?	Cameras, drones, Dogs and seaport police.
What do you see as the future of dryports, and how are you preparing for changes in the industry and global supply chain?	They forecast the future demand and extend terminals accordingly. Dryports should also grow as ports in order to serve this demand.
What are the biggest challenges faced by ports?	Energy transition is the biggest challenge when whole port is considered.
Do you see dryports as complementary to seaports?	They can be of great use to the seaports with intermodal connections
How do you build and maintain relationships with terminal operators and other supply chain partners, and what strategies do you use to manage these interactions effectively?	Terminal operators are the tenants to the port who pay rent for leasing the terminal. Every terminal is managed by one person.
What are the cost elements involved and how would they change if dryport concept is implemented?	Rent for the land, commercial negotiation, competitiveness, depth of key walls and rent of the terminal.
Do you think dryports are useful for imports or exports or both? And why?	Both are same

Table B.2: Discussion with Terminal operators

Questions	**Answers**
What is a dryport according to you?	Dryport is an extension from the deep sea port but inland, connected to rail or barges.
What are the functions of their current terminal and what are they planning to expand?	Gas analysis, break bulk handling, feumigation process, customs clearance, postponement, reefer and dry container handling. Only planning to expand the volume.
How do you compare inland terminals to sea ports?	Small version of the activities performed at sea ports. Small ships, small terminals, turn arounds are lower than seaport.
What infrastructure and equipment are required to support terminal operations? Would there be any change if it is converted into a dryport?	Cranes, terminal trackers, gantry cranes, trucks, reach stackers, portal cranes and empty handlers. There will not be any change
What role does digitalization play in operations, and how do you use technology to improve efficiency and visibility?	It plays a huge role. ERP and TOS are used for booking and tracking. All terminals are connected to one system.
How do you compete with other terminal operators?	Compete and collaorate with other terminal operators. Main drivers are price and service. Trucking companies are the main competitors.
What strategies do you use to attract and retain shipping lines and other customers?	Price, quality and Co2 reductions. Focused on long term relationships.
How do you measure and evaluate the performance of your terminal, and what key performance indicators do you use to track progress over time?	Hours of the machines, safety, maintenace, payable moves per hour, week, month, year, turn around, the amount of trucking, idle time under the crane and percentage of truck and barges usage per day.
How do you collaborate with other actors in the logistics ecosystem, such as freight forwarders, trucking companies, barge operators, and rail operators, to create a seamless end-to-end supply chain?	By contracts, paying them on time and having a transparent supply chain.
How do you deal with empty container management?	Reuse, cleaning of empty containers and perform PTI for reefers and optimize the supply chain by using the empty container in the terminal.
How do you manage the interface between the inland terminal and seaport, and what strategies do you use to optimize container flows and reduce congestion?	By using portbase. ERP system is connected to almost every container terminal in port of Rotterdam.
What strategies do you employ to address environmental challenges and comply with regulatory requirements?	They use hydrogen, electric, and hybrid ships, fully electric terminal trackers, and environmentally friendly trucks
How would the quality of service differ if they convert it into a dryport?	Full service pakage will be useful for customers but clients prefer full container loads.
What modes of transportation are available for accessing your terminal?	Barges and trucks
Do you think dryports are useful for imports or exports or both? And why?	Both are same

Table B.3: Discussion with customers

Questions	**Answers**
How does the implementation of dryport concept affect the supply chain of your business?	It makes supply chain much flexible as they offer empty container management, PTI cleaning and value-added services.
How do you take environmental factors into consideration while transporting the goods?	They try to move 80% of the containers through dryports in order to reduce emissions.
What opportunities are you looking for in dryports?	Rail connections with them
What would be the main benefits to you from dryports?	Flexible supply chain, less waiting time for drivers and cost reduction
What is the difference between dryports and inland terminals?	Dryports are highly flexible and service oriented

Table B.4: Discussion with providers

Questions	Answers
What is a dryport according to you?	Dryport is an inland terminal that is connected to the seaport either just by road or road and other modes like rail and brage
Do you use inland terminals or do you directly drop off the contaiers at seaports?	Both. It depends on the location of a client and volume.
What are the main factors that you strive for improvement?	To enhance the supply chain efficiency.
Do you support the concept of dryport or not? And why?	No. It is better to improve the functions an inland terminal already has reather than adding new functions to it. At first capacity of the inland terminals have to be increased.
What role do sustainability and environmental considerations play in your logistics operations, and how do you address these issues in the context of dryports?	A tiny role, as sustainability is considered in the whole supply chain from the manufacturing to the distribution.
How do you evaluate the suitability of a dryport for your logistics needs, and what factors do you consider when selecting a specific dryport?	It depends on location, volume and client's requirements.
What are the cost elements in general that you take into consideration and how would they change if dryport concept is implemented?	Better supply chain than costs. Time and cost are the main elements.
Do you think dryports are useful for imports or exports or both? And why?	Mostly useful for imports rather than exports. Documentation is very complex for exports.

