Cold chain dynamics and insights into fresh fruit imports

A value stream map for analyzing operations, challenges, and opportunities for improving the global first-mile fresh fruit reefer cold chain
- Case study Port of Hamburg

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September 2023

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A master thesis submitted to the Delft University of Technology in partial fulfillment of the requirements for the degree of

Master of Science in Transport, Infrastructure & Logistics

by

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September 2023

To be defended in public on September 25th, 2023

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Acknowledgements

Finishing this thesis marks the end of my student career and thereby the end of my time at TU Delft. From the very first day I started my studies at the TU Delft, I held a clear aspiration to engage a segment of my education in Germany. This aspiration led me to the remarkable opportunity of writing my thesis in Hamburg, collaborating with both Kühne Logistics University (KLU) and the Hamburg Port Authority (HPA). The journey from setting up to realization has been a rewarding and transformative experience. I am deeply grateful for the enriching experience I have gained during my stay in Hamburg. I would like to express my gratitude and appreciation to all those who have been a part of my journey and contributed to successfully completing my master's thesis.

I extend my sincere thanks to my graduation committee Lori Tavasszy (TUD), Ron van Duin (TUD), Hanno Friedrich (KLU), and Felix Stoiber (HPA) for their effort, valuable advice, guidance throughout the various stages of this project, and most of all for the opportunity to work on this project here in Hamburg.
To my family, Dutch and German friends, and boyfriend, I would like to thank you for all your unwavering support. Your presence and encouragement have been a source of strength and inspiration.

Reflecting on this project, as well as my educational journey through my bachelor's and master's degrees, I can really see how much I have grown, both personally and academically. Overcoming challenges and gaining knowledge have made me stronger and more knowledgeable. Throughout this research, my passion and interest in maritime reefer logistics operations were clearly highlighted. I'm excited about the prospect of starting a career in this field soon.

Noor Dreesmann

Hamburg/Delft, September 2023

Executive Summary

Research context and methodology

Ports operations are crucial within large-scale supply chains, effectively facilitating the seamless flow of information, commodities, and financial resources. The complex nature of supply chain operations has grown considerably due to structural and strategic shifts, with ports adopting a corporate approach to streamline their logistics. This transformation aims to maintain a significant position within modern logistics and global networks. Among supply chains within port logistics, the food supply chain stands out as the most sensitive and vulnerable. This sensitivity is particularly noticeable in the fresh fruit segment, where products significantly impact human health standards and possess perishable characteristics. The transportation of such perishable commodities requires specialized refrigerated supply chains, commonly referred to as cold chains, with reefer containers predominantly facilitating their transport. The global fresh fruit trade's substantial increase has led to expanding global supply chain operations. Nevertheless, not all ports possess the same readiness to take advantage of the increased demand for fresh fruit trade, as demonstrated by the case of the Port of Hamburg. Despite the food industry being a significant client of the Port of Hamburg, the port has not effectively adapted to the increased trend in fresh fruit handling. This specific segment within the port has shown limited growth for many years. The Hamburg Port Authority is motivated to investigate this operational gap within the port's activities. Their aim is to gain a comprehensive understanding of the operations, challenges, and potential directions for enhancement within the fresh fruit segment of this cold chain.

Existing literature primarily addresses the broader food cold chain, overlooking the import logistics value processes. This oversight deprives the efficiency of specific elements like import first-mile processes, highlighting a significant gap in transparent operational structures for the import-oriented reefer cold chain within the fresh fruit segment. Understanding global first-mile fresh fruit reefer (GFFR) cold chain activities, challenges, and opportunities is key to improving this cold chain logistics at the Port of Hamburg. Therefore, this research aims to explore transparent processes and value structures, identifying strengths, weaknesses, opportunities, and threats for improvement. This aims to support supply chain stakeholders in accommodating the improvement potential within the Port of Hamburg. The research objective leads to the following research question:

"How can supply chain stakeholders effectively accommodate the global first-mile reefer cold chain, with respect to the fresh fruit food segment in the Port of Hamburg?"

To address the research question, a case study is conducted. This case study encompasses several research elements, including a literature and background review, value stream mapping, and opportunity analysis. By combining the findings from these research elements, the research presents the improvement potentials within the Port of Hamburg, answering the research question.

Findings

Through literature review and interviews, the background study categorized five key stakeholder categories influencing the GFFR cold chain at the Port of Hamburg: (port and customs) authorities, terminal operators, cold storage operators, forwarders, and importers. These stakeholders nurture interconnections across diverse supply chain stages, highlighting this cold chain's complexity. Value stream mapping provided deeper insight into these interdependencies, revealing the material and information flows that cross operations and stakeholders.

Various material flows were identified by the value stream mapping, and categorized into four alternative current state maps: direct distribution (including customs scans), indirect distribution, distribution with troubleshooting activities, and distribution with additional processing and logistics services activities. Information flows facilitated cargo movement across these material flows, with stakeholders exchanging information daily to link operations together. The GFFR cold chain in the Port of Hamburg features numerous material and information value streams originating from diverse processes and stakeholders. The complexity of connecting these elements highlights the importance of managing their relationships for optimal cold chain efficiency. Value stream mapping revealed the underlying structure of the value chain, highlighting critical issues like customs scans and quality checks, as well as potential improvements such as additional services, buffer storage, information exchange, and location strategy. These insights guided the focus on specific GFFR cold chain aspects during the opportunity analysis.

The opportunity analysis addressed both internal and external strengths, weaknesses, opportunities, and threats of the GFFR cold chain in the Port of Hamburg, revealing improvement potentials. The internal aspects, focusing on value chain operations, revealed strengths within the operations of buffer storage and additional processing activities while also highlighting weaknesses like customs scan, groupage network, cold storage capacity, operating area, and port area. Regarding external opportunities and threats, the Port of Hamburg is affected by various dynamics within the fruit cold chain and its own operations. These dynamics present opportunities, such as enhancing the food cluster, investing in port infrastructure, and increasing container volume. These opportunities have the potential to address certain threats, including challenges related to vessel scheduling, operational costs, connectivity with shipping lines, and climate change.

The main potentials identified via a SWOT analysis are improving the customs scanning process and enhancing the food cluster at the Port of Hamburg. Addressing internal weaknesses associated with delays and costs of customs scans is crucial due to disruptions in the GFFR cargo flow. Balancing the number of scans and their impact on cargo flow is essential for improved efficiency. Key considerations involve expanding the number and capacity of customs locations, prioritizing perishable goods, and strategic port allocation of the customs locations. Successful implementation requires the customs authority's active engagement and collaboration with forwarders and importers.
The potential to enhance the Port of Hamburg's food cluster addresses internal weaknesses and external opportunities and threats, including current groupage network limitations, shipping line connectivity, and attracting more container volume throughput. This potentially benefits the GFFR cold chain, boosting demand and potentially attracting shipping lines for a stronger market presence. It also streamlines the groupage network for improved transport efficiency and cost savings. However, in the competitive fresh fruit market, strategic importer clustering—possibly grouping non-competing market importers—is vital. Effective realization requires collaboration among importers, forwarders, and other stakeholders to establish a robust food cluster.

Conclusion & Recommendations

Concluding this research, the primary focus for supply chain stakeholders to effectively accommodate the improvement of the global first-mile fresh fruit reefer cold chain lies within maintaining and enhancing the complex relationships between the cold chain's operations and stakeholders. Furthermore, optimizing the GFFR cold chain in the Port of Hamburg may benefit from improving its potential concerning customs scanning procedures and establishing a robust food cluster network.

Future research aiming to build upon this research is suggested to work on the following research suggestions:

- To enhance understanding, future analysis should integrate quantitative data to evaluate the impact of identified potentials on crucial aspects of the cold chain like the key drivers.
- Incorporating shipping agencies into the research scope is recommended, emphasizing their strategic relevance. This inclusion can enhance cold chain comprehension, potentially unveiling additional critical challenges and approaches for improvement.
- Analyzing the competitive dynamics of the GFFR cold chain in the Port of Hamburg, alongside other ports like Rotterdam and Antwerp, is essential to determine the importance of necessary improvements.

Additionally, the following research suggestions are provided for consideration by the Hamburg Port Authority:

- Shift the focus to cluster management, imposing on HPA's neutral position in competitive dynamics to enhance cold chain efficiency through effective cluster management.
- Undertake further research on cold chain connectivity. This approach will facilitate a deeper comprehension of current interests, evolving dynamics, and preferred strategies within the cold chain.

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1.Introduction

1.1. Research context and problem statement

Ports and their logistics operations are crucial as connecting hubs within large-scale supply chains, effectively ensuring the smooth movement of information, goods, and financial resources (Tongzon et al., 2009; Bo & Meifang, 2021). The significance of ports becomes even more evident when considering their essential contribution to global trade. Since the majority of international trade relies on sea routes, maritime transport becomes a vital component that significantly impacts the global economy and worldwide trade (D.-P. Song, 2021). In international trade, the maritime industry guarantees the delivery of 80% of goods across the globe (United Nations, 2022; Bodewig, 2020; Haidine et al., 2021). In Europe, maritime transport plays a key role by transporting 75% of its external trade and facilitating smooth and efficient trade flows within and beyond the European Union (European Environment Agency & European Maritime Safety Agency, 2021; Bodewig, 2020).

In recent global production changes, the complex nature of supply chains has increased significantly. The restructuring of port logistics, involving a shift towards a more corporate approach of ports aimed at sustaining a vital position within modern logistics and global economics networks, has the potential to change the dynamics of logistics and value-driven activities, as well as the effectiveness of supply chains(Notteboom, 2017; Md ibrahim & Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020). This change highlights the critical importance of logistics efficiency to port competitiveness (Alavi et al., 2018; Stock et al., 2000). As a result, supply chain stakeholders need to strike new balances between competing objectives and priorities, such as increased competition, changing customer requirements, and environmental pressures (United Nations, 2022; Luo et al., 2022; Van der Lugt et al., 2013; Chang & Talley, 2019; Cullinane et al., 2005). These structural and strategic changes may influence the operating landscape of supply chains.

Among all product supply chains, the food supply chain is one of the most sensitive and vulnerable contexts of port logistics (Unurjargal, 2019). Within the food supply chain, fruit and vegetable segments are highly relevant considering their significant influence on human health standards (World Health Organization, 2018) and their perishable characteristics. Most fruits and vegetables have a limited shelf-life and are time-sensitive, as this food type rapidly deteriorates, leading to a decline in quality and becoming unsafe for human consumption (Klopott, 2019). Ensuring the quality and safety of fruit and vegetables, and transporting these perishable goods necessitates refrigerated supply chains, commonly referred to as cold chains. Within the cold chain, refrigerated containers (also called 'reefer') have become the standard used transportation form, claiming a substantial 80% market share (Jedermann et al., 2014; Arduino et al., 2015; Mercier et al., 2017; Castelein et al., 2020). In addition to the primarily containerized characteristic of the cold chain, the global fruit and vegetables cold chain is facilitated by multi-modal transport (Z. Liu et al., 2014; Steadieseifi et al., 2014; Keeley et al., 2021). Given these aspects, reefers prove to be the best suitable choice for such transportation due to their capacity to offer logistical flexibility, cost-efficiency, and precise temperature-controlled features (Jedermann et al., 2014; Arduino et al., 2015; Mercier et al., 2017; Castelein et al., 2020).

As highlighted by (Klopott, 2019), based on the United Nations Commodity Trade Statistics Database, there has been a notable growth in the global trade of perishable food products between 2000 and 2017. This trend continues to persist in the present. Fresh fruit holds a significant share of the global trade of perishable food. The growth in the fresh fruit segment can be explained by the increasing demand of customers concerned with healthier diets, requirements in food quality and transport, and the availability of fruit all year around (Reynolds et al., 2014; Soto-Silva et al., 2016). While the increased demand drives the expansion of supply chain operations on a global scale, it is important to note that not all ports are equally positioned to support the increased volume of fresh fruit trade. Particularly, the Port of Hamburg emerges as an example of a port that seems to deviate from the trend of benefiting from these increased economies of scale within fresh fruit handling. Even though the food industry is one of the most important customers of the Port of Hamburg, the port is not accommodating to the current trend in fresh fruit handling. In 2016 alone, nearly 25.5 million tonnes of food and agricultural products were handled via Hamburg, representing about 18.5 percent of total port throughput (Hafen Hamburg Marketing e.V., 2017). However, this segment within the Port of Hamburg has displayed minimal growth for many years. The Hamburg Port Authority is motivated to investigate this operational gap within the port's activities. Their aim is to gain a comprehensive understanding of the operations, challenges, and potential directions for enhancement within the fresh fruit segment of this cold chain.

Understanding the fresh fruit reefer cold chain activities, challenges, and opportunities has practical relevance for the Port of Hamburg to benefit from growing fresh fruit handling operations and academic relevance. The understanding is academically important for enhancing cold chain logistics. Improvement of the cold chain is needed to maintain and protect food quality, which is a significant challenge with the rapidly developing cold chain logistics resulting from the increasing demand for fresh food in the market (L. Zhang & Wang, 2019; Yan et al., 2021). Another major challenge that should be considered is the cold chain's complexity. Because of the multiple links in the cold chain and the many stakeholders involved, transporting perishable products such as fresh fruit is more complicated than storage (Snowdon, 2022).

While all kinds of academic research are performed on the food reefer cold chain and restructuring of port logistics, research on the integration of importing first-mile supply chain logistic activities in the food cold chain has not been studied empirically. So far, it becomes apparent that most research on food cold chain logistics is focused on a complete cold chain with no specific orientation to the value processes of import logistics. This can be explained by the crucial role of transparent operations of the entire supply chain, from harvesting to distribution to the end-consumer. However, by focusing on the whole supply chain, the efficiency of different specific elements, such as import first-mile processes, is deprived. Within the scope of the knowledge gaps, a significant shortcoming emerges concerning the lack of a transparent operational structure of the import-oriented reefer cold chain of the fresh fruit segment. Additionally, the value chain structure for this segment is not yet substantiated. Furthermore, the primary challenges and potential opportunities for integrating and especially improving both systems are unknown.

This research aims to analyze the transparent process and value structures by exploring and providing insight into the integration of value streams regarding the first-mile fresh fruit reefer cold chain on an organizational level and find challenges and potential opportunities for improving these activities in the Port of Hamburg. Additionally, recommendations can be given to improve this specific supply chain.

1.2. Research questions

This research aims to fill the knowledge gaps about the value chain structures, challenges, opportunities, and potential of the first-mile fresh fruit reefer cold chain segment of food supply chain logistics. These knowledge gaps result in the following main research question:

"How can supply chain stakeholders effectively accommodate the global first-mile reefer cold chain, with respect to the fresh fruit food segment in the Port of Hamburg?"

The following sub-questions jointly answer the main research question:

1. How are supply chain stakeholders involved in the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?
    a) Which supply chain stakeholders are involved?
    b) What are the supply chain-related activities of the stakeholders?
    c) How are the stakeholder's activities related to each other?
2. How is the global first-mile value chain structured for the Port of Hamburg's fresh fruit reefer cold chain?
    a) What processes and activities are considered in the value chain?
    b) What are the material and information flow?
    c) How are the material and information flows connected?
    d) What critical issues and potential improvements can be defined?
3. What are the potentials for improvement for supply chain stakeholders to effectively accommodate the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?
    a) What are the strengths and weaknesses of the value chain?
    b) What are the opportunities and threats of the fruit cold chain and the Port of Hamburg?
    c) What are the improvement strategies?

Answering the first two sub-questions provides a clear overview of the global first-mile fresh fruit reefer cold chain's value streams, operations, and stakeholders. By combining the results with the new insights into the challenges and opportunities gained by answering the last sub-question, insight and recommendations may be provided to support decision-makers in accommodating the first-mile fresh fruit reefer cold chain. As a result, the main research question is answered.

1.3. Research scope

The scope of this research is discussed in Table 1.1

Table 1.1.: Scope aspects and description

Aspect	Description
Cold chain	This research refers to the refrigerated supply chain as the cold chain.
Food segment fresh fruit	This research focuses on perishable fruit transported as fresh fruit, excluding frozen fruit. The choice of fresh fruit over frozen fruit was made because transporting fresh fruit is more sensitive regarding satisfying requirements, resulting in a more complex system. This system can most likely be generalized for frozen fruit and vice versa less efficiently.
Global first-mile transport	The transportation network from the land side of the port area to the hinterland distribution centers is considered first-mile transport for this research.
Import	The imported value streams are the focus of this research because most fruit is produced outside Germany and is mostly imported.
Reefer transport	In this research, the transport of a refrigerated container is referred to as reefer transport. This specific focus is chosen because refrigerated containers transport 80 % of the food cold chain. So, specialized refrigerated vessels are excluded.
Port of Hamburg	This research focuses on the supply chain logistics activities of the Port of Hamburg. This means only activities related to supply chain stakeholders in the Port of Hamburg are included.
Supply chain stakeholders	In this research, supply chain stakeholders, such as terminal operators, cold storage operators, transport operators, forwarders, and importers, and port-related stakeholders, such as (port) authorities, are referred to as supply chain stakeholders.
GFFR cold chain	GFFR cold chain refers to the Global First-mile fresh Fruit Reefer cold chain

1.4. Relevance

The relevance of this research comes forth in multiple ways, as shown by the following bullet points:

- The societal relevance of this research lies within the benefits of pointing out bottlenecks and possible improvements in food cold chain processes and value streams, which may result in better food safety and quality specified to the fresh fruit segment.
- The research has scientific relevance for the global first-mile reefer market since no previous integration analyses exist for this specific scope. The methodology used in this research may be helpful for other aspects of the research area, such as different food commodities or even other cold chain products and scopes.
- This research has specific relevance for the Port of Hamburg because a better understanding of the operations, challenges, opportunities, and logistics stakeholders involved in the food cold chain in the Port of Hamburg may result in more specific developments and improvements.
- By developing the framework of the specific supply chain processes and value streams as part of a case study, empirical knowledge is included in the design, adding added value to a framework based on theory. The developed framework should therefore be more relevant and usable in practice.

1.5. Thesis structure

This report is structured as follows: after describing the research context and problem statement, research questions, scope, and relevance of this thesis in Chapter 1, the methodology used to answer the research questions is described in Chapter 2. Chapter 3 consists of a background study in which the relevant literature concerning port logistics in supply chains, the fruit supply chain, the reefer cold chain, the global first-mile fresh fruit reefer (GFFR) cold chain, the GFFR cold chain in the Port of Hamburg, and the Port of Hamburg's GFFR cold chain stakeholder overview is discussed. The information retrieved by the background study forms relevant insight and the basis for the value stream mapping and opportunity analysis by providing an understanding of the GFFR cold chain. Chapter 4 describes the value stream mapping performed and its analysis. In Chapter 5, the opportunity analysis of the GFFR cold chain is discussed. Finally, Chapter 6 concludes the report with a conclusion, discussion, and recommendations.

2. Methodology

This chapter describes the research approach and methods used to answer the research questions stated in Chapter 1. As the research approach is discussed in the first section (Section 2.1), the second section outlines the methods used and their relevance to the research (Section 2.2).

2.1. Research approach

This research aims to analyze a transparent process and value stream framework by exploring and providing insight into value chain activities and structures of the global first-mile fresh fruit reefer (GFFR) cold chain on an organizational level and find challenges and opportunities for improving these activities and structures. This insight is given by creating a framework that consists of a background study, value stream mapping (VSM), and opportunity analysis, which help to map out the potential for improvement of this cold chain.

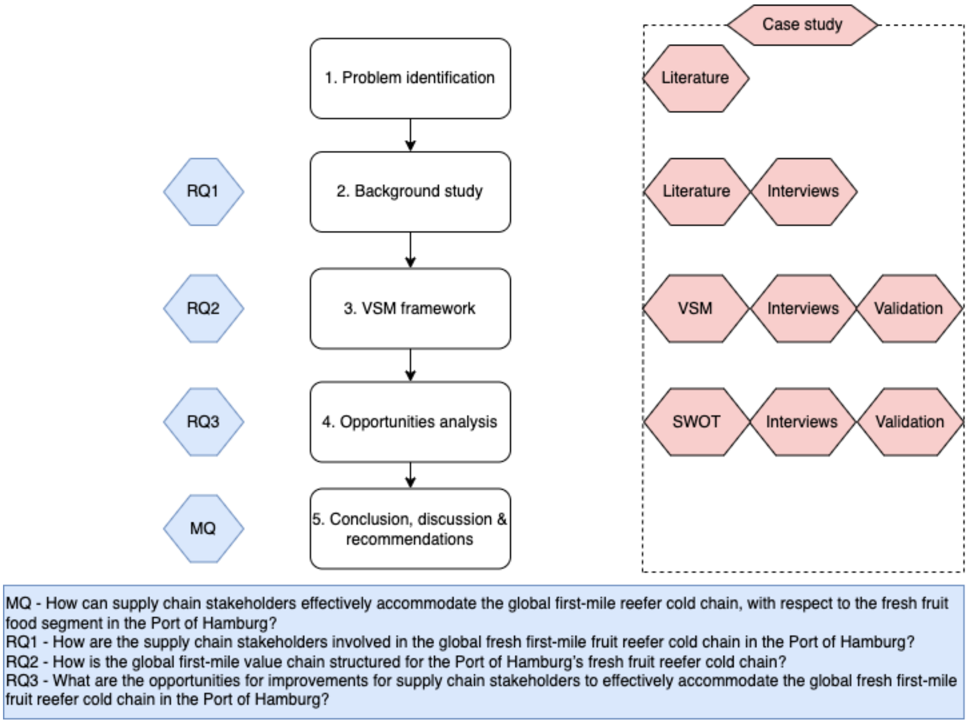

Figure 2.1.: Visualization research approach

The research is split into five research elements. The research elements concerning the research questions and methods are depicted in Figure 2.1. The first research element identified the context, landscape, and problem of supply chain logistics specified to the GFFR cold chain. The problem was converted to a research question that was answered by performing all research elements. In the second element, a background study was conducted. The insight from the background study, including literature review and interviews, was used to understand different aspects of the GFFR cold chain. Moreover, the background study created a base for mapping the GFFR cold chain-related value streams. The third element involved mapping out the supply chain value streams by performing a value stream mapping. Port-specific information for the third research element was gained by conducting interviews with supply chain stakeholders to create value stream maps specified for fruit cold chain logistics for the Port of Hamburg. Furthermore, interviews were conducted as validation of the value stream maps. After analyzing and verifying the results of the maps, the opportunity analysis was performed by conducting a SWOT analysis as the fourth element of this research to obtain more insight into the potential for improvement in the GFFR cold chain. This insight was gathered and validated by the stakeholders by performing interviews. Finally, the findings are discussed, and recommendations on which aspects may be improved or further investigated to improve the GFFR cold chain.

2.2. Methods

This section discusses the different methods that are used in the research. The primary methodology used in this research is a case study performed at the Port of Hamburg, specified to the global first-mile fresh fruit reefer cold chain. The methods of literature research, interviews, value stream mapping, and SWOT analysis have been conducted in addition to the case study. This section explains the steps to perform the methods and their relevance to the research.

2.2.1. Case study

A case study is a methodology that investigates specific research questions in a case setting, which is abstracted and collated to get the best possible answers to the research questions (Gillham, 2000). As a research strategy, a case study is used in various situations to contribute to the knowledge of individual, group, or organizational levels (Yin, 2003). Since a detailed, in-depth description and insight into logistics activities specified for the GFFR cold chain on an organizational level is needed, a descriptive case study is an appropriate strategy (Johannesson & Perjons, 2014; Naz et al., 2022). A descriptive case study aims to provide knowledge by producing a rich and detailed system description. With the focus of a case study on depth and context, this method differs from survey or experiment methods. Additionally, to perform a case study successfully, complexity is essential as a case study investigates a variety of factors, events, and relationships that occur in a real-world case (Johannesson & Perjons, 2014). Given this crucial complexity, the GFFR cold chain system suits well to perform a case study.

In a case study, information can be gathered through documents, interviews, direct observation, and physical artifacts (Gillham, 2000; Yin, 2003, 2009). This case study uses interviews and documents to understand logistics activities for the GFFR cold chain. The analysis of the GFFR cold chain must be performed region-specific because the relative significance of activities and operations efficiency differ per port and so by region. The case study is conducted for the Port of Hamburg in this research.

2.2.2. Literature research

As supply chain logistics and food cold chain structures have already been analyzed, literature research is conducted to determine what aspects of these structures are related to the specific supply and value chain of GFFR cold chain logistics. Additionally, challenges and opportunities to improve the operations of this particular supply chain are identified partly by performing this methodology. The literature research uses scientific literature from search engines on the internet and grey literature partially provided by experts from the Port of Hamburg. The latter might not be scientific articles but expert knowledge on the subject. Relevant articles are used for backward and forward snowballing to verify if the references used in the article are equally applicable.

The following requirements made the literature review selection: first, published in 2019 and published as an academic article in a journal; after this, the period was changed to the last 15 years. The literature was searched via Scopus and Google Scholar. An exception to the requirements was made for the introduction and port- and stakeholder-specific information. Keywords used per research part are presented in Table 2.1.

Table 2.1.: Keywords used for literature review

Research part	Keywords
Problem definition	"port logistics", "maritime logistics", "port management", "container", "cold chain", "reefer (container)", "supply chain", "value chain", "food", "fruits and vegetables"
Methodology	"case study", "semi-structured interview", "interview methodology", "Value Stream Mapping", "VSM", "value stream map approach", "SWOT (analysis)", "SWOT methodology"
Background study	"supply chain", "port logistics", "cold chain", "containerized", "reefer (container)", "(fresh) fruit", "perishable food", "perishable transport", "processes", "operations", "added value services", "Port of Hamburg"

2.2.3. Interviews

Next to the literature research, interviews have been conducted to validate and adjust the insight and data to the specific case study of the Port of Hamburg. Conducting interviews is a method of collecting qualitative data for research (Carter & Little, 2007). The reason for choosing this method for (partly) answering sub-questions in this research is that it is oriented on the specification of implementation of supply chain-related structures in a specific area, like the case study of the Port of Hamburg.

Interviews can be divided into three categories: structured, semi-structured, and unstructured. Since clear answers are needed for this research, but it is expected that more information is required than closed questions and answers, a semi-structured interview method is most appropriate. Semi-structured interviews are based on open-ended questions (Gillham, 2000). This type of interview is performed with a list of questions prepared by the interviewer to ensure that all relevant topics are asked. Nevertheless, the order of the questions is based on how the conversation goes (Runeson & Höst, 2008). Preparing the questions and relevant topics provides an interview focus and guide to ensure that the data collected from various participants is similar and comparable (Taylor, 2005; Kallio et al., 2016; Naz et al., 2022). A semi-structured interview can create a good understanding of the underlying thoughts and relationships between the GFFR cold chain and its logistics operating stakeholders.

To gather information and conduct the semi-structured interviews properly, preparation is set up in a detailed procedure containing seven elements based on Fylan (2005) and Omolola & Olenik (2021), depicted in Figure 2.2. It should be noted that the interviews have been conducted in two rounds. For both interview rounds, the preparation differs in ways of a variety of focus. Nevertheless, the seven elements process applies for both rounds.

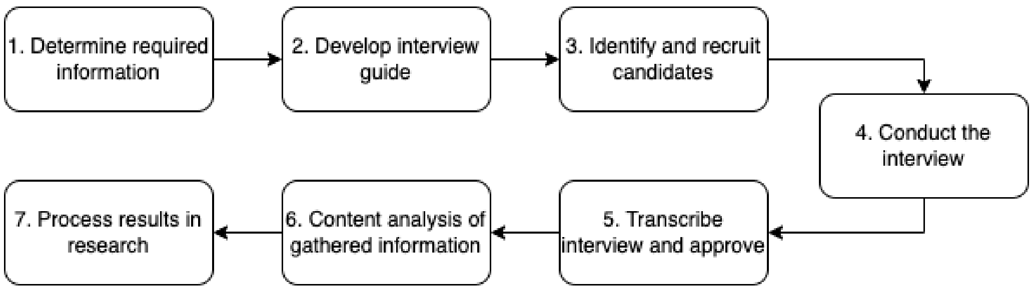

Figure 2.2.: Overview interview process (based on Fylan (2005) and Omolola & Olenik (2021))

The first element was determining the required information to be gathered via interviews. A literature review and evaluation of previous work was conducted. The goals of the two rounds of interviews differ. The first interview goal was to obtain input for the value stream activities and the stakeholders' position in the GFFR cold chain. The second interview goal was to verify the research's presented value streams and obtain insight into the stakeholders' perspectives on associated challenges and opportunities. The second element of the interview methodology was developing an interview guide. An interview guide consists of a list of questions that directs the interview toward the central research topic (Whiting, 2008; Krauss et al., 2009; Magaldi & Berler, 2020). Depending on the interview round, questions have been ordered per topic discussed in the interviews. This is important to ensure that the question order is logical. Appendix B describes the preparation of the interview guides more extensively, including the interview questions. Next, the interview candidates were identified and recruited. The presented stakeholder overview in Chapter 3 supports identifying the interview candidates. The difference in stakeholder characteristics, such as operating or regulating activities in the GFFR cold chain, is relevant to consider when identifying the candidates. After identifying the interview candidates, the candidates were contacted, and the interviews were scheduled. The fourth element was to conduct the interview. Depending on the agreement per interview, the interview was conducted online via two online platforms Microsoft Teams and Zoom, or face-to-face. With the consent of the participants, the interview was recorded. Recording the interviews contributed to the most complete way of processing. The interviewer was better focused on the questions and the participant than ensuring the notes were as complete as possible and all relevant information was captured. After conducting the interview, the recordings were transcribed, and summaries of the relevant information from the transcribed interviews were e-mailed to the participants for approval. The transcripts were adapted to the participant's approval to ensure confidentiality. The sixth element included the content analysis of gathered information. The analysis plan was determined before the interview data was collected, as it helped to capture all pertinent data. First, data from transcriptions were coded to identify and label topics, similarities, and differences in the interview data. Coding provided an overview of the responses per topic compared to the relevant aspects of this research. The difference in interview rounds, stakeholder perspectives, and positions was considered. Secondly, ensuring the rigor of the interview results was necessary. This research established trustworthiness through member checking of the interview findings. Appendix C discusses the interview coding and summaries. The seventh and final element was to process the results in the research report. The results of the first interview round were used as input to perform the background study and value stream mapping. The second interview round results verified the presented value stream maps and supported the opportunity analysis. The results from the interviews contributed to answering the research questions.

An overview of all participated stakeholders in the interviews is shown in Table 2.2. The participants were selected based on their position in the GFFR cold chain in the Port of Hamburg. The positioning of the stakeholders is discussed in Section 3.6. As can be seen, the different participants are referred to with a reference number. The reference number is used throughout the research reporting and analyzing the results of the stakeholder overview (Chapter 3), value stream mapping (VSM) (Chapter 4), and opportunity analysis (Chapter 5). Not all stakeholders were included in both interview rounds due to the relevance or availability of the stakeholders in the interview period. Moreover, additional stakeholders were contacted throughout the research period, which resulted in these participants not contributing to the first interview round but being relevant for the second round. Their perspective was essential and still of influence for the VSM because the second interview round validates the value streams and not only focuses on the challenges and opportunities.

Table 2.2.: Overview interview participants

Reference	Stakeholder type	Perspective	Round
A	Importer	German retailer via Port of Rotterdam	2
B1	Cold storage operator & Importer	Expertise in processes in cold storage	1 & 2
B2	Cold storage operator & Importer	Expertise specialized in bananas	1 & 2
C	Importer	German retailer via Port of Hamburg and Rotterdam	2
D1	Authority	Expertise in strategy and special projects	1
D2	Authority	Various expertise in strategy, road, and rail transport	2
E	Terminal & cold storage operator	Expertise in reefer and fruit handling	1 & 2
F	Importer	German retailer via Port of Hamburg and Rotterdam	2
G	Forwarder	Expertise in forwarding	1 & 2
H	Importer	German retailer via Port of Rotterdam	2
I	Authority	Expertise in agro-food in the Port of Rotterdam	2
J	Forwarder	Expertise in forwarding	1 & 2

The research supporting companies mainly provided potential participants' contacts. This helped to contact the right person with expertise in the GFFR cold chain. Additionally, participants' expertise and contact information were gathered through online research. All candidates were contacted via e-mail with an explanation of the research and a request for an interview. Sometimes, additional information was given via a phone call. The interview date and time were established if a participant accepted the proposal. Background information was provided by e-mail 1 to 2 days before the interview. This was mainly useful to direct the interview to the proper research focus and to gather more in-depth information about the GFFR cold chain.

It appeared to be challenging to get in contact with all stakeholders involved. Nonetheless, at least one participant of all stakeholder categories was interviewed, obtaining the most relevant information for the value stream structure and opportunity analysis from various perspectives. In total, 18 interviews were conducted.

2.2.4. Value Stream Mapping (VSM)

To make improvements in a supply chain, it is necessary to have a transparent understanding of the processes and value flows within a system. To understand what is meant by the term *system* of value stream mapping, it is relevant to understand the difference between the terminology supply chain, value chain, value streams, and processes. The term *supply chain* encompasses all efforts to produce and deliver a final product or service from a supplier to the end-customer (Cooper et al., 1997; Feller et al., 2006). The supply chain perspective focuses mainly on a material flow's supply efficiency and costs. The terminology *value chain* refers to the process in which businesses receive raw materials, add value to them through processes, such as production and manufacturing, to create a finished product, and then sell the finished product to consumers (Walters & Rainbird, 2004; Feller et al., 2006). Thus, the shift in focus defines the difference. Moreover, the difference between a *supply chain* and a *value stream* can be defined as that a *supply chain* encompasses all activities of all stakeholders involved in the product or service cycle. In contrast, a *value stream* only refers to specific activities that add value to a product or service (Ceylan, 2011; Hines & Rich, 1997). Lastly, regarding this research, a value stream is generally a product-oriented flow of processes on a higher level of detail (Kuhlang et al., 2013). In short, a *supply chain* is defined by a downstream perspective of the flow of goods and supplies from the source to the customer, while a *value chain* is characterized by an upstream perspective referring to the customer as a source (Walters & Rainbird, 2004; Feller et al., 2006).

Value Stream Mapping (VSM) is a methodology developed to collect all actions (both value-added and non-value-added) required in a supply chain to bring a product through its essential main flows (Rother & Shook, 2003). VSM provides a transparent, unbiased, fact-based insight into how processes should be managed to achieve and sustain high-performance levels (Deming, 2000; Martin & Osterling, 2014). A lean mapping technique facilitates a comprehensive understanding of system interdependence. By providing this understanding, the variety of supply chain flows throughout the system can be visualized and linked (Dinesh et al., 2007; Rother & Shook, 2003). Additionally, the quantitative nature of VSM provides the foundation for strategic decision-making (Martin & Osterling, 2014). As Womack et al. (1990) and Womack & Jones (1996) describe, a value stream is the sequence of activities required to design, produce, and deliver a good or service to an external customer. The activities include information and material flows. Nevertheless, not all value stream activities may occur sequentially but parallel to other work. Additionally, value stream activities are not just performed by an organization itself but also by third parties and even the customers themselves. A variety of forms of value streams are (1) information, (2) material, (3) support/ value-enabling such as IT support, recruiting, and sale cycles, and (4) product life cycle (Martin & Osterling, 2014). These forms can be categorized into value-adding (VA) streams, non-value adding (NVA), and necessary but non-value adding (NNVA) (Hines & Rich, 1997; Monden, 2019; Singh et al., 2011).

Various methodologies can be employed to identify and analyze process mappings, such as Workflow Techniques, Business Process Model and Notation (BPMN), Data Flow, Unified Model Language (UML), SIPOC, and IDEF0 diagrams. Each method presents its unique advantages and disadvantages, with some more oriented toward micro or macro-level scopes and others focusing on information or workflow systems. For this research, the specific focus on analyzing the organizational level of the whole system and the influence of stakeholders within the context of the GFFR cold chain led to the selection of particular methods. Given the emphasis on the organizational level, particularly the macro-level of the system, specific methods that primarily target micro-level processes and systems, such as BPMN diagrams, were not included. Moreover, it is essential to note that comprehending the GFFR cold chain to enhance overall performance necessitates understanding both the material flow and the information flow across different system components, encompassing the interrelationships among all processes and diverse stakeholders, which resulted in more selection or even combination of methods to gain the proper insight.

The VSM methodology aligns seamlessly with the research goals due to its characteristics focused on the macro-level system and documenting the relationships between the manufacturing processes and the controls used to manage these processes (Singh et al., 2011). Value stream mapping, from the macro perspective, provides the means and tools for decision-making and work design to define strategic improvements to work and regulate a flow, whereas process-level mapping enables people on a micro level to design tactical improvements (Martin & Osterling, 2014). VSM, operating from a macro perspective, facilitates decision-making for strategic improvements within the GFFR cold chain. Moreover, VSM's broader outlook encompasses both individual processes and the entire process overview, crucial for considering relationships with various business partners along the same supply chain (Dinesh et al., 2007; Rother & Shook, 2003). Given the complex nature of the GFFR cold chain involving numerous stakeholders, this holistic approach proves relevant and valuable.