Table B.5: Discussion with Province of Gelderland

Questions	Answers
What is a dryport according to you?	It is an intermodal terminal with customs clearance and other services and its bigger in size compared to a normal terminal.
What is the Province of Gelderland's overall vision and strategy regarding the development of dryports within the region?	Looking at the dryport to make it more sustainable to make it more attractive to the shippers like Nike, Heineken, etc.
How does it perceive the role of dryports in enhancing regional economic development, trade and logistics connectivity?	Dryport offers accessibility to the international market which helps companies reach in a smarter way. This will contribute to regional development.
What are the key criteria or factors in considering suitable locations for dryports?	It depeneds on the accessibility to different modes, location of logistic companies, spatial planninga nd money. A proper business case is needed in order to invest.
What would residents think about the dryport concept?	There might be extra hindrance on the local level. Effective stakeholder management has to be performed to reduce the impacts.
What types of collaborations or partnerships exist between the government, terminal operators, logistics companies, and other stakeholders to support the growth and operations of dryports?	"Logistics valley" - collaboration between local government, HAN, logistic companies, provinces, etc. They look for solutions together - human capital, sustainable, labour market.
What is the structure of the government with respect to port-hinterland relations?	"convenant emissielabel binnenvaart" - working on inland shipping sector to reduce emissions and also work also at regional level with municipalities to plan on the expansion of new business plans within a region. Regionale programma's werklocaties - predict the future demand to know what companies will be at water.
What are the incentives offered for the use of certain infrastructures like railways and barges?	Yes, modal shift subsidy from the national government. They help the companies in modal shift - regional level by province
What are the key challenges and opportunities the Netherlands faces in the development and expansion of dryports, and how are these being addressed at the national level?	Actors, most importantly shippers and the availability of sufficient space. If there are enough shippers that use dryport, then this concept will work.

C

Survey for Best-Worst method

Importance of the functions of a dryport

I am conducting this survey as a part my master thesis. The objective of the research is to develop a maturity model for dryports.
Dryport is defined as "an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport".

A maturity model is a structured framework used to assess the level of maturity of an organization or system in achieving specific objectives.

The aim of this survey is to evaluate the importance of the different functions of a dryport. Based on their importance, they will be placed in the different maturity levels of the maturity model which will be developed in the later stage. The survey is anonymus and responses will solely be used for academic purposes. Estimated time to fill the survey is around 10 to 15 min.

Please read the questions carefully before responding. Note that this survey is slightly different from the traditional survey (especially the importance rating part).

chandushathati@gmail.com Switch account

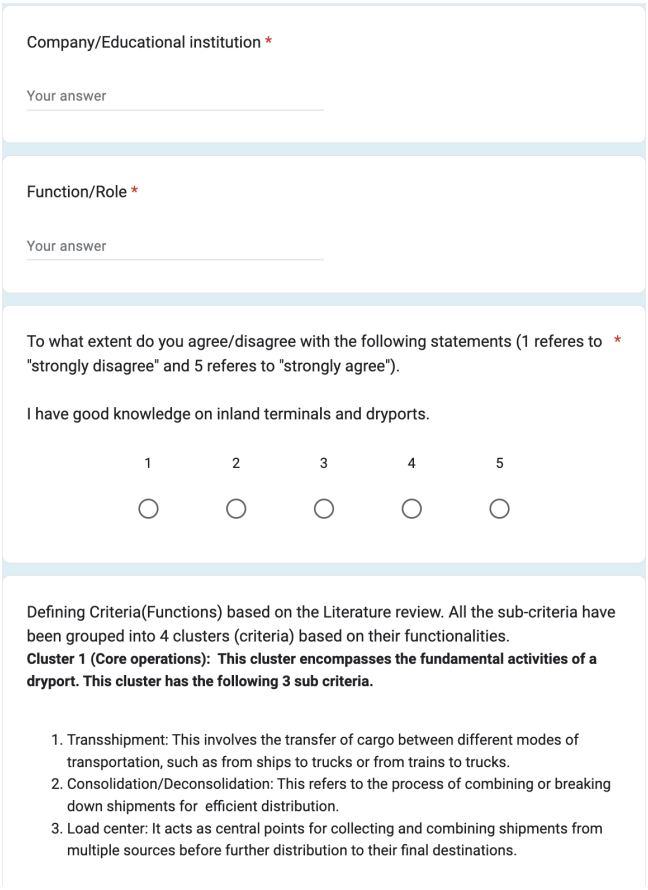
Not shared

* Indicates required question

Area of expertise/department *

Your answer

Figure C.1: Survey form 1



Company/Educational institution *

Your answer

Function/Role *

Your answer

To what extent do you agree/disagree with the following statements (1 referes to "strongly disagree" and 5 referes to "strongly agree"). *

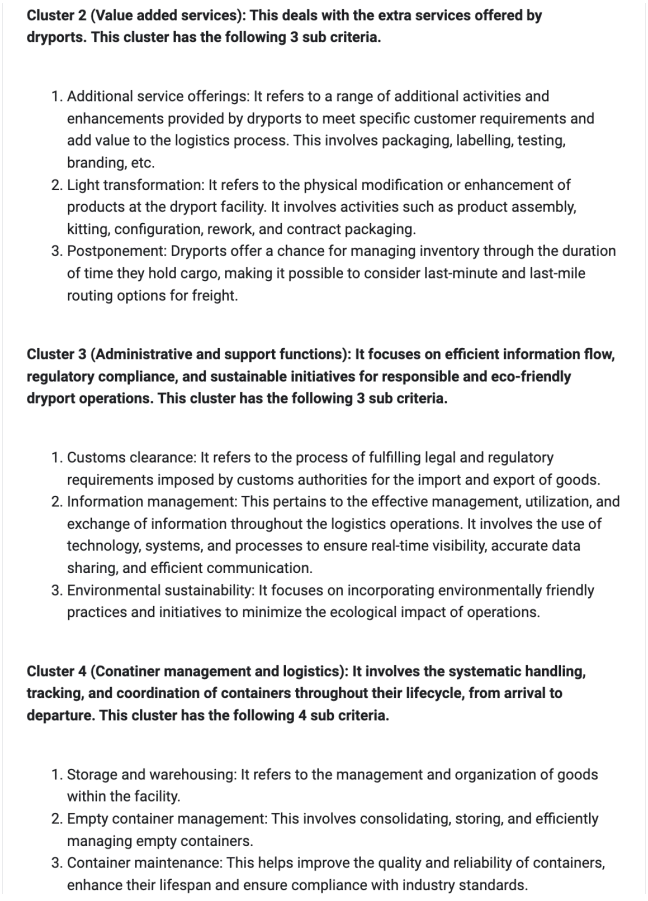
I have good knowledge on inland terminals and dryports.

1 2 3 4 5

Defining Criteria(Functions) based on the Literature review. All the sub-criteria have been grouped into 4 clusters (criteria) based on their functionalities.
Cluster 1 (Core operations): This cluster encompasses the fundamental activities of a dryport. This cluster has the following 3 sub criteria.

1. Transshipment: This involves the transfer of cargo between different modes of transportation, such as from ships to trucks or from trains to trucks.
2. Consolidation/Deconsolidation: This refers to the process of combining or breaking down shipments for efficient distribution.
3. Load center: It acts as central points for collecting and combining shipments from multiple sources before further distribution to their final destinations.

Figure C.2: Survey form 2



Cluster 2 (Value added services): This deals with the extra services offered by dryports. This cluster has the following 3 sub criteria.

1. Additional service offerings: It refers to a range of additional activities and enhancements provided by dryports to meet specific customer requirements and add value to the logistics process. This involves packaging, labelling, testing, branding, etc.
2. Light transformation: It refers to the physical modification or enhancement of products at the dryport facility. It involves activities such as product assembly, kitting, configuration, rework, and contract packaging.
3. Postponement: Dryports offer a chance for managing inventory through the duration of time they hold cargo, making it possible to consider last-minute and last-mile routing options for freight.

Cluster 3 (Administrative and support functions): It focuses on efficient information flow, regulatory compliance, and sustainable initiatives for responsible and eco-friendly dryport operations. This cluster has the following 3 sub criteria.

1. Customs clearance: It refers to the process of fulfilling legal and regulatory requirements imposed by customs authorities for the import and export of goods.
2. Information management: This pertains to the effective management, utilization, and exchange of information throughout the logistics operations. It involves the use of technology, systems, and processes to ensure real-time visibility, accurate data sharing, and efficient communication.
3. Environmental sustainability: It focuses on incorporating environmentally friendly practices and initiatives to minimize the ecological impact of operations.

Cluster 4 (Conatiner management and logistics): It involves the systematic handling, tracking, and coordination of containers throughout their lifecycle, from arrival to departure. This cluster has the following 4 sub criteria.