The VSM approach in this research involves strategically reviewing the supply chain's activities and mapping these processes. Within the context of this research, the representation of physical and information flows of the global fresh fruit reefer container cold chain is created by the following six steps (partly based on (Rother & Shook, 2003)):

1. Identification specific value stream to be reviewed (scope)
2. Identify material flow
3. Identity information flow

4. Analyze flow categories
5. Analyze critical issues
6. Identify improvement potentials

The first four steps are discussed in Chapter 4, and the last two steps are included in the opportunity analysis presented in Chapter 5. It should be noted that, in general, performing a VSM also includes mapping out the future state value streams. However, this research focuses on identifying the current state and analyzing critical issues in the current state. Further research into strategic and structural gaps and the potential impact of these improvements is necessary to create the future state value stream map that provides the strategic framework to make tactical improvements. Further description of performing the VSM for this research is elaborated in Chapter 4.

2.2.5. SWOT analysis

In this research, the opportunity analysis involved a SWOT analysis methodology to uncover improvement potential. The SWOT analysis framework is a structured planning tool that provides significant insights into the factors that either promote or hinder the progress of an organization or industry (Irfan et al., 2020). This insight is provided by assessing aspects of a system in terms of the strengths, weaknesses, opportunities, and threats (Jackson et al., 2003; Kim, 2005). The internal aspects, encompassing strengths and weaknesses, refer to factors that are under the control of the business or, in this research context, the stakeholders engaged in the GFFR cold chain. The external aspects, which encompass opportunities and threats, are factors beyond the businesses' control (Bull et al., 2016; M. E. David et al., 2017; Hill & Westbrook, 1997; Lee & Sai on ko, 2000; Shariatmadari et al., 2013).

In addition to assessing internal and external factors within a system, a SWOT matrix (Figure 2.3) was constructed to effectively generate alternative options for a business in terms of strategies (Lee & Sai on ko, 2000; Valentin, 2001; Wang, 2007; Weihrich, 1982; Benzaghta et al., 2021). This approach serves as a structured framework, shedding light on how an organization's strengths and weaknesses align with emerging opportunities and threats. Decision-makers, in light of these internal and external dynamics, can formulate four distinct strategies: SO (Strengths - Opportunities), ST (Strengths - Threats), WO (Weaknesses - Opportunities), and WT (Weaknesses - Threats) (Bayram & Üçüncü, 2016; F. David et al., 2019; Thomas et al., 2014; Benzaghta et al., 2021). The SO strategy takes advantage of opportunities, while the ST strategy focuses on reducing threats. The WO strategy aims to address weaknesses to create new opportunities, and the WT strategy aims to mitigate threats by reducing weaknesses.

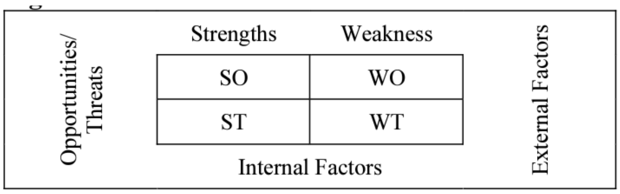

Figure 2.3.: SWOT Matrix (Benzaghta et al., 2021)

The SWOT analysis serves as a practical tool during the evaluation phase, offering initial insights into potential future consequences of a system (Armstrong, 1982; Robinson & Pearce, 1988). This methodology is widely recognized for its user-friendliness and does not necessitate complex computer systems or software (Beeho & Prentice, 1997; Benzaghta et al., 2021). By conducting a SWOT analysis, a solid foundation for effective strategy formulation is provided in this research.

3. Background study

This chapter discusses the background study of this research. The background study is relevant to gaining information for understanding the global first-mile fresh fruit cold chain in the Port of Hamburg. The understanding of port logistics in supply chains (Section 3.1), the fruit supply chain (Section 3.2), the reefer cold chain (Section 3.3), the Global First-mile fresh Fruit Reefer (GFFR) cold chain (Section 3.4), GFFR in the Port of Hamburg (Section 3.5), and stakeholders involved in this cold chain in the Port of Hamburg (Section 3.6) are of relevance to perform the value stream mapping and opportunity analysis.

It should be highlighted that this chapter is based on literature research and expertise from GFFR cold chain stakeholders gained by conducting interviews. Keywords used for literature review in almost all sections are: "supply chain", "cold chain", and "(fresh) fruit". The following more specific keywords used for literature review per sections are given: Section 3.1 "port logistics"; Section 3.2 "perishable food", "reefer (container)"; Section 3.3 "containerized", "reefer (container)", "perishable transport"; Section 3.4 "perishable food", "reefer (container)", "processes", "operations", "added value services"; Section 3.5 "Port of Hamburg", "containerized", "reefer (container)"; Section 3.6 "Port of Hamburg".

3.1. Port logistics in supply chains

The last few decades have profoundly restructured the port and maritime sectors. An evolving new approach perceived ports as business ventures regardless of their institutional, operational, or functional status. The wave of the corporatization of port authorities in Europe reflects the increasing business and market-oriented approach to port management and logistics (Notteboom, 2017). This approach is crucial because ports have seen a decrease in their role as dominant players in multi-modal systems caused by the supply chain restructuring and containerization (Sletmo, 1999; Pallis et al., 2011; Mangan et al., 2008). Restructuring the port logistics is still essential because ports must be seen as elements in the value-driven supply chain and, thereby, should add value to shippers and third-party service providers. With the restructuring, improving port activities, and the integration of ports into the world economy, it can be seen that ports are playing an increasingly important role in modern logistics as a vital node in the logistics process and global economics (Md ibrahim & Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020). The port's role as a critical node consists of being a linking point in larger logistics chains in a global distribution channel. To let these global channels be successful, a higher level of collaboration and coordination is needed (Alavi et al., 2018).

As port- and supply chain-related stakeholders communities are expanding and organizational complexity is tremendously growing, port executives are called to manage the different interests and goals of various participants, to build unanimity and attract the resources required for port strategies (Van der Lugt et al., 2013; D. W. Song & Parola, 2015). In maritime transport's current fast-evolving operating landscape, stakeholders must strike new balances between competing objectives and priorities (United Nations, 2022). Over the last few years, these objectives and priorities in the port's environment have been mainly about increased competition, changing customer requirements, and environmental pressures. Increased competition occurs not only between port-related stakeholders within a port but also between ports worldwide due to better transportation infrastructures and facilities and increased port density, resulting in improved hinterland access. Competition increased among the ports serving the same hinterland because seaports no longer have an exclusive hinterland (Luo et al., 2022; Van der Lugt et al., 2013; Chang & Talley, 2019; Cullinane et al., 2005).

The way port logistics service supply chains are constructed has become an essential method for ports to strengthen their competitiveness and meet the customer's demand for fast, agile, and flexible competition (Fosso Wamba et al., 2018; Yang, 2019). As Alderton (2013) and Alavi et al. (2018) discuss, port services can be divided into three primary services and activities: marine service, terminal service, and logistics and value-added services. The marine services are provided via nautical infrastructure, terminal services via quay and berth infrastructure, and logistics and value-added services via port superstructure. The port's logistics value-added services exceed the primary logistics facilitation, such as storage in warehouses and shipping. Value-added services include supply chain processes such as repackaging, labeling, or setting up logistic networks. This kind of service adds value to the initial value of the cargo shipped, thus benefiting the cargo's owner and stimulating the efficiency of the supply chain (Menegaki & Alexopoulos, 2017; Alderton, 2013).

3.2. Fruit supply chain

With the increase in consumption, which boosted the scale of supply chain processes, consumers and other regulatory organizations increased their interest in monitoring the whole process of the product cycle, especially for the sake of safety and genuine provenance. Among all product supply chains, the food supply chain is one of the most sensitive and vulnerable contexts of port logistics (Unurjargal, 2019).
Food can be categorized per shelf-life. It can mainly be divided into short or long shelf-life, also classified as time-sensitive (perishable) and non-time-sensitive food. Perishable food commodities have a limited shelf-life and are time-sensitive because this food type may rapidly deteriorate and lose quality in ambient temperature and atmosphere, becoming unsafe for human consumption. Perishable food commodities include agricultural goods such as fruit, vegetables, and animal (such as fish and meat) products (Klopott, 2019). From the food cluster, the fruit and vegetable segments are highly relevant because the WHO regards the intake of fresh fruits and vegetables as one of the essential indicators of human health standards (World Health Organization, 2018). This indicator is determined due to the positive effect on improving human health and preventing the occurrence of trace element deficiency and chronic diseases by the intake of fresh fruits and vegetables (Qi et al., 2022; W. Liu et al., 2021; Kaulmann & Bohn, 2014; A. Chen et al., 2016; Mainvil et al., 2011).

As Klopott (2019) discusses, based on the United Nations Commodity Trade Statistics Database, there has been a growth in the global trade of perishable food products between 2000 and 2017 by 119.2 million tonnes. As seen in Figure 3.1, fresh fruit has a significant share in the global trade of perishable food. The growth in the fresh fruit sector can be explained by the increasing demand of customers concerned with healthier diets, requirements in food quality and transport, and the availability of fruit all year around (Reynolds et al., 2014; Soto-Silva et al., 2016). Moreover, fruit provides many health benefits because it is an essential source of nutrients such as vitamins, minerals, and bio-active compounds (Onwude et al., 2016; Salehi & Aghajanzadeh, 2020; Jiang et al., 2020; Cömert et al., 2020; Onwude et al., 2020). As is pointed out by Rodrigue (2014) and Van Duin et al. (2018), fresh logistics chains, such as the fruit supply chain, are more and more based on the export of fruit and vegetables from Africa and Middle and South America. Over the last decades, in global trade, the European Union has dominated the import and export market of fresh fruit (Soto-Silva et al., 2016).

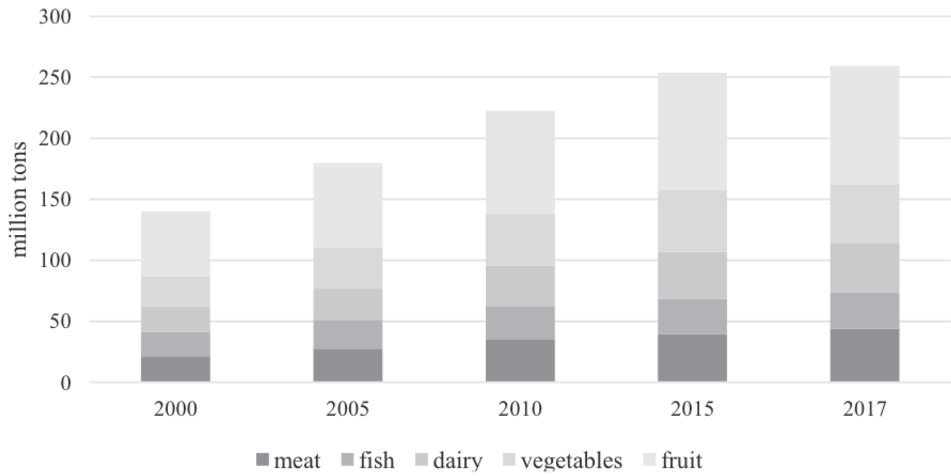

Figure 3.1.: Global trade of perishable food in 2000-2017 (Klopott, 2019)

Tan et al. (1998) defines a supply chain structure as a network of business units and facilities that produce raw materials, transform them into intermediate goods and final products, and distribute final products to customers. The fresh fruit supply chain refers to a complete functional structure network chain connecting all stakeholders in the physical movement from farmers to the end-consumer (Xu et al., 2020; Y. Zhang et al., 2022). Perishable food, including fresh fruit, is mainly transported by the cold chain, primarily containerized. The processes of the containerized cold chain are similar to the general food supply chain. However, the products in the supply chain should be kept under an acceptable temperature range, ensured by using refrigeration technology (Y. Chen & Yang, 2022; Han et al., 2021; Zhao et al., 2018). The proper temperature range is needed to slow biological decay processes and deliver safe and high-quality foods to consumers (Li et al., 2021). For this reason, refrigeration is a crucial element in enhancing the quality of fresh fruit and extending the shelf-life (Onwude et al., 2020). As such, it is essential to cool down fresh fruit as soon as possible after harvest to preserve their quality and maximize shelf-life (Tagliavini et al., 2019). Moreover, the proper temperature range must be kept from the point of production and processing to the distribution to the end-consumer (Montanari, 2008). The temperature aspect of the entire supply chain results in complexity. The supply chain has become even more complex with the increased global trade of fresh fruit transport.

Fruit commodities vary in many aspects that influence the fruit's shelf-life and quality, such as color, flavor, softening, and texture. Understanding the variety of additional conditions for storage and transportation per fruit type contributes to achieving optimum quality and shelf-life in the fruit supply chain. Table 3.1 points out the recommended atmospheric conditions needed per fruit type, based on Hamburg Süd (2019), Behdani et al. (2019), and Bachmann & Earles (2000). It should be noted that the approximate shelf-life is given from the moment the fruit is harvested and is held in ambient air. It can be seen that the approximate shelf-life differs per research because, in the fresh fruit transport sector, no precise or firm data is given. Nevertheless, the results largely converge, except for kiwifruit.

Table 3.1.: Overview fresh fruit commodities (Hamburg Süd, 2019; Behdani et al., 2019; Bachmann & Earles, 2000)

Fruit commodity	**Recommended Temperature (°C)**	**Relative humidity (%)**	**Approximate shelf-life after harvest (Hamburg Süd, 2019)**	**Approximate shelf-life after harvest (Behdani et al., 2019; Bachmann & Earles, 2000)**
Apples	-1 to + 4	90 to 95	4 - 31 weeks	13 - 35 weeks
Apricots	-0.5 to 0	90 to 95		1 - 3 weeks
Avocados	+4 to +13	85 to 95	2 - 3 weeks	2 - 4 weeks
Bananas	+13 to + 14.4	90 to 95	2.5 - 3 weeks	1 - 4 weeks
Blackberries	-0.5 to 0	90 to 95		2-3 days
Blueberries	-0.5 to 0	90 to 95	1.5 - 2 weeks	2 weeks
Cherries, sweet	-1 to 0	90 to 95	2 - 3 weeks	2 - 3 weeks
Dates	0 to +2	65 to 85	26 - 52 weeks	
Grapefruit	+10 to +15	85 to 90	4 - 8 weeks	6 - 8 weeks
Grapes	-0.5 to 0	85 to 95	4 - 22 weeks	2 - 8 weeks
Kiwifruit, green, golden	-0.5 to +5	90 to 95	8.5 - 13 weeks	13 - 22 weeks
Lemons	+ 10 to +14	85 to 95	4 - 13 weeks	4 - 26 weeks
Limes	+8 to +12	85 to 90	2 - 5 weeks	3 - 5 weeks
Lychee	+2 to +6	90 to 95	3 - 5 weeks	
Mandarins	+4 to +8	90 to 95	3 - 8 weeks	
Mangoes	+8 to +14	95 to 95	2 - 4 weeks	
Melons, cantaloupe, charentials	+2 to +5	90 to 95	1 - 2 weeks	
Melons, Galia, orange flesh	+7 to +8	90 to 95	2 - 3 weeks	
Melons, water, honeydew, piel de sapo	+ 9 to + 12	85 to 95	2 - 3 weeks	2 - 3 weeks
Oranges	+2 to +10	85 to 90	4 - 13 weeks	8 - 12 weeks
Papayas	+7 to +13	85 to 90	1 - 3 weeks	
Peaches, nectarines	-0.5 to 0	90 to 95	2 - 5 weeks	2 - 4 weeks
Pears	-1.5 to 0.5	90 to 95	4 - 35 weeks	8.5 - 30 weeks
Persimmon, kaki	-1 to +1	85 to 95	3 - 13 weeks	
Physalis, cap gooseberries	+9 to + 16	65 to 85	3 - 6 weeks	
Pineapples	+7 to +13	85 to 90	2 - 3 weeks	2 - 4 weeks
Plantains	+9 to +12	85 to 95	1 - 4 weeks	
Plums	-0.5 to 0	90 to 95	2 - 5 weeks	
Pomegranates	+5 to +9	90 to 95	8.5 - 13 weeks	
Raspberries	0.5 to 0	90 to 95		2 days
Strawberries	-0.5 to 0	90 to 95	2 - 8 days	5-7 days

Various atmospheric conditions influence the optimum quality and shelf-life of fresh fruit. Among these factors, temperature and humidity conditions are the most noteworthy conditions (Abeles et al., 1992; Behdani et al., 2019; Hamburg Süd, 2019; Van Duin et al., 2019; Kumar et al., 2020). The temperature condition includes the set point and deviation of temperature control of the fruit commodities transported. As all fresh fruit commodities are transported as chilled fruit, generally kept at a set point temperature above -5 °C, it can be stated that the generally allowed deviation is +/- 1 °C (Van Duin et al., 2019).

To guarantee continuous temperature control of refrigerated containers (also known as reefers), not only the set point and deviation are taken into account, but also minimizing the offline time and ambient temperature of the fresh fruit (Van Duin et al., 2019; Kumar et al., 2020). Fluctuating temperatures while storing and transporting the fruit negatively affect the quality and shelf-life. Storing fruit above optimal temperature may shorten the shelf-life, and storing fruit below optimal temperature may also cause damage such as discoloration and improper ripening (Rodrigue, 2014). Moreover, although temperature and humidity are the most important factors mitigating the perishability of fruit, the ethylene and respiration conditions are also significantly influenced. Ethylene is a plant hormone that regulates many physiological reactions of fresh fruit (Abeles et al., 1992; Behdani et al., 2019). The fruit continues to generate chemical reactions once harvested. These chemical reactions consume oxygen and release carbon dioxide, water, and ethylene. Per fruit commodity, ethylene gas influences ripening on a different level. For these reasons, the conditions within the reefer containers are highly relevant to ensure the quality of the fresh fruit commodities during transport (Rodrigue, 2014).

3.3. Reefer cold chain

Cold chain refers to temperature-controlled transportation along a supply chain that allows for trade in perishable products (Rodrigue & Notteboom, 2017; Goedhals-Gerber et al., 2017). Recent studies into the cold chain, specializing in the food supply chain, give insight into the wide range of product categories transported by the cold chain (Castelein et al., 2020; Hamburg Süd, 2019; Fefelova, 2018; Klopott, 2019), which is shown in Figure 3.2. An outstanding observation from Figure 3.2 is that not only perishable goods but also non-perishable goods, such as electronics and footwear, are transported in the cold chain by refrigerated containers. This trend occurs because of the sensitivity to extreme temperatures of these non-perishable goods (Castelein, 2021). Nevertheless, non-perishable goods are a very small share of cold chain cargo. One of the most relevant cold chain cargo is food products. Its history can partly explain this. While the first refrigerated ship for the banana trade was introduced in 1902, pharmaceuticals and medical supplies transported via the cold chain are a much more recent activity. Of the food products, fruits and vegetables are most commonly transported by the cold chain. The fruit banana is the world's most significant commodity transported in the food reefer cold chain, accounting for 20% of all seaborne reefers trade (Rodrigue & Notteboom, 2017).

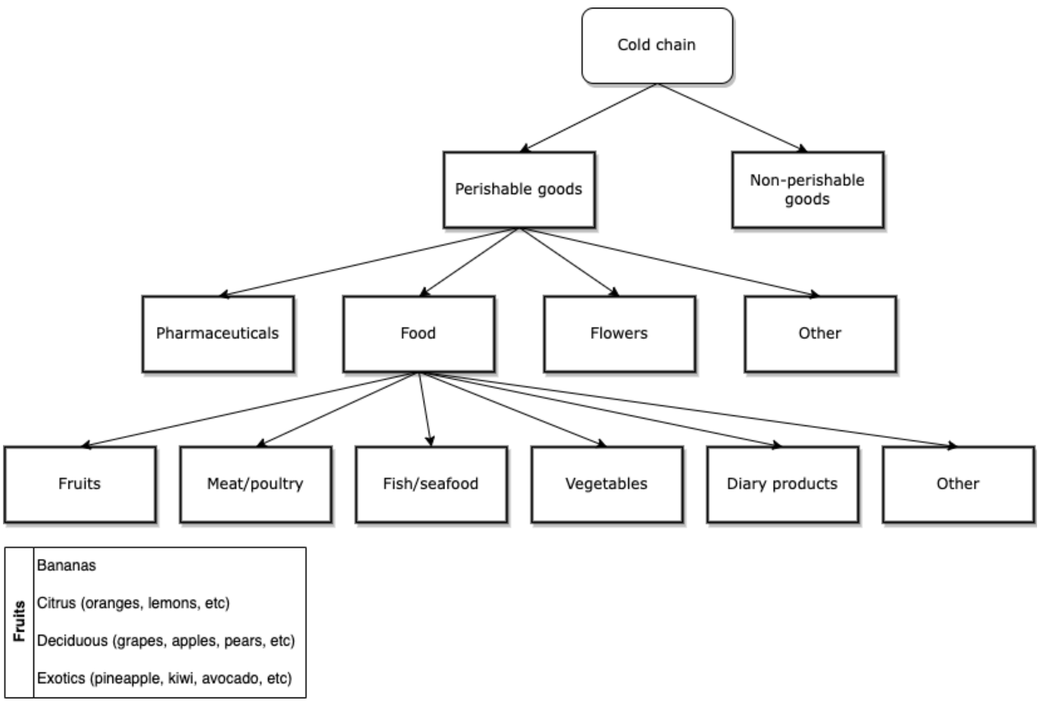

Figure 3.2.: Overview of the product categories of the cold chain logistics, specified on the research focus

Although specialized vessels (20 % of the market share) may also be used to transport perishable food with a short shelf-life, reefer containers have become the standard used transportation form (80 % of the market share) because they provide greater logistical flexibility and cost-efficiency for smaller shipments (Jedermann et al., 2014; Arduino et al., 2015; Mercier et al., 2017; Castelein et al., 2020). Great growth can be seen in the share of reefer usage, considering that 33 % of the refrigerated transport capacity in maritime shipping was containerized in 1980 (Rodrigue & Notteboom, 2017) compared to the 80% nowadays. The increasing use of reefer follows the shift to the containerization of general freight (Goedhals-Gerber et al., 2017).

The equipment and facilities in cold chain logistics rely on refrigeration equipment such as low-temperature facilities, cold storage warehouses, refrigerated vehicles, freezers, display cabinets, and domestic refrigerators (Gao et al., 2021; James & James, 2010; Zhao et al., 2018; Y. Chen & Yang, 2022). There is a wide range of technologies for producing cold conditions for food handling equipment for the different cold chain logistics processes. The technologies vary between using ice to more complex systems such as hydro-cooling or vacuum cooling, and from small walk-in cold rooms to large refrigerated warehouses for storage (Kitinoja, 2013). The reefer container cools down the air circulated in the container by two fans. The cool circulation is provided via the cold air flows that flow into the cargo hold at the bottom of the container and the warmer air that is fed back into the cooling unit at the top. In this way, the cooled air is circulated through and around the products in the container (Castelein et al., 2020; Hamburg Süd, 2019; Fefelova, 2018). The main difference between chilled and frozen transport is that the cooled airflow in the container of chilled cargo goes through the content, while in the case of frozen cargo, the airflow goes around the cargo (Fefelova, 2018).

The suitability of using different cool technologies depends upon the food product category being handled and the level of sophistication of the cold chain. Fresh fruit is mainly transported by chilled transport. Nevertheless, the preferred temperature differs per fruit commodity. The preferred temperature per fruit commodity is stated in Table 3.1. The temperatures in reefer containers may differ dependent on the preferred temperature. The most common temperature standards that are used to transport products in a reefer container are (Castelein et al., 2020; Van Duin et al., 2019; Hamburg Süd, 2019; Fefelova, 2018):

- Deep frozen - generally kept at a set-point temperature below - 25 °C
- Frozen - generally kept at a set-point temperature below -10 °C
- Chilled - generally kept at a set-point temperature above -5 °C
- Mid-chilled - generally kept at a set-point temperature above -3 °C but below +16 °C

The urge to stay within the preferred temperature range is vital to provide integrity of a shipment along the cold chain (Rodrigue & Notteboom, 2017). Maintaining a constant temperature range at a required set-point within a reefer is depended on the right conditions of packaging, a secure energy supply, and adequate handling of the container at various transfer points (Castelein, 2021). Different temperature requirements within the cold chain products lead to reefers' power requirements variations. One of the most essential requirements is a small bandwidth time to switch reefers on or off due to the sensitivity to temperature fluctuations of fresh food (Van Duin et al., 2018). Reefer units require an electric power source during transportation and at a container yard. The turnover of reefers between the multi-modal transportation modes is a critical process for switching bandwidth time on or off because of the difference in power sources. The power is provided directly by the ship's generator for ship reefer transport. For rail transport, diesel generators are used. Power for transport by road is mainly provided by a clip-on generator or underslung generator(Rodrigue & Notteboom, 2017). At container yards, reefers generally are responsible for about 30-35 % of the energy consumption (Sapiña et al., 2013; Geerlings & Van Duin, 2011; Van Duin et al., 2018). The different temperature requirements per transportation node highlight the relevance of a connected cold chain to ensure cargo quality.

3.4. Global First-mile Fresh Fruit Reefer (GFFR) cold chain

A specific challenge for managing the perishable supply chain, like the fresh fruit cold chain, is the deterioration in the quality of products over time throughout the different stages of the supply chain (Rong et al., 2011; Behdani et al., 2019). The global fruit (GF) cold chain is generally the physical movement of products from the processes of harvesting to processing, packaging, storing, transporting, and retailing until it reaches the final consumer under a preferred, acceptable temperature range (Acciaro et al., 2018; Unurjargal, 2019; Behdani et al., 2019; Shabani et al., 2015; Mercier et al., 2017; Kitinoja, 2013). Figure 3.3 visualize the main stages in a global fruit cold chain, based on Behdani et al. (2019) and Castelein (2021). It should be emphasized that this visualization is a simplification and only outlines the physical processes, not the administrative, transaction, and governance processes that support but are not directly involved with the physical supply chain processes (Van Baalen et al., 2008).

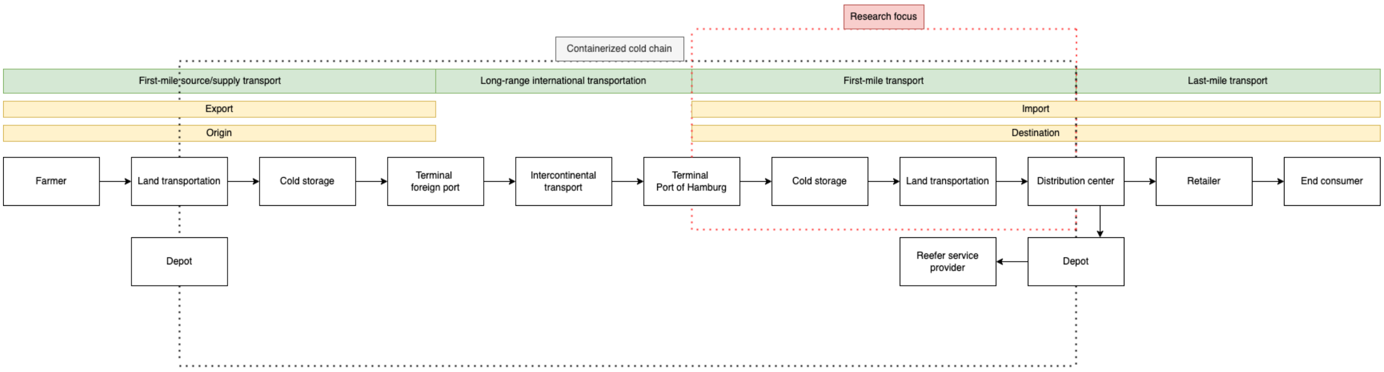

Figure 3.3.: Overview of global fruit cold chain stages (based on Behdani et al. (2019); Castelein (2021))

The first stage is to harvest and pre-cool the products at the farm. Pre-cooling is one of the most important stages in the cold chain operations used in the maintenance of perishable food due to existing reefer technologies mainly being designed to maintain an acceptable temperature range within the reefer and not reduce the temperature of products inside the reefer (Ryan, 2017; Brosnan & Sun, 2001). After harvesting and pre-cooling, the cargo is consolidated in a reefer container from an empty depot. From this point onward, the containerized fruit cold chain can be called a global fruit reefer (GFR) cold chain. The fruit cargo must be transported to cold storage facilities where the cargo is stored temporarily. Additional processes, such as packaging or processing, are sometimes needed to prepare the GFR cargo for long-range transport. After shipping the GFR cargo via long-range international transport from the port of origin to the port of destination - usually a journey of several weeks- the products must be unloaded from the ship and stored in cold storage facilities. The cargo remains in cold storage until transported to the hinterland's distribution center. Cold storage is essential in the GFR cold chain because, like any other good, fruit can rarely be made immediately available for final consumption. To facilitate cold storage, large refrigerated warehouses may be used. Further, specialized distribution centers have been designed to support the time-sensitive and efficient storage of fruits (Fefelova, 2018). At a distribution center, the reefer is stripped, after which the fruit cargo is further distributed. Additionally, the container and product flows are separated at the distribution center. The product flow continues in its last stage, the last-mile distribution of fruit cargo to the end consumer via a retailer. The container flow is the flow of stripped reefers to the reefer service provider via a depot. The reefer container is then re-positioned to be used for other cargo types. The last flow is of relevance to connecting the containerized cold chain.

The red-dotted line in Figure 3.3 represents the research focus on the global first-mile fruit reefer (GFFR) cold chain. As can be seen, the containerized transport flow is not fully included. The decision to concentrate solely on imported reefer transport is made due to this research's time and available information limitations. Including export and import distribution stages would not be feasible within this study's scope. Therefore, the deliberate focus on import activities is informed by the fact that a larger quantity of fruit is imported to Germany than exports. Moreover, the decision to narrow the scope to the first-mile, rather than encompassing all import stages, including first and last-mile distribution, aligns with the emphasis on containerized cold chain dynamics. The containerized transport terminates at the distribution center, where the reefer container is typically unloaded. Subsequently, the cargo is no longer transported using a reefer container.

The research focus is taken into account by creating a more deep-in look at activities and the stakeholders involved in the GFFR cold chain. In this research, the material and information value stream flow of reefer fresh fruit cargo is reflected, leaving aside other activities and parties involved as financial, legal, information support (IT), and administrative transactions that are needed to make container movements possible. Nevertheless, governmental-related activities and stakeholders are included in addition to the logistic-related stakeholders. Governmental-related stakeholders are included due to the regulating and support function of their processes in the GFFR cold chain, specified to the port processes. Next to this, shipping agents and reefer service providers are not included in the research scope because these stakeholder categories are mainly indirectly involved in the GFFR physical processes of the first-mile distribution and so have more of a role as a third party, hired by one of the other operating stakeholders. For example, terminal operators unload the shipment of the shipping agents. The main stakeholder categories involved in the GFFR cold chain are presented in Figure 3.4.

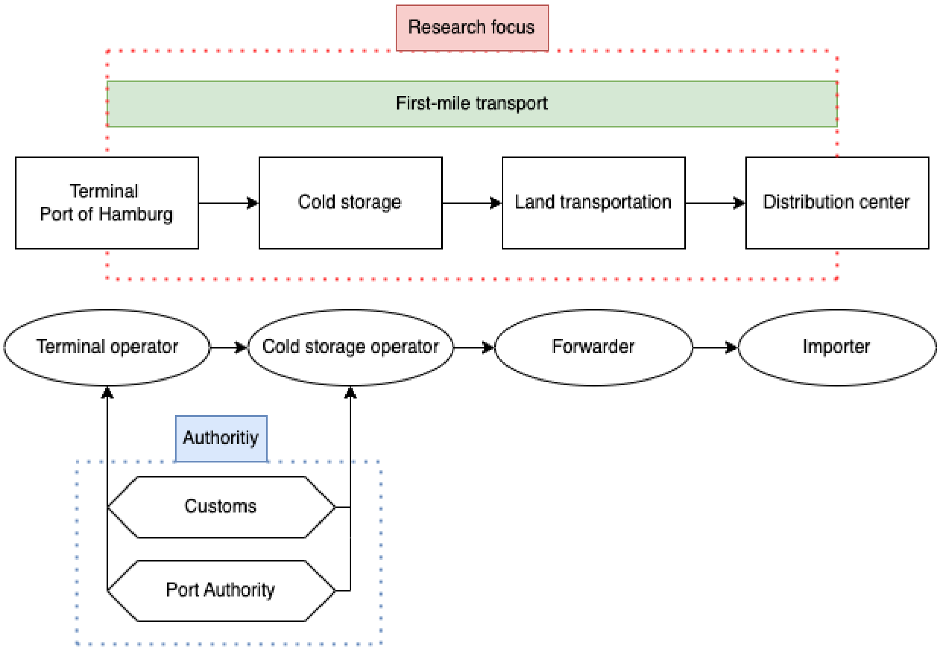

Figure 3.4.: Overview of main stakeholders categories involved in GFFR cold chain (based on Castelein (2021)

The overview in Figure 3.4 presents the main operating logistic and governmental stakeholders per process stage in the GFFR cold chain. The importing stakeholder (party ordering cargo in a reefer) usually contracts a logistics service provider (terminal operator, cold storage operator, and forwarder) to arrange transportation from the terminal gate to the distribution center where the reefer is unpacked and stripped. The cargo is further distributed and/or processed (Castelein, 2021). For the logistics service providers of the GFFR cold chain, next to cold transportation, cold storage is essential to maintain the quality of products over time throughout the different stages of the first-mile supply chain. For this reason, the connection of material and information flows between the terminal operator, cold storage operator, and forwarder is highly important.

Next to the logistics stakeholders, governmental stakeholders have been taken into account. Van Oosterhout (2008) and Castelein (2021) distinguish three important governance-related stakeholders: port authorities, customs, and food safety authorities. Port authorities manage the port's infrastructure and act as port regulators. Customs organizations control the transnational transport flows in the GFFR cold chain, and hence, stakeholders must comply with customs regulations when importing their cargo. Customs are especially relevant in the GFFR cold chain because storing and transporting chilled food is a special challenge. Many legal regulations and hygiene rules must be observed during storage and transport (Hamburg Port Authority, 2022). Food safety authorities manage the food safety regulations applied to the cargoes typically transported in reefer containers. Since food safety authorities are generally active in the country of origin, they are left out of the research scope.

3.5. GFFR cold chain Port of Hamburg

After a general understanding of port logistics in supply chains, the fruit supply chain, the reefer cold chain, and the GFFR cold chain are given, more insight are discussed on the Port of Hamburg and the GFFR cold chain in the Port of Hamburg. This insight contributes to the case study focus of this research.
The Port of Hamburg is Europe's third-largest seaport, with a total cargo throughput of over 126 million tonnes in 2021 (Hamburg Port Authority & Dakosy, 2021). One of the port's main cargo turnover modes is container handling. Container handling is provided in the port by the four high-performance container terminals and seven multi-purpose terminals where alongside conventional general cargo, containerized cargo is handled (Hafen Hamburg Marketing e.V., 2023c). With 82.3 million tonnes transported in 2022, container handling accounts for around 70 % of the total handling in the Port of Hamburg. Of these container handling, about 5.631 million tonnes of cargo was turned over in reefer containers. Sea transshipment of reefer containers in the Port of Hamburg has been relatively constant over the last ten years. Measured against the total handling of containers in TEU, this was around 7 percent (Hafen Hamburg Marketing e.V., 2023a).

The containerization grade of over 70% of all bulk cargo transported worldwide sees the importance of not only reefer but also container handling in general. In the Port of Hamburg, almost 99 % of the total general cargo handled is handled by container cargo (Hafen Hamburg Marketing e.V., 2023a). Using containers for transport provides logistics operators flexibility and cost-efficiency, especially for multi-modal transport as needed in ports. The Port of Hamburg facilitates a good multi-modal infrastructure as a vital node in supply chains (Hamburg Port Authority, 2022). Being Europe's largest port rail hub with about 300 km of rail tracks connected to its hinterland (Hamburg Port Authority & Dakosy, 2021), the port provides a good connection to its hinterland.

Its connection to the hinterland makes the Port of Hamburg an essential hub for transporting food cargo throughout Germany. Especially for transporting perishable and temperature-sensitive produce (Hafen Hamburg Marketing e.V., 2023c). Compared to food production and consumption, Germany is dependent on food imports. The most important import goods include milk and dairy, meat and fish, as well as fruit and vegetables. In 2020, around 22 million tonnes of food were handled in the Port of Hamburg. Of which around 1.4 million tonnes of fruit and vegetable. In addition, around 1.2 million tonnes of fruit and vegetables were transported, previously processed (Statistisches Landesamt für Hamburg und Schleswig-Holstein, 2020).