1. Storage and warehousing: It refers to the management and organization of goods within the facility.
2. Empty container management: This involves consolidating, storing, and efficiently managing empty containers.
3. Container maintenance: This helps improve the quality and reliability of containers, enhance their lifespan and ensure compliance with industry standards.

Figure C.3: Survey form 3

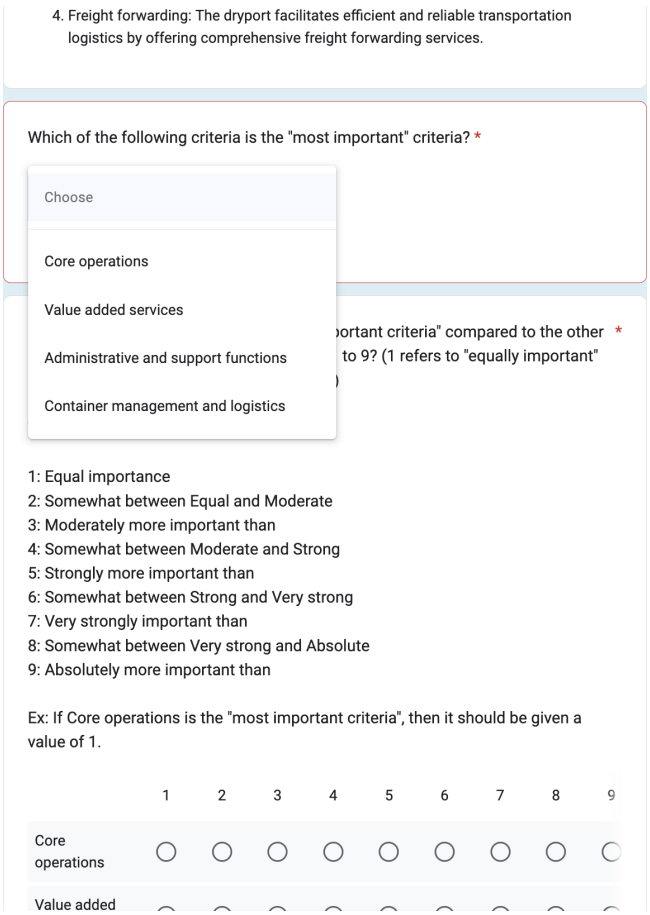


Figure C.4: Survey form 4

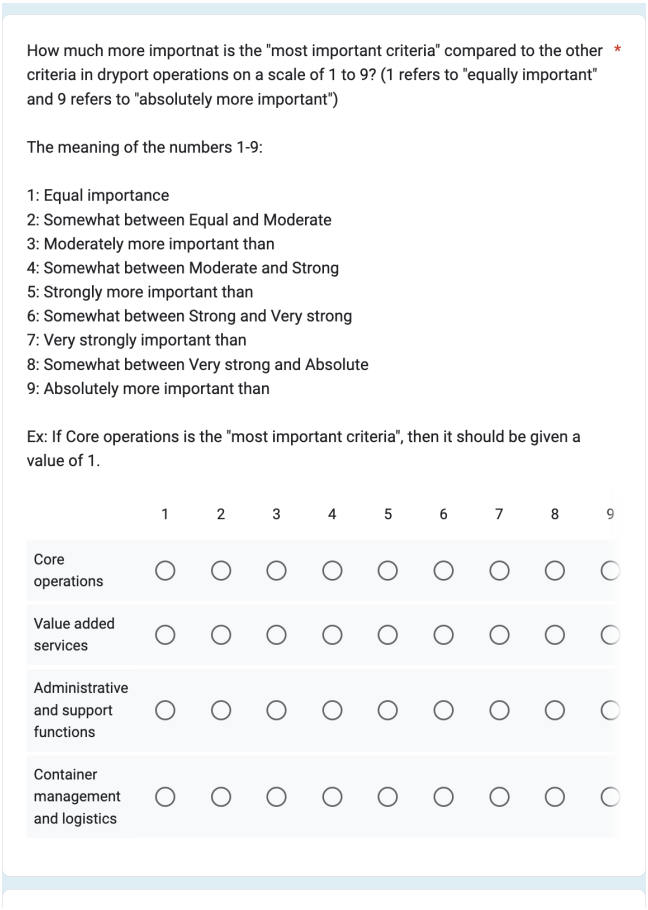