The food industry is one of the Port of Hamburg's most important customers. In 2016 alone, nearly 25.5 million tonnes of food and agricultural products were handled via Hamburg, representing about 18.5 percent of total port throughput in 2016 (Hafen Hamburg Marketing e.V., 2017). Nevertheless, hardly any growth has been seen in this segment in the Port of Hamburg for many years. In addition, there are existing uncertainties about the food cluster in the Port of Hamburg. Consumers are increasingly making decisions about their food consumption under ecological aspects: away from global, toward regional, or even local food (Hamburg Port Authority, 2022). The fresh fruit and vegetables segment has decreased by 25,5 %, of which all cargo is containerized (Mail contact HHM, 2023).

The Port of Hamburg is next to cargo handling stakeholders, home to various stakeholders that see themselves as service providers for the food industry. These stakeholders are active in the field of food logistics and provide, among other things, corresponding cold storage capacities and forwarding services. The port has a very specialized market, which is divided between the traditional "Hamburger Quatiersleute" (Hamburg quarter people) and stakeholders with a focus on temperature-controlled and special project logistics (Hamburg Port Authority, 2022). The main stakeholders involved in the GFFR cold chain are described in Section 3.6.

3.6. Port of Hamburg's GFFR cold chain stakeholder overview

As presented in Figure 3.4, supply chain stakeholders involved in the research focus of the GFFR cold chain can be mainly divided into five categories: authorities, terminal operators, cold storage operators, forwarders, and importers. This section discusses the different categories and the stakeholders active in the Port of Hamburg, also presented in Table 3.2. To gain port-specific information, next to literature research, interviews were conducted with stakeholders involved in the Port of Hamburg's GFFR cold chain. It should be noted that conducting interviews with all stakeholders was not possible.

Table 3.2.: Overview stakeholders involved in GFFR cold chain in the Port of Hamburg

Authorities	Terminal operators	Cold storage operator	Forwarders	Importer
Hamburg Port Authority	EUROGATE	FRIGO Coldstore Logistics	Heuer Port Logistics	ALDI
German Customs Authority	HHLA	HHLA Frucht- und Kühl-Zentrum	Kuehne+Nagel	EDEKA
		NORDFROST	Ulrich Stein Spedition	LIDL
			Weidner & Co.	REWE
			Wichmann Spedition	
		Other cold storage operators	Other forwarders	Other importers

3.6.1. Authorities - Port authority

As discussed previously, GFFR cold chain's two most important governance-related stakeholder types are considered in this research: port authorities and customs. Port authorities operate to meet a diverse spectrum of strategic goals such as financial performance criteria, ensuring the competitiveness of the port cluster, sustainability goals, and meeting responsibilities to a wide range of stakeholders on national and local government level (Van der Lugt et al., 2013; Verhoeven, 2010; Castelein, 2021). GFFR cold chain stakeholders depend on port authorities for the quality of their shared infrastructure, cluster management, and port regulations. In the supply chain-oriented logistics environment, port authorities undertake actions that improve the integration of a port and port-related stakeholders in the supply chain. To provide this improvement, actions such as data-sharing technologies, development of relationships with foreland and hinterland stakeholders, the pursuit of value-added activities, and improved connectivity are implemented by port authorities (Castelein, 2021; D. W. Song & Panayides, 2008).

Verhoeven (2010) discusses four port authority functions: traditional landlord, regulator, operator, and community manager. The port authority has more coordinative and stakeholder management responsibilities in these functions. Some port authorities actively use the policy instrument concessions to take on a mediating, facilitating role towards the supply chain- and port-related stakeholders that operate in or through a supply chain cluster but are not involved in the operation themselves. Port authorities generate revenue by granting concessions to terminal operators and charging port dues to vessels calling at the port (Castelein et al., 2020). In the GFFR cold chain in the Port of Hamburg, the Hamburg Port Authority (HPA) executes the function of the port authority.

Hamburg Port Authority

The Hamburg Port Authority (HPA) has been responsible for the water- and land-side infrastructure, improving safety and profitability at the port, planning and implementing construction projects, and managing property since 2005 (Hamburg Port Authority, 2023). HPA is responsible for restructuring and development projects in the Port of Hamburg that promote port growth in line with market demands. The authority provides port infrastructure, enhances the port's strategic competitiveness, improves customer services, establishes and maintains long-term customer relations, and represents the Port of Hamburg in its dealings with the European Union and other organizations (World Port Source, 2023). HPA combines efficiency and environmental awareness, not least thanks to the use of state-of-the-art technologies and innovative projects such as smartPORT. HPA, therefore, maintains close contact with the shipping, logistics, and service sectors. HPA aims to maintain and extend the Port of Hamburg's position as Germany's leading transshipment hub in the long term (Hamburg Port Authority, 2023). The port authority is not specifically involved in the GFFR cold chain logistics operations in the Port of Hamburg. Overall, HPA does not provide any direct service for transporting the cargo but provides supporting infrastructure over water, road, and rail. For example, looking at the container terminals, all four container terminals are connected to rail infrastructure, which HPA provides. However, the terminal operators provide the infrastructure at the terminals, such as power connections for reefers, not HPA.

3.6.2. Authorities - Customs authority

Customs authorities are the gatekeepers of international trade. In international shipping, import declarations about imported goods shipments must be lodged with the respective customs authority (Martincus et al., 2015; Segers et al., 2019). Customs authorities control the transnational transport flows in the GFFR cold chain, and hence, stakeholders must comply with customs regulations when importing their cargo. Imported reefers may be selected for inspections via scans or checks by customs. These customs inspections take time, an important process in the time-sensitive transport of perishable cargo.

Customs are especially relevant in the GFFR cold chain because storing and transporting chilled food is a special challenge. Several legal regulations and hygiene rules must be observed during storage and transport (Hamburg Port Authority, 2022). Moreover, reefers tend to be selected more frequently, as many types of fruit tend to be transported from regions known for drug production (Castelein, 2021). Since 2013, the Port of Hamburg has conformed to the rules of the European Customs Seaport. This includes that all cargo arriving from outside the European Union must be registered with the ATLAS IT system, which is run by the German Customs (Hafen Hamburg Marketing e.V., 2023b). In the GFFR cold chain in the Port of Hamburg, one main stakeholder executes the function of the customs authority: the German Customs Authority.

German Customs Authority

The Bundeszollverwaltung (Federal Customs Service) serves as the customs authority for the Federal Republic of Germany and operates under the Federal Ministry of Finance. Its primary role involves managing revenue from trade tariffs and taxes while overseeing the movement of goods through import, transit, and export processes. The Customs Service plays a crucial part in preventing the illegal import or export of prohibited items, including weapons, narcotics (drugs), and other dangerous substances.

One of its key responsibilities is offering executive and fiscal administrative services to the federal government. The German Customs Authority collaborates with various companies to carry out customs procedures, with a significant office in the Hamburg region known as the Hauptzollamt Hamburg. This office holds jurisdiction over the port of Hamburg and handles a range of customs procedures (Law office O&W, 2023).

3.6.3. Terminal operator

Terminal operators execute the function of handling containers at the interface between maritime and land transport, using dedicated equipment (e.g., cranes and automated guided vehicles) to load and discharge containers from container ships and transfer them to hinterland transport modalities (Lun & Cariou, 2009). Handling containers by terminal operators includes container unloading, terminal turn-over, transport to cold storage, and direct transport to hinterland transport commodities. In the GFFR cold chain, most cargo transfers from the ship to the hinterland via cold storage. Terminal operators are required to coordinate activities within the same port due to the growing importance of hinterland transport on consolidated modalities (Castelein, 2021).

Most major gateway ports have multiple container terminal operators, mostly private sector stakeholders. Terminal operators are granted a land concession from the port authority in exchange for a concession fee and additional provisions that should contribute to and ensure broader societal goals of the port (Notteboom & Verhoeven, 2010; Theys et al., 2010; Castelein, 2021). Two container terminal operators are active in the Port of Hamburg: HHLA and EUROGATE. EUROGATE has some reefer points on its terminal. However, HHLA is the market leader in the Port of Hamburg fruit handling. The container terminals in the Port of Hamburg are presented in Figure 3.5.

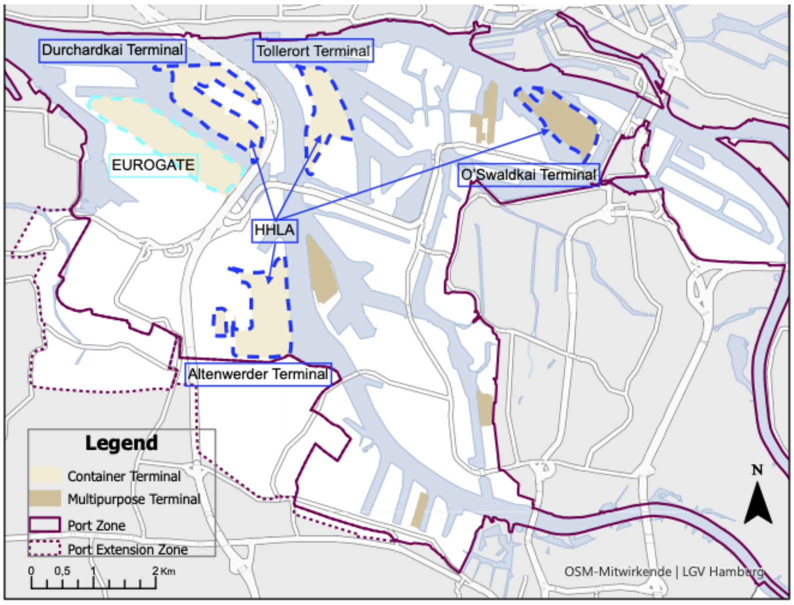

Figure 3.5.: Overview container terminals in the Port of Hamburg

Hamburger Hafen und Logistik AG (HHLA)

Hamburger Hafen und Logistik AG (HHLA) stands as a leading European company specializing in port and transport logistics. Central to HHLA's operations is its container handling within seaports and inter-port container transport connecting German and European hinterlands. Within the Port of Hamburg, HHLA operates three key container terminals: Altenwerder, Burchardkai, and Tollerort (Hamburger Hafen und Logistik AG, 2023d) and one multi-purpose terminal O'Swaldkai (Hafen Hamburg Marketing e.V., 2023c). Notably, the Burchardkai terminal, being the oldest and largest container-handling facility in the Port of Hamburg, is responsible for processing one out of every three containers within the port (Hamburger Hafen und Logistik AG, 2023a).

HHLA Frucht- und Kühlzentrum, situated at the O'Swaldkai multi-purpose terminal in Hamburg, stands as Germany's largest fruit-handling facility. Equipped with over 300 electricity connections for reefer containers, the facility effectively powers the reefer cooling system. HHLA's commitment to maintaining an unbroken cold chain is evident in its utilization of state-of-the-art ship and ground handling equipment, swiftly transferring pallets to climate-controlled warehouses for preservation (Hamburger Hafen und Logistik AG, 2023c).

EUROGATE

EUROGATE Container Terminal Hamburg is one of Northern Europe's main transport hubs due to Hamburg's excellent hinterland connections by road, rail, and feeder. As a container terminal operator, EUROGRATE handles the loading and discharging of container vessels at seaports on behalf of shipping lines (EUROGATE, 2023).

3.6.4. Cold storage operator

The cold storage operator is a specialized cold chain operator in cold storage. Due to the temperature-sensitive characteristics of GFFR cold chain cargo, this storage is essential to maintain the cargo's quality. The stakeholders are spread all over the port, sometimes even into the Billbrook industrial park. This requires additional transport and long distances to deliver the refrigerated containers (Hamburg Port Authority, 2022).

Three leading cold storage operators are active in the Port of Hamburg: HHLA Frucht- und Kühl-Zentrum, FRIGO Coldstore Logistics, and NORDFROST. In addition to the above-mentioned stakeholders, a large number of smaller and very specialized stakeholders are active in the field of temperature-controlled logistics in the Port of Hamburg. For example, the stakeholders Heinrich Osse Lagerhaus and Lagerhaus Harburg Spedition offer the storage and ripening of fruit and vegetables of organic quality. Moreover, EDEKA is building a cold storage facility in the port. Figure 3.6 presents the geographical location of EDEKA and the three largest companies in the reefer logistics sector and their sites in the Port of Hamburg.

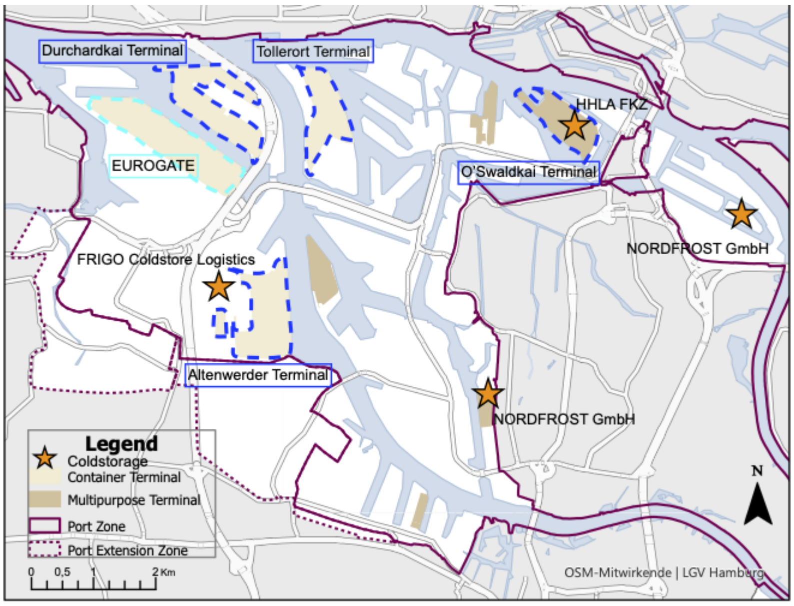

Figure 3.6.: Overview locations main cold storage warehouses in the Port of Hamburg

HHLA Frucht- und Kühl-Zentrum

HHLA's Frucht- und Kühl-Zentrum (FKZ) plays a important role in handling and storing refrigerated cargo, with a special focus on various types of fruit. The total capacity comprises 13,000 pallet spaces, and the refrigerated warehouses can be set separately within a range of -2 and +14 degrees Celsius. HHLA's fruit and refrigeration center(FKZ) discharges approximately 50,000 tonnes of bananas from South America and 80,000 tonnes of apples (New Zealand), pineapples (Costa Rica), grapes (South Africa), citrus fruit (South Africa), and potatoes (Israel & Egypt) every year. HHLA FKZ is the market leader in the Port of Hamburg fruit handling, and 80% of the fruit is bananas (Hamburger Hafen und Logistik AG, 2023c). Notably, 100% of the bananas handled have been containerized since 2019 (Hamburger Hafen und Logistik AG, 2023c).

FRIGO Coldstore Logistics GmbH

FRIGO Coldstore Logistics GmbH, situated in the Altenwerder port area, is a prominent player in refrigerated logistics. Their specialization lies in storing temperature-sensitive cargo while ensuring an unbroken cold chain. With operations dating back to 1996, FRIGO has established itself as an independent full-service provider in temperature-controlled logistics within the Port of Hamburg (FRIGO coldstore logistics, 2023). The company's expertise primarily revolves around the handling and storage of temperature-controlled goods. Operating three facilities within the Port of Hamburg (Hamburg Port Authority, 2022), FRIGO boasts a substantial storage area encompassing 40,000 pallet spaces. Among these, 28,000 pallet spaces maintain a temperature of minus 24 degrees Celsius, 2,500 are set at 0 degrees Celsius, and an additional 500 can be individually cooled according to specific requirements within a multi-temperature room (FRIGO coldstore logistics, 2023). Nevertheless, FRIGO's primary focus is on storing frozen goods, which means it has less involvement in the fresh fruit cold chain within the Port of Hamburg.

NORDFROST GmbH & Co. KG

NORDFROST manages a national network of 40 logistics locations and holds the top spot in frozen food logistics across Germany. Their European-wide logistics network covers refrigerated cargo distribution, offering a range of services from traditional transport and warehouse logistics to retail logistics, food processing, port logistics, and project transportation (NORDFROST, 2023). Within the Port of Hamburg, the NORDFROST Group operates two cold stores and a facility in Moorfleet (Hamburg Port Authority, 2022).

Other cold storage operators

In addition to the three leading cold storage operators mentioned above, many smaller and very specialized stakeholders are active in temperature-controlled logistics in the Port of Hamburg. For example, the stakeholders Heinrich Osse Lagerhaus and Lagerhaus Harburg Spedition offer the storage and ripening of fruit and vegetables of organic quality (Hamburg Port Authority, 2022). Heinrich Osse Lagerhaus GmbH provides additional to cold-storage value-added services such as food processing, quality control, campaign logistics, and container handling (Heinrich Osse Lagerhaus GmbH, 2023). Moreover, it should be noted that EDEKA is an importing stakeholder, however, it is also building a cold storage facility EDEKA Fruchtkontor. For this reason, EDEKA Fruchtkontor can also be categorized as a cold storage operator.

3.6.5. Forwarder

In this research, forwarders include logistics and transport service providers, such as inland carriers, for transport from the port to the distribution center. Forwarders arrange the transport of GFFR cold chain cargo for clients. Forwarders provide the (transport) connection of reefer fruit cargo between the terminal gates and the distribution center (Castelein, 2021). This connection is provided either by train, barge over inland waterways, or by truck over the road, or a combination of these modalities as multi-modal transport.

In the GFFR cold chain in the Port of Hamburg, various forwarding stakeholders operate the transport from the port to the distribution center. Next to its function as a forwarder, the main forwarding companies in the Port of Hamburg also provide customs clearance services. Customs clearance services are provided for the cargo by the forwarder, which deals with the customs authorities. The four main forwarding companies involved in the GFFR cold chain in the Port of Hamburg are Heuer Port Logistics, Ulrich Stein Speditions, Weidner & Co., and Wichmann Spedition. All four leading forwarders also support the GFFR cold chain by providing customs clearance processes [G,J]. Next to these companies, Kuehne+Nagel is pointed out as a forwarding company that provides the additional service of providing cold chain network connections.

Heuer Logistics

Founded as "Frucht-Spedition Heuer," Heuer Logistics specializes in fruit and food logistics, originally founded as a fresh fruit forwarding company in Bremen (Heuer Logistics, 2023). They provide services ranging from storage and terminal handling to customs clearance. Operating a cold storage facility in Bremerhaven, Heuer Logistics primarily provides customs and authority handling services for the GFFR cold chain in the Port of Hamburg.

Ulrich Stein Spedition

Ulrich Stein Spedition specializes in fruit-forwarding logistics, particularly as a tropical fruit importer. Ulrich Stein's expertise encompasses a thorough understanding of customs regulations, as well as the specialized agencies responsible for plant protection, goods condition, and bio-certificates (Hamburger Hafen und Logistik AG, 2023b). Dominating the market, Ulrich Stein holds a substantial 60% market share in fruit forwarding within the Port of Hamburg.Their business model spans from the arrival of fruit in the port to loading refrigerated trucks for distribution centers.

While Ulrich Stein doesn't possess its own quality inspectors for customs clearance, the company collaborates closely with specialized service providers in this realm. Beyond customs clearance and forwarding, Ulrich Stein handles the disposition, encompassing scheduling and verifying the availability of requested fruit quantities on the requested days. This data is then forwarded to the terminal, effectively linking importers, terminal operators, and customs clearance stakeholders.

Weidner & Co.

Weidner & Co. is a fruit forwarding company specializing in the logistical processing of fresh fruit, especially bananas and pineapples, within the Port of Hamburg. Weidner & Co. provides services such as unloading, storage, transport, and customs. The company cooperates with many transport companies, which helps bundle several loads, resulting in good temperature-controlled transport to the hinterland of Germany (Weidner & Co., 2023).

Wichmann Spedition

Wichmann Spedition, recognized as a reliable and competent partner in the logistics sector, plays a role as a forward agency in the GFFR cold chain at the Port of Hamburg. Their services encompass forwarding and customs clearance handling for this cold chain (Spedition Wichmann, 2023).

Kuehne+Nagel

Kuehne+Nagel, a forwarding company in the GFFR cold chain, possesses a profound comprehension of the distinct requirements of perishable logistics, guaranteeing timely deliveries in optimal conditions. Next to forwarding, the company provides a cold chain network with connections with partners in the cold chain, such as specialists for packaging, transport, and storage according to Kuehne+Nagel's global quality and safety standards, which are specified to the requirements of the shipped fruit cargo. Kuehne+Nagel provides end-to-end solutions (Kuehne+Nagel, 2023).

Kuehne+Nagel does not have its own ships or reefer containers, positioning the company as a customer of carriers and other stakeholders entrenched within the cold chain network. However, the differentiating factor lies in its service-oriented approach. Unlike a purely cargo-centric focus, Kuehne+Nagel prioritizes the market and its collaborative partners. The company maintains a 24/7 availability, poised to deliver solutions to emergent challenges. Furthermore, its integration across the entire fruit cold chain ecosystem, from farmers to importers, underscores its commitment to this service.
In its commitment to transparency and reliability, Kuehne+Nagel furnishes customers with daily updates and diligently oversees on-time deliveries. It is worth noting that while KN sea freight does not extensively engage in last-mile distribution, this is attributed to the relatively constrained demand for such transport services among their customer base (Kuehne+Nagel, 2023).

Other forwarders

Forwarders operate in different transport segments (rail, road, inland waterways). Therefore, various forwarding parties are involved with the GFFR chain in the Port of Hamburg. Due to this wide variety of stakeholders that provide the logistics network in the cold chain, it is not possible to provide a complete overview of the forwarding stakeholders involved in the GFFR cold chain. Forwarding stakeholders are contacted mostly via an importer or other logistics providers to connect the cold chain with the port and hinterland network.

3.6.6. Importer

Importers, cargo owners engaged in fruit trade, typically contract third-party services to transport their fruit consignments. Within the GFFR cold chain operating at the Port of Hamburg, the fruit transport ecosystem is closely intertwined with four prominent retailers, ALDI, EDEKA, LIDL, and REWE, collectively holding a substantial 85-90% market share in Germany. Beyond these major retail players, a diverse array of smaller importing stakeholders also participates. Considering its unique position within the GFFR cold chain at the Port of Hamburg, EDEKA is pointed out as one of the four major retailers.

EDEKA Fruchtkontor

EDEKA ZENTRALE Stiftung & Co. KG is Germany's leading corporation in the food trade. EDEKA is one of the few trading companies with their own competence center for fruit and vegetables: the EDEKA Fruchtkontor. As a competence center for fruit and vegetables within the EDEKA cooperative network and the largest fruit importer in the metropolitan region, EDEKA Fruchtkontor Nord has been operating from the Port of Hamburg for decades. Since 2006 EDEKA Fruchtkontor Nord has been operating from Kleiner Grasbook. Direct access to the Elbe is central to EDEKA's food procurement from 80 countries worldwide. In this way, not only 129 EDEKA supermarkets and 37 Netto shops in Hamburg but also thousands of other food markets throughout Germany are supplied with fruit and vegetables of the best quality (EDEKA, 2022). This network is important to guarantee no interruption in the cold chain. EDEKA Fruchtkontor can provide this guarantee because it is responsible for all processes, from unloading the containers of the vessels to supplying them to the regional distribution centers. Additionally, EDEKA Fruchtkontor is more or less a troubleshooting warehouse that deals with all quality issues that may appear after the transport of goods overseas.

Currently, EDEKA Fruchtkontor has four ripening warehouses in Germany. EDEKA is building a new fruit storage in the Port of Hamburg, which is planned to operate by the end of 2024. EDEKA is building a new ripening plant on Kleiner Grasbook and an overall expanded logistics hub for fresh fruit and vegetables. EDEKA Fruchtkontor will increase its annual volume from around 105,000 pallets to 160,000 pallets (EDEKA, 2022). Next to these four ripening houses, EDEKA is building an additional fifth ripening warehouse in the Netherlands. The ripening plant will contribute to the ripening process of around 61,000 tonnes of bananas, avocados, and mangoes in the 58 ripening rooms (Dittrich, 2022; EDEKA, 2022). 46 large ripening rooms will be available for bananas and 12 smaller ones for other types of fruit.

Other importers

All stakeholders involved in the retail of perishable seaborne fresh fruit can be classified as importers within the GFFR cold chain. The diversity in stakeholders can be segmented based on the specific retail objectives they serve. For instance, supermarket branches might act as cargo owners with the aim of directly selling the goods to end consumers. On the other hand, additional importers are operating who process the cargo before it reaches the end consumers. This practice is evident with entities such as restaurants or jam-producing companies. This indirect retail of fruit in the GFFR cold chain complicates creating a complete overview.

3.7. Concluding remarks background study

Performing the background study provided essential insight into the GFFR cold chain. This insight contributed to understanding the different aspects of this cold chain and how these aspects are connected. The background study is relevant to performing the value stream mapping and opportunity analysis in this research and answers the first research question.

Ports and their logistics operations are crucial as connecting hubs within global supply chains. The evolving approach of corporatized restructuring in port logistics is affecting global supply chains, reshaping their dynamics. The integration of ports into the global economy impacts the key dynamics and balance between competing objectives and priorities of stakeholders, such as increased competition, changing customer requirements, and environmental pressures.

The food supply chain within port logistics is notably sensitive and vulnerable, particularly for perishable goods. These goods have a short shelf-life and are prone to rapid deterioration, posing safety risks for consumption. Within the perishable food trade, fresh fruit has a significant market share. Perishable food products, including fresh fruit, have experienced substantial growth in global trade in the last decades, which drives the increased expansion of supply chain operations on a global scale. Nevertheless, not all fresh fruit supply chains seem to deviate from this trend, like the food trade via the Port of Hamburg, which displayed minimal growth over the last few years. Even when the food industry is one of the Port of Hamburg's most important customers.

The fresh fruit supply chain is similar to the general food supply chain, however, it necessitates temperature control, achieved through refrigeration technology. Refrigerated containers, or reefers, dominate this segment with over 80% market share, providing cost-effective logistics and adaptable temperature management throughout the supply chain. Reefer containers maintain varied temperature requirements. Fresh fruit is mainly transported in a chilled condition, generally kept at a set-point temperature above -5 °C, allowing a deviation of +/- 1 °C. Maintaining the desired temperature range is crucial for shipment integrity along the cold chain. Achieving a constant temperature within reefers depends on proper packaging, a secure energy supply, and careful container handling at transfer points. Managing perishable supply chains, like the fresh fruit cold chain, faces the challenge of preserving product quality as it degrades across different supply chain stages.

This research scope focuses on the global importing fresh fruit cold chain stages, including the material and information value stream flows of reefer fresh fruit cargo. Leaving aside other activities and parties involved as financial, legal, information support (IT), and administrative transactions, that are needed to make container movements possible. This results in the focus on the operations from when a reefer arrives at the port of origin to distribution to the distribution center. Stakeholders included in this scope can be categorized as authorities (port & customs), terminal operators, cold storage operators, forwarders, and importers.

Research question 1 - How are the supply chain stakeholders involved in the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?

The first research question is addressed by understanding the stakeholders involved and their activities within the GFFR cold chain at the Port of Hamburg. The supply chain stakeholders are categorized into five main groups for the research focus: port & customs authorities, terminal operators, cold storage operators, forwarders, and importers. An overview of the identified supply chain stakeholders for the Port of Hamburg is presented in Table 3.3.

Table 3.3.: Overview stakeholders involved in GFFR cold chain in the Port of Hamburg

Authorities	Terminal operators	Cold storage operator	Forwarders	Importer
Hamburg Port Authority	EUROGATE	FRIGO Coldstore Logistics	Heuer Port Logistics	ALDI
German Customs Authority	HHLA	HHLA Frucht- und Kühl-Zentrum	Kuehne+Nagel	EDEKA
		NORDFROST	Ulrich Stein Spedition	LIDL
			Weidner & Co.	REWE
			Wichmann Spedition	
		Other cold storage operators	Other forwarders	Other importers

In the scope of the research, it is important to understand how the supply chain stakeholders are involved in the GFFR cold chain, which their activities can illustrate. GFFR cold chain stakeholders rely on the port and customs authorities in various ways. The port authority provides infrastructure quality, cluster management, and compliance to port regulations. In supply chain logistics, the port authority undertakes actions to enhance the integration of supply chain stakeholders within the GFFR cold chain. In the Port of Hamburg, the port authority does not directly engage in physical cargo movement but provides supportive water, road, and rail transportation infrastructure. The customs authority oversees transnational transport flows, necessitating stakeholders' compliance with importing customs regulations. In addition to standard customs clearance, imported reefers might undergo inspections via scans or checks by customs. Customs play a crucial role in the GFFR, given the challenges of handling chilled food, which entails compliance to numerous legal regulations and hygiene standards during storage and transportation.

Terminal operators handle containers at the interface between maritime and land transport, using dedicated equipment to load and discharge containers from vessels and transfer them to hinterland transport modalities. In the GFFR cold chain, most cargo transfers from the vessel to the hinterland through cold storage. Facilitating the physical connection of a reefer within the cold chain establishes a mutual reliance between the terminal operator, forwarder, and cold storage operator.

Cold storage operators play a crucial role in the GFFR cold chain due to the perishable nature of the cargo. Mishandling the cargo can result in quality and value decay. These operators serve as the link between the forwarder, importing stakeholder, and the cold chain. Notably, in the Port of Hamburg, EDEKA stands out as an importing stakeholder that extends its influence in the supply chain by establishing and managing its own cold storage facility. This strategic move transforms EDEKA into both an importer and a cold storage operator.

Within this context, forwarders hold a critical role in establishing and nurturing relationships with other stakeholders, given their comprehensive connections with all participants in the GFFR cold chain. Among these stakeholders, the leading forwarders in the Port of Hamburg not only facilitate the transportation link between terminal gates and distribution centers, facilitated through cold storage facilities but also manage customs clearance, establishing a direct link with the customs authority. This central position underscores their vital connection within the GFFR cold chain.

Importers are the cargo-receiving stakeholders within the GFFR cold chain, primarily driving demand in the cold chain. Importers establish connections with other stakeholders by enlisting their services to oversee reefer cargo handling until its delivery to distribution centers. Four major importers in the Port of Hamburg -ALDI, EDEKA, LIDL, and REWE- operate from the port. These retailers have combined a market share of 85-90 % in fruit retail across Germany.

Addressing the first research question revealed the interconnections among various supply chain stages and stakeholders' operations, primarily emphasizing the interdependency of activities. These relationships are further explored through value stream mapping to explore the material and information flows between GFFR cold chain operations and its participating stakeholders.

4. Value stream mapping

This chapter describes the value stream mapping (VSM) performed in this research. The value stream mapping begins with the system definition of identifying the value stream scope, discussed in Section 4.1. After the content is defined, value stream maps are created by identifying the material and information flows related to the activities in the GFFR cold chain in the Port of Hamburg, presented in Section 4.2. The current state maps are discussed by a reference map (Section 4.3) and alternative maps (Section 4.4). These maps are discussed, focusing on the value stream map's flow categories and critical issues, depicted in Section 4.5. At last, the conclusion is given in Section 4.6.

4.1. System definition

The product family identified for this VSM is fresh fruit transported in reefers. Even when fresh fruit commodities differ per preferred transport temperature, this group of products passes through similar processing stages and are all transported by reefers - in this research focus - which is the common equipment needed in the processes, and thereby defines a product family as discussed by Rother & Shook (2003). The product family includes all variants of fruit transported in a preferred set-point temperature range above -5 °C but below +16 °C, also known as fresh fruit transport. The system's limits are set to the GFFR cold chain scope, shown in Figure 4.1. The system's limits include processes from terminal turn-over from the vessel to delivery at the distribution center (DC), where the fresh fruit cargo is dispatched from the reefer. It should be noted that reefers may be stripped at the distribution center and already at the cold storage facility, causing GFFR cold chain cargo to be transported to distribution centers using refrigerated vehicles instead of reefers. However, all relevant processes, including unloading before reaching the distribution center, are included due to their significance to reefer-transported cargo and their similarities to cases of reefers being stripped at cold storage or distribution centers.

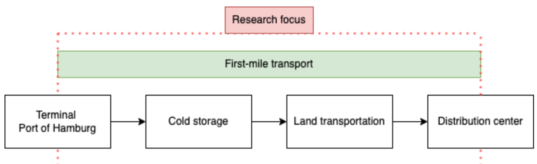

Figure 4.1.: VSM system of GFFR cold chain

In addition, within the fresh fruit transported in a reefer product family, some commodities need additional processing, such as ripening or (re)packaging, before being distributed to the importing stakeholder, and some do not. Besides, strict safety and quality requirements may result in additional processes. These additional processes result in various cargo flows, illustrated in several value stream alternatives in the VSM. The different value streams identified are as follows:

- Direct distribution
- Direct distribution via cold storage warehouse
- Indirect distribution via a buffer storage
- Direct & indirect distribution with a customs scan
- Direct & indirect distribution with troubleshooting activities
- Direct & indirect distribution with additional processing activities
- Direct & indirect distribution with logistics service activities

To create a clear overview of the various cargo flows and associated value streams that may occur, the following value stream maps of the same product family have been created: (1) a reference distribution map including all variants; (2) a direct distribution map (including customs scan); (3) indirect distribution map; (4) distribution with troubleshooting activities map; and (5) distribution with additional processing and logistics service activities map.

4.2. Current state mapping

A VSM current state map is a tool that helps understand a system's material and information flows. The current state map is mapped out from the end-customer processes and services and is, from this point, mapped out upstreams because products should be driven by customer demand (J. C. Chen & Cox, 2012). Since the GFFR cold chain's scope at the Port of Hamburg excludes end-customer processes, the process most closely connected to the end-customer -the importer's distribution center (DC)- is regarded as the starting point. The demand originating from the importer constitutes a crucial element within the framework of the value stream mapping. The data was collected via interviews with stakeholders of the GFFR cold chain in the Port of Hamburg, which provided detailed information and insight into the system [B1,B2,E,G,J].

The symbols used to visualize the processes are presented in Figure 4.2 and elaborated in Table 4.1, both based on Rother & Shook (2003) and Muñoz-Villamizar et al. (2019). Description of the symbols used contributes to creating a transparent map that can be understood by various stakeholders involved in the GFFR chain.

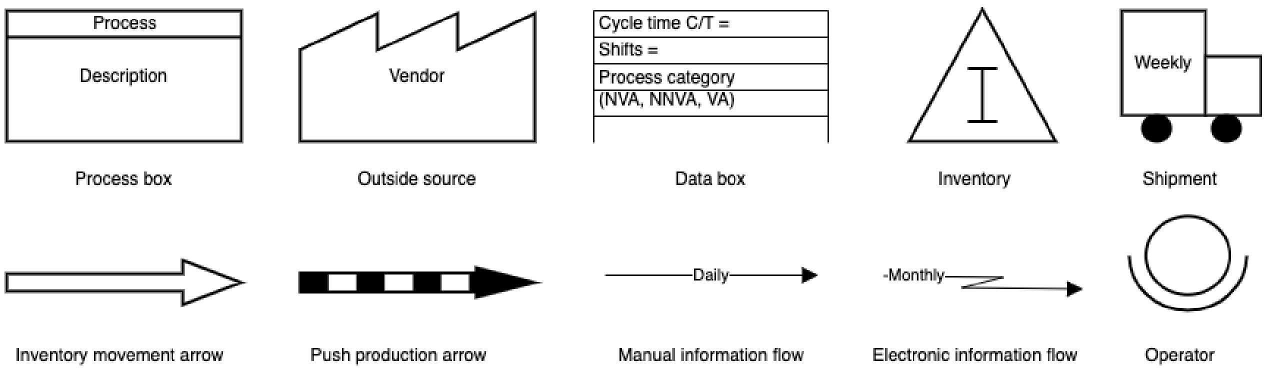

Figure 4.2.: VSM symbols (adapted from Rother & Shook (2003) and Muñoz-Villamizar et al. (2019))

Table 4.1.: Mapping symbols and description (adapted from Rother & Shook (2003) and Muñoz-Villamizar et al. (2019))

Symbol	Description
Process box	A process box is used to indicate a process. The general rule of thumb for using a process box is that it indicates a process in which the material flows. The material flow is ideally a continuous flow. So, when a material flow stops, processes are disconnected and the process box stops.
Outside source	The vendor/outside source represented outside sources that feed into the system's processes. Mostly a supplier or customer.
Data box	Different types of information is essential to support a process. For this reason, a data box is connected to each process box. A data box includes information such as cycle time (C/T), the number of people required to operate the process (also indicated by the operator icon), available working time (the working time per shift at the process), and the process category (non-value adding (NVA), necessary but non-value adding (NNVA), and value-adding (VA)). All time is presented in hours.
Inventory	Inventory is important to understand where the flow is stopping. Inventory may happen at multiple locations between two processes, which is presented by inventory triangles for each location.
Shipment	The shipment symbol represents an external shipment. The frequency of shipments is labeled below the symbol (daily, weekly, monthly). It should be noted that the shipment from the supplier to the terminal of origin is a combination of transport modes, road, rail, and overseas. Adjusting to represent all shipment types, not just truck shipments, simplifies the system.
Inventory movement	The movement of raw materials coming from suppliers or finished goods going from factory to customers are presented by this type of arrow.
Push movement	A 'push' movement of materials presents the movement from one process to the next initiated within the system.
Manual information flow	A simple arrow indicates a manual information flow between processes.
Electronic information flow	A broken arrow indicates electronic information flow between processes.
Operator	The operator indicates where an operator or worker must operate the process. Additionally, an indication of the number of operators required is noted.