Figure C.5: Survey form 5

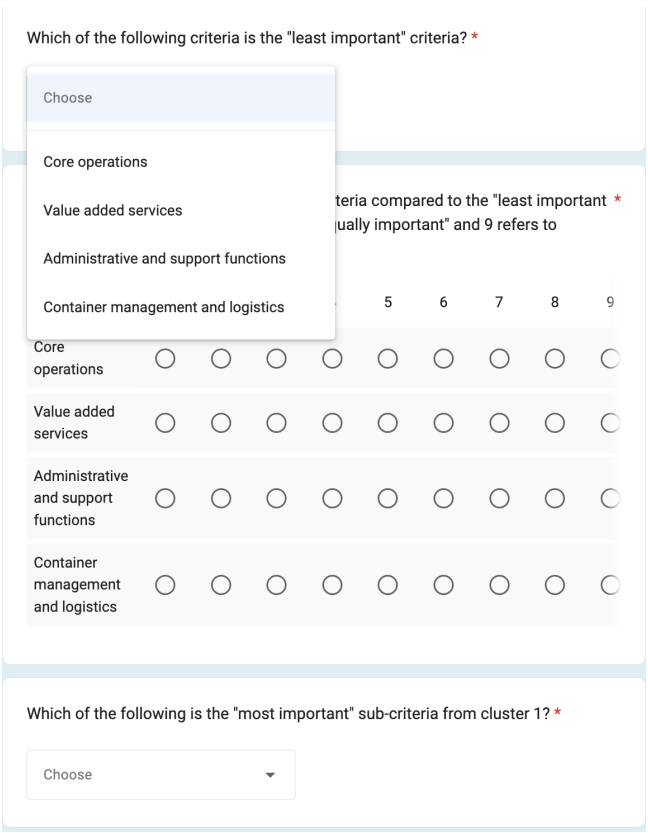


Figure C.6: Survey form 6

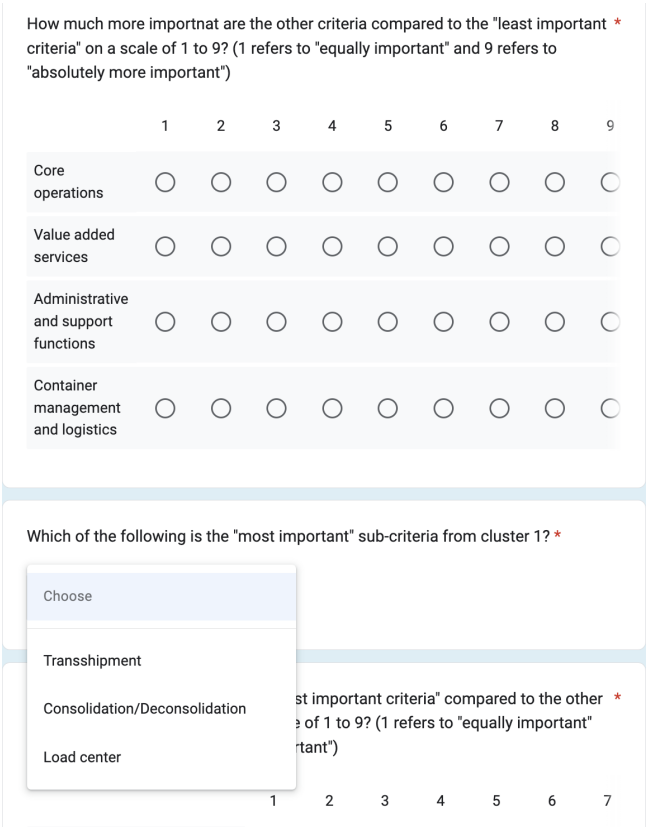


Figure C.7: Survey form 7

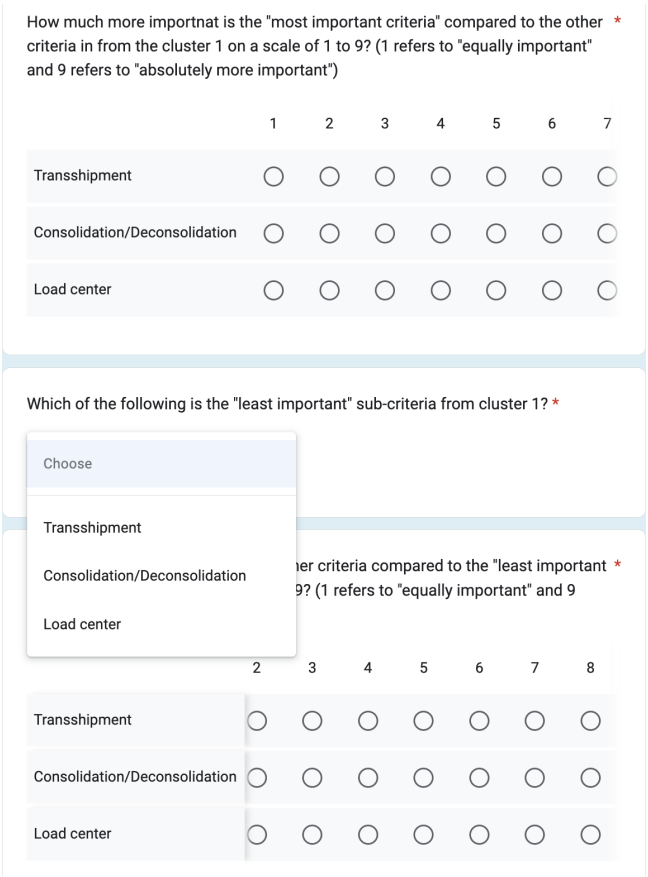


Figure C.8: Survey form 8

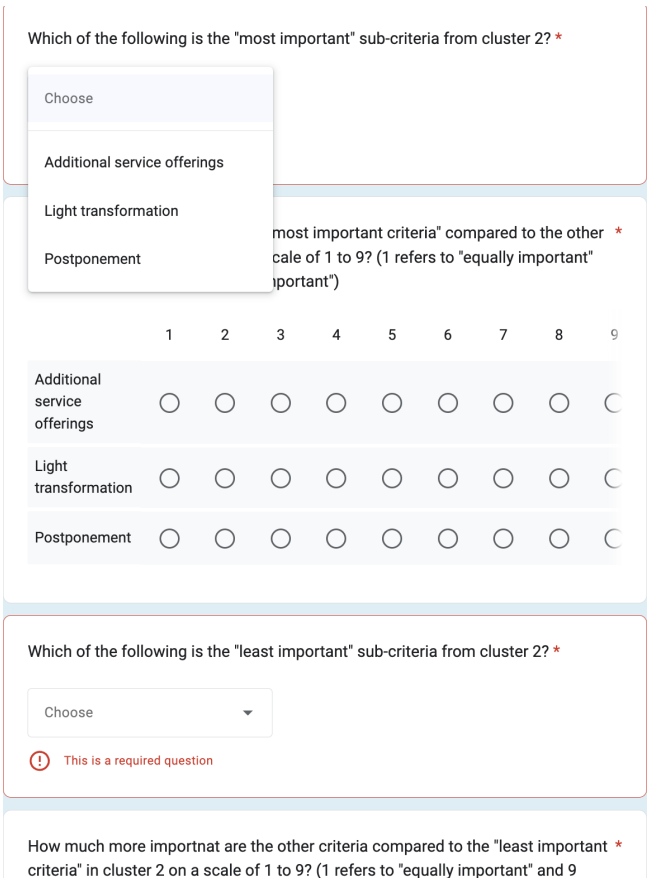


Figure C.9: Survey form 9

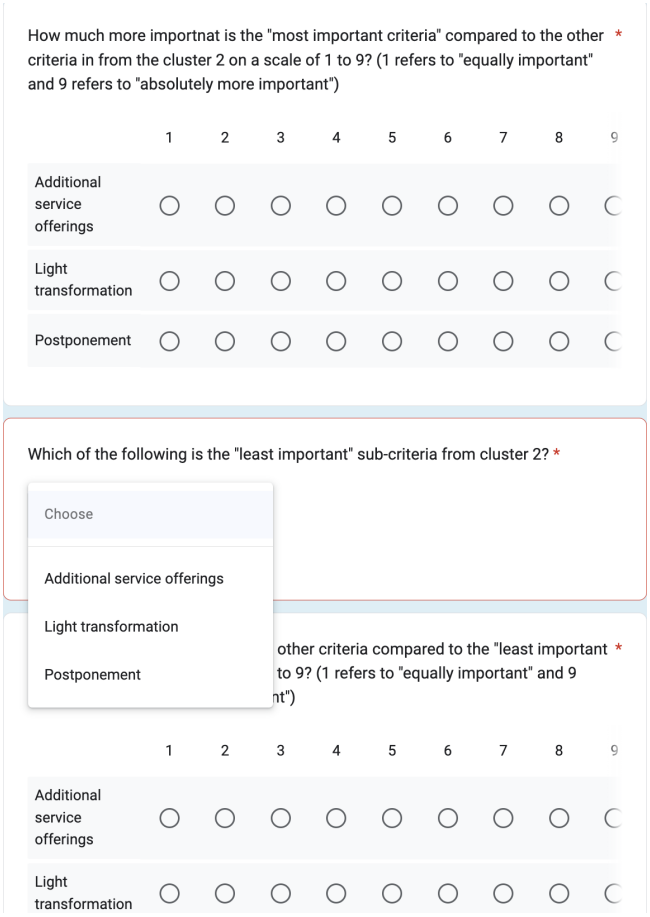


Figure C.10: Survey form 10

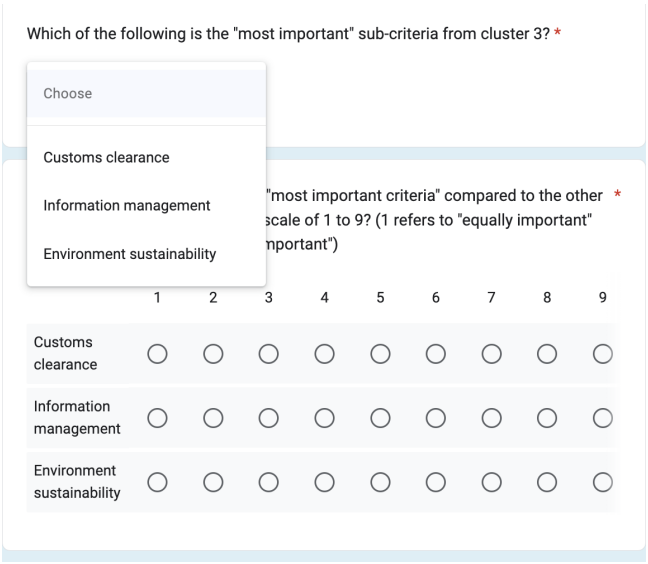


Figure C.11: Survey form 11

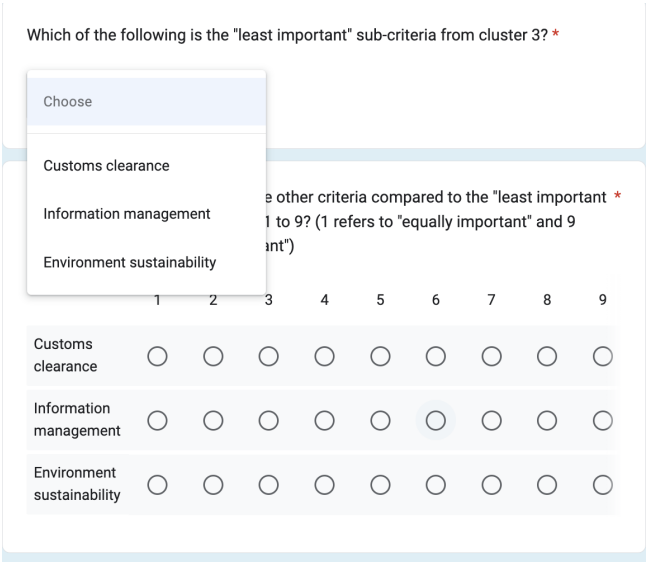