Additional visualization aspects have been introduced to the value stream maps to provide a more clear division between various potential cargo flows that may occur. Furthermore, processes related to terminals, customs locations, and cold storage facilities have been outlined to enhance understanding of operational locations and the associations between operating stakeholders and these locations, as well as the transition between them. The additional visualization aspects are presented in the additional legend in Figure 4.3. The blue, green, and orange boxes correspond to cargo handling locations. This classification improves the clarity in recognizing the locations and stakeholders participating in various processes within the GFFR cold chain. Subsequently, the use of dotted lines indicates the separation of alternative flows. Dotted arrows and boxes in the alternative maps visually represent this differentiation. While these alternatives might primarily address certain aspects like troubleshooting or additional processing activities, the dotted boxes indicate potential preceding phases. This is essential for understanding the sequential order of the GFFR cold chain phases.

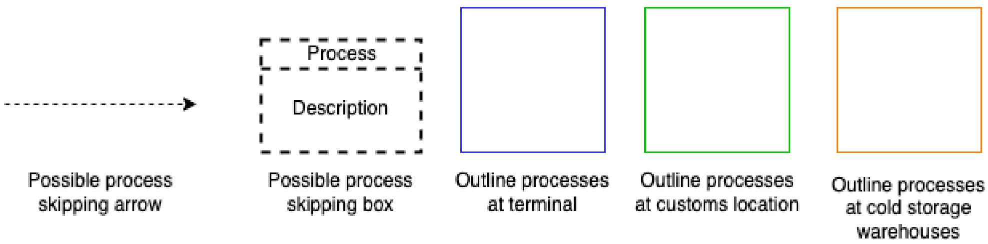

Figure 4.3.: Additional VSM visualization aspects

An initial overview of the entire flow, including sub-processes within the GFFR cold chain, was established to initiate a value stream map construction. This upper-level perspective was then refined to zoom in to map every individual step within a process category (Rother & Shook, 2003). This overarching flow assists in comprehending the various cargo flows and sub-processes, laying the groundwork before identifying the actual operations. The sub-processes of the GFFR cold chain are presented in Figure 4.4.

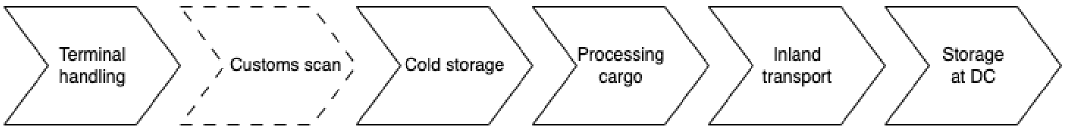

Figure 4.4.: GFFR cold chain sub-processes in the Port of Hamburg

Within this value stream system, various handling flows for GFFR cargo occur influenced by factors like customs scans, general troubleshooting activities, and additional processing such as ripening for specific fruit commodities like bananas and mangoes. To highlight the flow variants, a decision flowchart is created, outlining the decision steps that lead to flow differentiation. The decision flowchart, depicted in Figure 4.5, visualizes four primary influencing factors: distribution choice, customs scan performance, troubleshooting activity performance, and additional processing activity performance. It is important to note that certain decision points may overlap; however, this does not affect the presentation of different cargo flows and associated value streams.

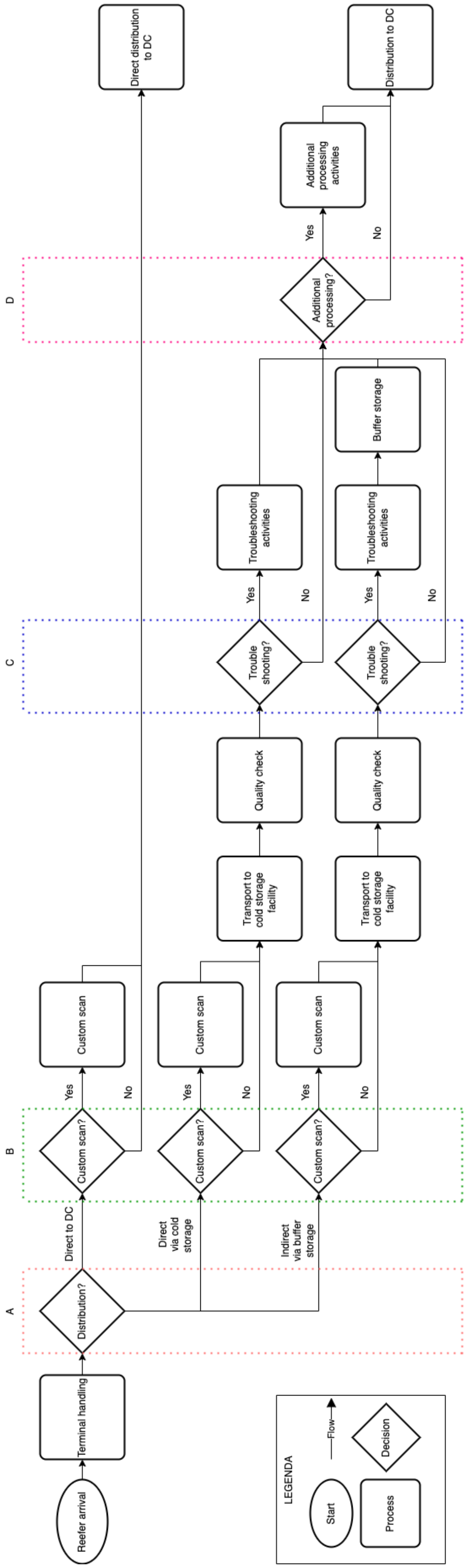

Figure 4.5.: Decision flowchart of GFFR cold chain

As depicted in Figure 4.5, upon the arrival of a vessel carrying reefer containers at the Port of Hamburg's terminal, the terminal operator undertakes the handling of the reefer containers. At this juncture, the choice between direct and indirect distribution is made (A). In the case of direct distribution, the reefer is either directly transferred to the importer's distribution center (DC) or undergoes immediate processing at the cold storage warehouse before distribution. Both of these scenarios represent direct flows of GFFR cargo. On the other hand, for indirect distribution, a decision is taken regarding the storage location for the GFFR cargo, leading to the establishment of buffer storage. Alongside the distribution decision, there is the determination to conduct a customs scan (B). The customs authority announces whether a container is selected for a customs scan or not at the moment of reefer clearance by the shipping agency during container handling at the terminal. It is important to distinguish between customs checks and customs scans. Customs checks are conducted to grant clearance for the GFFR cargo and its accompanying documentation. In contrast, customs scans involve an extra inspection of a reefer container, encompassing scanning the container and verifying its contents. In the event of selection for a customs scan, the container is put on hold, and further steps are withheld until it successfully undergoes inspection [B1,B2,E,G,J].
After customs clearance by the authority, a third decision comes into play (C). This decision revolves around whether troubleshooting activities are necessary to uphold the GFFR cargo's quality, a determination made through a thorough quality check. Given the high requirements associated with this cargo type, a quality check is essential. The outcome of the quality check determines the extent of troubleshooting procedures required. Further logistical and logistical activities are executed for cargo processing (D), following any potential troubleshooting steps. Notably, buffer storage may occur after the quality check and troubleshooting processes. Lastly, preparations for distribution to a distribution center encompass tasks like loading the inland carrier vehicle [B1,B2,E,G,J].

4.3. Current state reference map

The current state reference map provides a general overview of all operations that may be performed in the GFFR cold chain in the Port of Hamburg. Material streams focus on transporting, handling, and storing fresh fruit cargo, while information operations relate to the support of these identified processes through information flows. Data collection for the material flow was initiated with an interview involving an importing stakeholder and progressed backward to the terminal operator. This data collection gathered information like process cycle times (C/T), the number of workers, shift counts, and phase time indication. This data was collected based on average input provided by the interviewed experts. Once data for both material and information flows was compiled, processes were linked using arrows on the map to depict connections. These arrows illustrate how each process and workstation receives daily, weekly, or monthly schedules from control centers. Notably, the quantity of material is not a consideration; the focus is on the value stream for the cargo of a single reefer container. This simplification is necessary due to the considerable variation in the amount of freight per fruit commodity shipped within one reefer and the varying number of arriving reefer containers carrying fresh fruit cargo on each ship arriving at the Port of Hamburg.

Initially, a more global description of the value stream depicted in Figure 4.6 is provided by referring to the locations *(1) terminal, (2) customs, and (3) cold storage warehouse(s).* This description briefly outlines all potential processes that may occur.
The current state of the GFFR cold chain initiates with the arrival of a container ship transporting fresh fruit reefer containers to the Port of Hamburg *(1 - Terminal).* Upon the vessel's docking at the terminal, the terminal operator takes charge of the containers. This involves unloading the reefers from the vessel and temporarily placing them in storage at the terminal to enable subsequent transfer utilizing diverse types of equipment.
2 - Customs: After the terminal's container handling phase, which typically lasts 1 to 2 days, the reefer is transferred to the customs area for a customs scan. This process entails scanning and inspecting the contents of the reefer, alongside securing customs clearance. On average, a customs scan introduces an extra delay of 1 to 3 days to the overall cargo handling timeline.
3 - Cold storage warehouse(s): The following stage involves the management of the cargo within cold storage warehouse(s). In the Port of Hamburg, cold storage operations may be distributed among multiple warehouses, necessitating the relocation of cargo between distinct locations based on the particular operation. These inter-warehouse transfers contribute to extra transit time during the handling process. The reefer is unloaded at a controlled temperature at the cold storage facility. Subsequent, a series of processes occur, including quality checks, buffer storage, troubleshooting, additional service processing, and other additional logistical service activities. The execution of these procedures is overseen either by the cold storage operator or by third-party

entities. After completing all required processes, the cargo is temporarily stored before being transferred onto the inland carrier, facilitating distribution to the importing stakeholders' distribution centers. The importer undertakes the task of distributing the cargo to the end consumers. The duration of the activities at the cold storage facility fluctuates, spanning between 1 to 21 days, depending upon specific requirements for ensuring the delivery of appropriate cargo to the importing stakeholders [B1,B2,E,G,J].

In addition to the material flows, the information flows are depicted in Figure 4.6. Although the information flows remain consistent across various value stream map alternatives, the specific information exchanged within these flows differs depending on the specific processes involved.
The information flow originated from the information provided by the importers, who base their demand on the end-consumers' demand, which is the value chain's foundation. In this context, the importer's distribution centers contact the control centers, which provide regular updates regarding the requested supply, aligning with daily demand from retail shops. This demand serves as an essential input for the importer's control center to guide the material and information flows of distribution.

In turn, the importing control center establishes communication with suppliers at two distinct levels. Initially, orders are placed monthly or seasonal, outlining a forecast for the anticipated supply. Additionally, real-time updates concerning the products are exchanged on a daily basis. While the planning primarily relies on monthly or seasonal forecasts, daily interaction is essential to address unforeseen variables impacting the supply. Factors like weather conditions, illnesses, and fruit quality issues, beyond the scope of planning, underscore the need for daily updates [B1,B2,G,J]. For instance, in cases where the supply is hindered by crop failure or delayed shipments, an alternative supply source must be sought.

Moreover, the importing control center maintains communication with the operational logistics stakeholders to ensure the efficient handling of fresh fruit cargo upon arrival at the destination port. In some cases, importing stakeholders employ network-providing companies to manage interactions with logistics operators. Nevertheless, the information flow remains unchanged. The leading logistics participants encompass the terminal operator, cold storage operator, and forwarder, necessitating daily communication. Container invoicing delivers documentation and packing lists, ensuring all stakeholders are aware of the container and its loaded cargo for each vessel. Forwarding stakeholders receive copies of purchase orders, a vital component for invoicing and maintaining process traceability [B1].

Lastly, the customs authority contributes to the information flow by granting customs clearance. In cases where extra inspections are performed through customs scans, the customs authority communicates relevant information to the terminal operator and forwarder, who subsequently notify this information to the importer and cold storage operator.

In conclusion, the GFFR cold chain system encompasses numerous information streams necessitated by the diverse processes and stakeholders participating in the cold chain. The consistent daily exchange of information is crucial for establishing a cohesive and interconnected cold chain system.

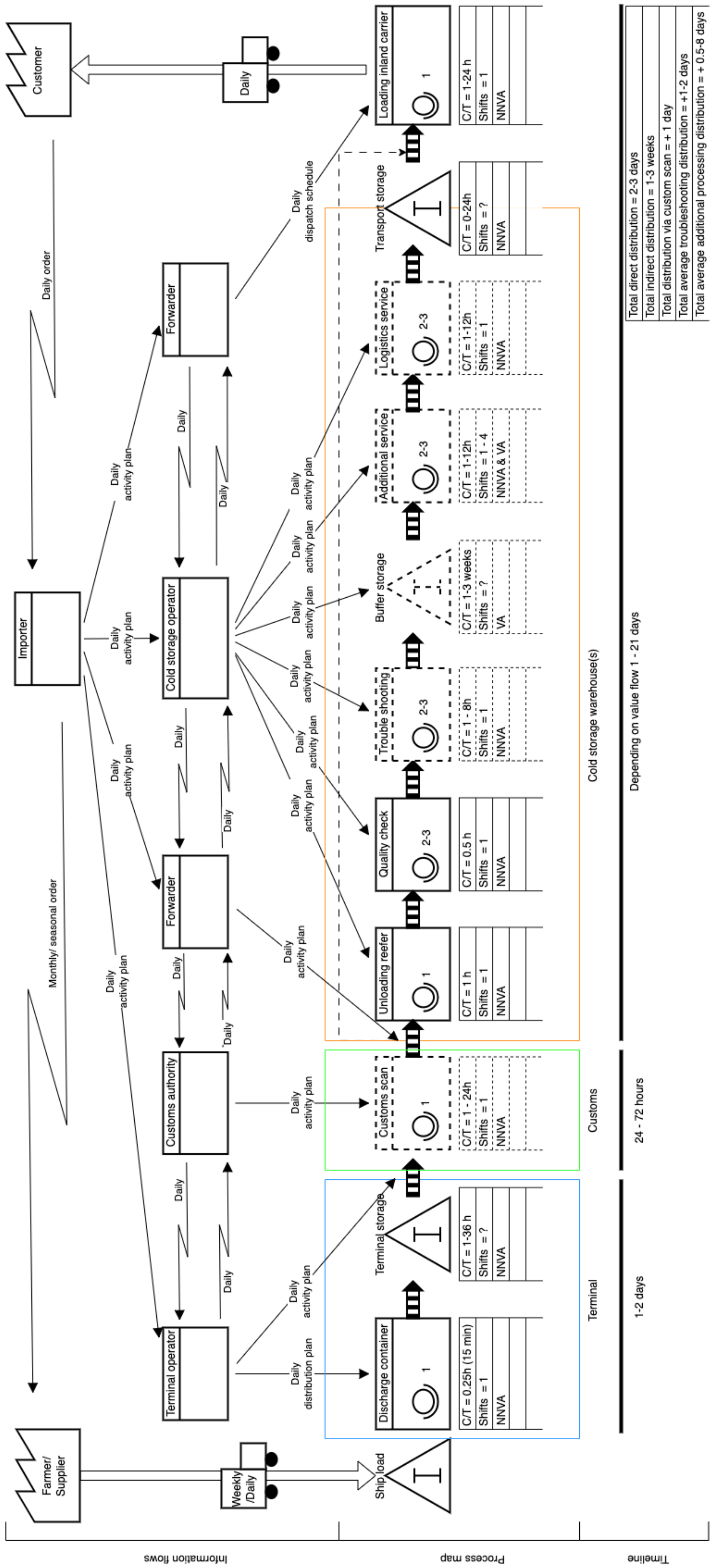

Figure 4.6.: Reference VSM of the current state GFFR cold chain value streams

4.4. Current state alternatives

After creating the reference current-state map of the VSM system, all stakeholders should be able to understand the entire process system. This understanding is essential to understanding the challenges and opportunities of the GFFR cold chain and how to accommodate improving the GFFR cold chain in the Port of Hamburg. The findings of the current-state VSM elaborate per the defined alternatives of value streams in the GFFR chain. Additionally to the generally discussed reference map (Section 4.3), a more deep-in elaboration per current state alternative map is given, including the following alternative maps: a direct distribution map (including customs scan) (Section 4.4.1); an indirect distribution map (Section 4.4.2); distribution with troubleshooting activities map (Section 4.4.3); and distribution with additional processing activities map, including additional and logistical service activities (Section 4.4.4). The descriptions are provided by referring to the operational locations *(1) terminal, (2) customs, and (3) cold storage warehouse(s).*

4.4.1. Direct distribution (including customs scan)

Two direct distribution value streams are defined: (1) direct distribution from the terminal to a ripening/distribution center in a reefer container and (2) direct distribution via a cold storage warehouse including cargo handling [B1,B2,E,G,J]. Both direct distribution value streams are presented in Figure 4.7. In the Port of Hamburg, bananas are over 80% of the fresh fruit cargo transported, and 10 to 15% of banana containers are transported directly to ripening facilities [E].

Direct distribution initiates when a container is unloaded from a ship and managed by the terminal operator. Upon the arrival of the GFFR cargo at the port, the food is cleared in the importer's name, facilitated by a service provider, often a forwarding company responsible for customs procedures [B1]. Despite the clearance of cargo under the importer's name, logistics providers are engaged by importers to oversee the container handling within the cold chain, and as a result, are designated and responsible for each individual process.