Figure C.12: Survey form 12

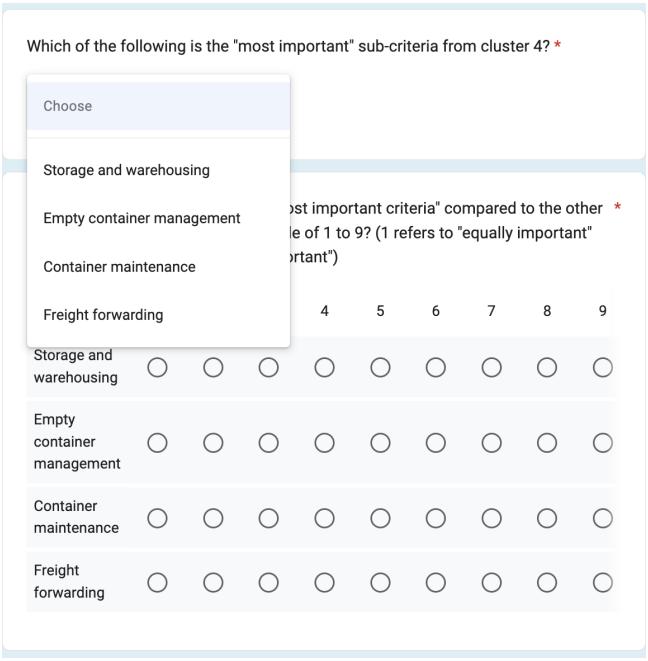


Figure C.13: Survey form 13

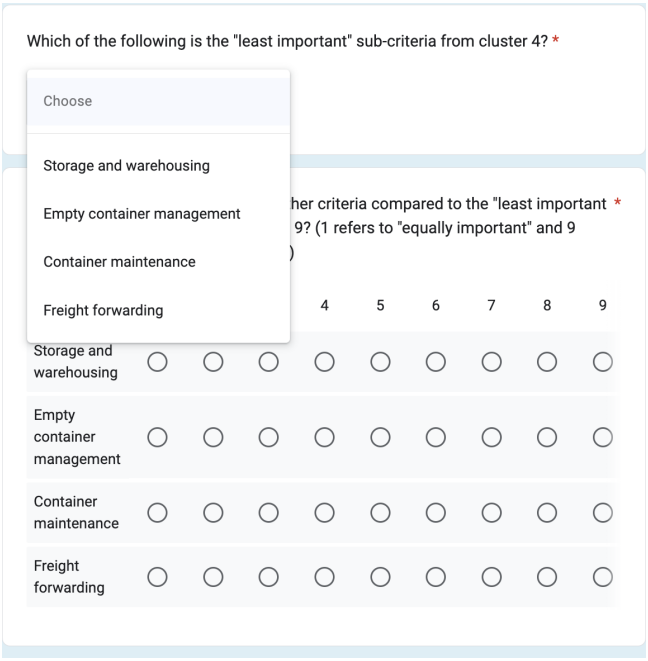


Figure C.14: Survey form 14

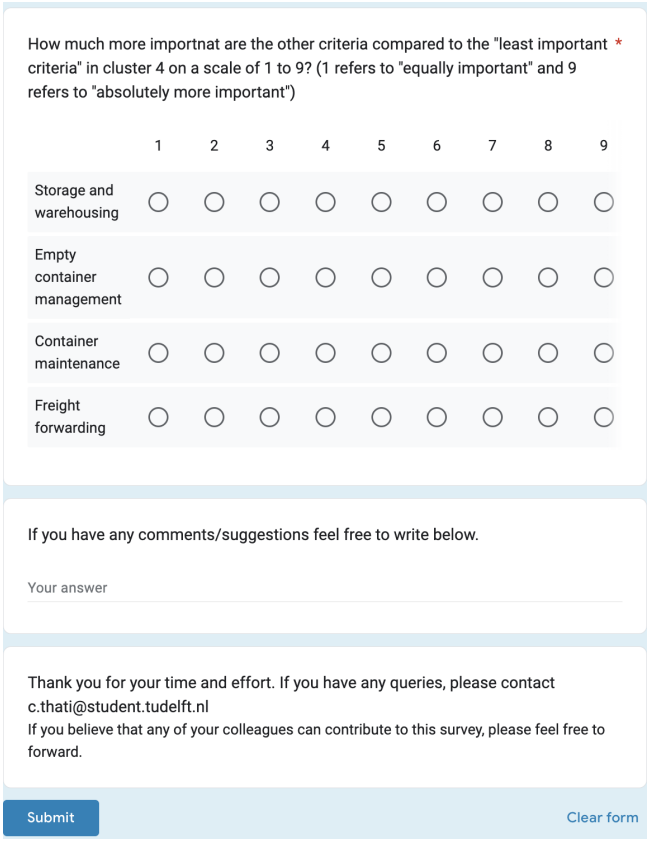


Figure C.15: Survey form 15

Area of expertise/department	Company/Educational institution	Function/Role	Knowledge on inland terminlas and dryports (to 5)
Dry Bulk Terminals	Dry Bulk Terminals Group / European Barge Union	President	4
Sales Management	BCTN	Regional Sales Manager	5
Mobility, Smart en sustainable logistics	Provincie Gelderland	Coordinator	4
Logistics and Ports	RUAS	Professor of Applied Sciences	4
Sustainable rail freight transportation	Sardar Vallabhbhai National Institute of Technology Surat India	PhD Research Scholar	4
Freight transport & logistics	TU Delft	Professor	1
Strategy/Consultant	Weltiston Logistics	Partner	5
Logistics	Fontys Hogescholen	Researher and Project manager	4
Logistics and Seafaring RDI	South-Eastern Finland University of Applied Sciences	Research Director	4
Dry Port Operations, Freight Transportation	Researcher, NIT Calicut ; Scientific	Researcher Faculty	4
Transport / logistics	Aviko	Transportmanager	5
International transport / CEO	Karkia sourena int'l transport co./ KNTU	CEO	4
Maritime and transport technology	TU delft	Student	5
Ports, container logistics	Port of Rotterdam	Programme Manager Business & Accounts	4
Logistics and transport	IMT mines Albi	Ph.D	3
Port and Shipping	Saif Powertec Ltd	Head of research and innovation	5

Figure C.16: Information about the experts