1 - Terminal: Container handling involves the discharge of containers and temporary terminal storage at the container terminal, which typically takes 1 to 2 days. The duration of container handling varies depending on whether the reefer is forwarded by truck or as part of a batch. Trucks transfer single containers, while batches involve multiple containers, resulting in a longer waiting time for dispatch. It is important to understand that the timely provision of container-handling services is crucial to avoid significant cost increases if a container's 'free time' is exceeded. The 'free time' refers to the period during which a container should be picked up, unloaded, and returned to the terminal. On average, this includes the discharge time plus an additional 3 to 4 days. Late pickup (incurring demurrage fees) or delayed return (leading to detention costs) can increase expenses. Container handling on schedule faced particular challenges last year due to congestion at the Port of Hamburg [E]. The flow of information is coordinated by the terminal operator, who maintains communication with the shipping agency regarding the shipload and vessel schedule, as well as with the forwarder and cold storage operator to ensure timely container pickup.

2 - Customs: Once a reefer container has been handled at the terminal, the cargo's transfer is taken over by a forwarder. This stakeholder manages customs clearance processes, which may involve customs scans. It is important to note that there is a distinction between a customs check and a customs scan. Customs checks are a standard procedure for obtaining customs clearance, involving both the cargo and its accompanying documentation. In contrast, customs scans involve extra inspections of a reefer through scanning and content examination. Customs clearance is always required for the distribution of a container, while customs scans only happen for about 10 % of the GFFR cold chain in the Port of Hamburg. Additional customs checks of the customs documents may occur periodically, typically at least once every three years, or even more frequently. Customs scans of containers are performed quite regularly, especially to detect narcotics (drugs) [B1,B2,E,G,J].

The container selection for a customs scan is based on various criteria, such as the origin port. Once a container is chosen for a customs scan, the carrier will notify both the operating and importing parties. This update indicates that the container is put on hold until it successfully clears inspection [G]. The customs scan procedure involves collaboration between the forwarder and the customs authority. The forwarder is accountable for the terminal pick-up and transfer to a cold storage facility, but they remain a client of the terminal operator. Thus, the terminal operator handles the physical logistics aspects. The forwarding company must request a slot from the customs authority to drop off or pick up a reefer container at the customs location. Slot reservations are made through a booking system, sometimes permitting same-day bookings while at other times requiring several days of wait.

The customs authority carries out the scan, and customs clearance is provided if the cargo meets the criteria. Yet, if narcotics are detected, an internal procedure is set in motion involving the police and customs authority. The forwarder and terminal operator are not notified of these findings as an ongoing investigation is launched to trace the recipients and individuals associated with the narcotics trade. The frequency of narcotics discoveries remains undisclosed [B1,E].

Aside from narcotics being detected in customs scans, drugs are occasionally discovered in shops or cold storage facilities. For instance, at a cold storage facility in the Port of Hamburg, drug discoveries may occur approximately once in a couple of years. When drugs are found in the cold storage, the entire facility is placed on hold, and the customs authority conducts scans of all boxes within the premises, which can extend up to three days [E]. In most cases, the cargo is cleared after the scan is completed. Unless explicitly informed, the forwarder, terminal operator, or importer will remain unaware of the potential discovery of narcotics. The duration of customs scans depends on the number of prohibited items discovered. For instance, if only 15 kg of forbidden goods are found, they will be taken out of the container, and the container will be cleared. However, should a larger quantity, say 500 kg, be detected, the container remains blocked for an extended period. Once the scan is finalized, forwarding operators are notified to arrange the container's pick-up [G].

Over recent years, the number of containers selected for customs scans on fresh fruit cargo has increased. This phenomenon is observed across various ports, not only in the Port of Hamburg. Notably, customs scans have seen a notable increase, particularly concerning banana and exotic fresh cargo originating from Central and Latin America [B1,B2,G]. Within the banana segment, about 10% of the containers are selected for customs scans. In the best-case scenario, a customs scan will lead to a delay of about 24 hours in handling GFFR cargo at the Port of Hamburg. Occasionally, this delay can extend to 2 to 3 days or even longer. Extended customs scan durations may result in heightened client dissatisfaction due to incurring demurrage, detention, and other additional costs.
For the customs scan to occur, the reefer must be moved to the designated customs location situated at Waltershof within the Port of Hamburg. While supplementary customs scans typically take around 1 to 2 days, customs clearance can be acquired within a remarkably short period, approximately 30 minutes, owing to the dedicated efforts of the customs authority in collaboration with cold storage operators [B1,E]. Regarding customs clearance procedures, most forwarders lack their own quality inspectors. Instead, they foster close partnerships with specialized companies proficient in this service [J].

3 - Cold storage warehouse(s): Once customs clearance is granted, the container proceeds to either direct distribution to a ripening or distribution center or is transferred to a cold storage warehouse. In both scenarios, unloading the reefer and conducting a quality check are conducted within controlled temperature settings. However, the ownership of these procedures varies according to the distinct execution locations. In the case of direct distribution, the importer bears complete responsibility, whereas direct distribution to a cold storage warehouse involves a stakeholder specializing in cold storage functions within the GFFR cold chain. For the purpose of this research, particular attention will be given to the unloading of reefer containers and the subsequent quality evaluation conducted at the cold storage facility.

Within the context of direct distribution through the cold storage warehouse, the cargo is unloaded and deposited into the cold storage facility. Subsequently, an external company undertakes an inbound quality assessment. A comprehensive arrangement with the customs authority streamlines thorough control, thereby, not every small cargo commodity undergoes inspection. The inbound quality check encompasses temperature, packaging condition, and fruit quality. Approximately 1% of the boxes are selected at random for checks [B1]. Moreover, these quality checks account for criteria like size, weight, sugar content, packaging, labeling, fruit classification, and more. Such criteria are dictated by legal regulations and the importing stakeholder's specific standards. Through these quality checks, the cargo's market suitability is evaluated. Any shortcomings or concerns are documented in a report, specifying areas for potential improvement. Subsequently, the cargo undergoes troubleshooting measures or is disposed of, based on the nature of the issue and the cold storage operator's discretion [B1,E,G]. Quality control for a single reefer should ideally conclude within 15 to 30 minutes. This procedure is digitized, with data recorded on a tablet. On average, 2 to 3 personnel are involved in conducting these quality controls [B1].

Once the quality check is successfully completed, the cargo is dispatched to the designated distribution center of the importing stakeholder. During the transition from the quality check to the loading onto the inland carrier, temporary storage for transportation purposes may be required. The duration of this storage period varies based on factors such as availability and logistics considerations between the cold storage facility and the inland forwarding stakeholder.

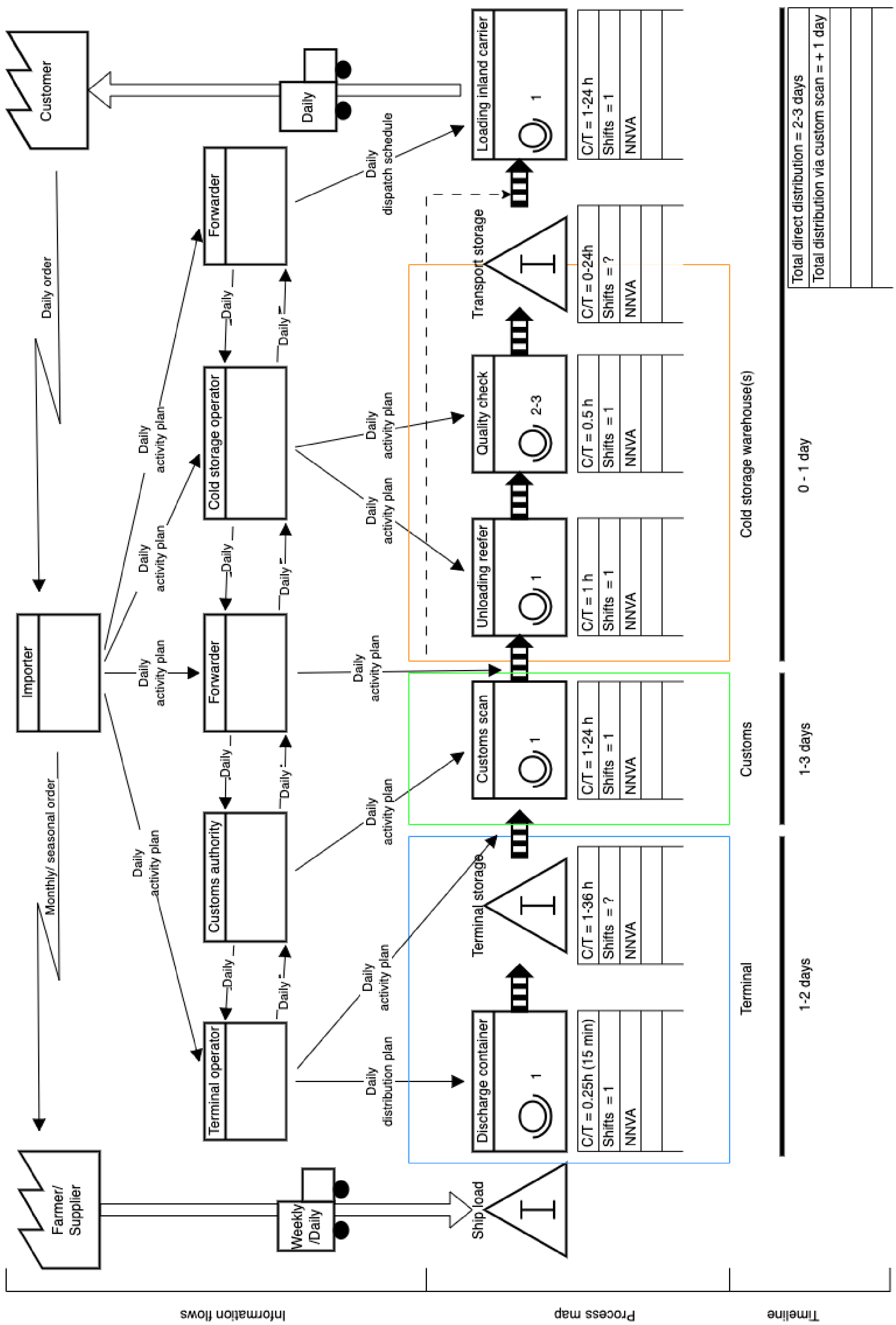

Figure 4.7.: VSM of the current GFFR cold chain direct distribution (including customs scan) value stream

4.4.2. Indirect distribution

Within the GFFR cold chain at the Port of Hamburg, both direct and indirect distribution of GFFR cargo are essential components of the value stream, as depicted in Figure 4.8. Indirect distribution, enabled through buffer storage *(3 - cold storage warehouse(s))*, holds significant relevance for the GFFR cold chain by managing shifts in demand and supply, as well as fluctuations in market prices. The feasibility of including buffer storage into the cold chain is dependent on the shelf-life of the fruit commodity [B1,B2,E].

3 - Cold storage warehouse(s): Buffer storage is crucial in supporting the fruit supply chain by providing valuable assistance to suppliers and (last-mile) distribution centers through cold storage options. Inland distribution centers often encounter capacity limitations, and by creating storage at cold storage warehouses, the burden on these centers can be reduced. Moreover, cargo can be strategically stored at the port of destination cold storage facilities, easing storage constraints at the supplier's end. For instance, long-shelf-life fruit commodities ready for distribution at the origin location but not yet planned can be transported to the Port of Hamburg and stored, allowing for better timing of fruit arrivals at the cold store facilities. This approach may result in fruit arriving at the cold store within 2 to 3 weeks while being sold over a more extended period, nearly 8 weeks [B1]. However, this practice is feasible only for long-shelf-life commodities (up to 6 weeks) and not for short-shelf-life fruits like grapes, which last 5 to 10 days.

Beyond addressing storage constraints, buffer storage serves as a strategic tool to respond effectively to sudden demand fluctuations. Bananas, for instance, are well-suited for buffer storage due to their transportation in a 'sleeping' state as green bananas, providing flexibility within the supply chain [B2,E]. Green bananas can be stored for 1 to 3 weeks, whereas after three weeks, they must be dispatched due to quality and market suitability concerns. On the other hand, fruits such as apples may be stored for approximately one month. EDEKA Fruchtkontor illustrates the advantages of this flexibility in buffer storage, allowing them to plan demand for weeks or months and enable regions to place daily orders, receiving fruit cargo promptly the following day, even as early as 3 am. This rapid response to consumer needs provides a competitive edge to the GFFR cold chain [B1].

Moreover, buffer storage effectively manages market price fluctuations, employing a similar strategic approach for demand fluctuations. Particularly, before entering buffer storage, fruit cargo undergoes a comprehensive quality check that might involve additional processing to ensure overall quality during storage. This quality check extends beyond the initial inspection, encompassing checks conducted during and after the buffer storage period to sustain the freshness and market appeal of the fruits.

In conclusion, while buffer storage offers the advantage of flexibility, it's essential to acknowledge that it also comes with substantial costs, making it an advantageous strategy to a certain extent.

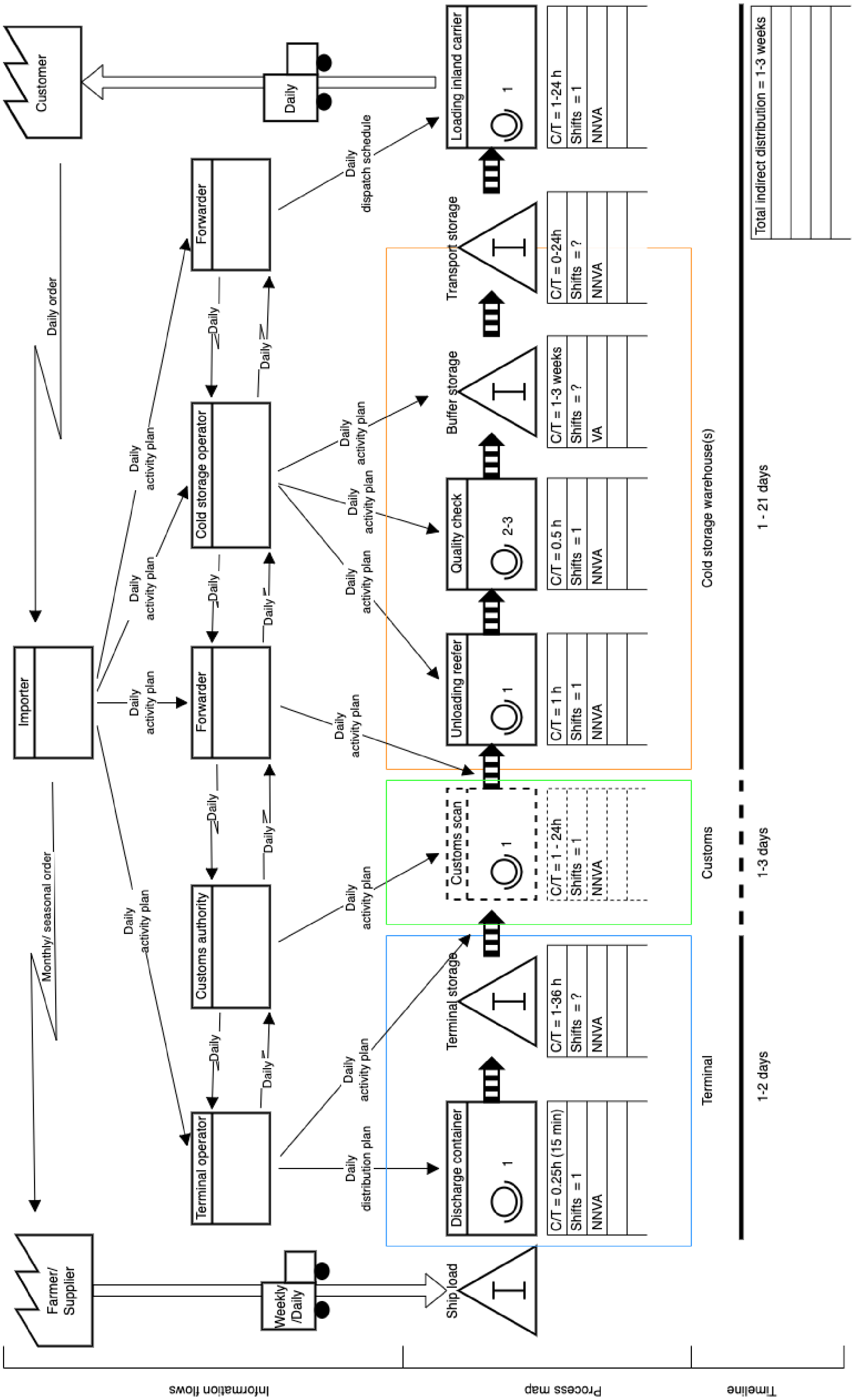

Figure 4.8.: VSM of the current GFFR cold chain indirect distribution value stream

4.4.3. Distribution with troubleshooting activities

Figure 4.9 illustrates the value stream of distribution with troubleshooting activities. Within the GFFR cold chain, a critical process is the quality check conducted on the fresh fruit cargo. This inbound quality check involves assessing factors such as temperature, packaging condition, and fruit quality to ensure suitability for the market. Given the perishable nature of fresh fruit and the importance of meeting market standards, these quality checks hold significant importance. If the fresh fruit cargo does not meet the quality requirements, the cargo may either be disposed of or further handled by troubleshooting activities *(3 - cold storage warehouse(s))* [B1,E,G]. Troubleshooting activities address quality issues that might arise after the goods have been transported overseas. These activities aim to resolve temperature-related problems, decay issues, and underweight concerns [B1]. To tackle these issues, various processes are predominantly employed: To address these challenges, a range of processes are utilized:

- Selection of fruit (temperature issues)
- Quality solving (decay issues)
- Modification of weight when possible (underweight issue)

3 - Cold storage warehouse(s): The selection of fruit is crucial in addressing temperature issues, especially the decrease in food loss. Once the inbound quality check identifies any temperature-related concerns, the cargo is carefully selected to check whether the fruit is suitable for normal marketing. This process involves evaluating the temperature sensitivity of the cargo and selecting those still suitable for sale. Post-selection actions align with both customs authority regulations and additional importer-specific requirements.

To address decay issues, a comprehensive quality-solving protocol is implemented. This process aims to identify and resolve factors contributing to the decay or deterioration of the fresh fruit cargo. It involves conducting thorough inspections, including visual assessments, to detect signs of decay, such as mold, discoloration, or texture changes. Once the decay issues are identified, appropriate measures are taken to mitigate them, which may include implementing improved packaging, adjusting storage conditions, or applying suitable treatments to extend the shelf-life of the fruit cargo. The quality-solving process ensures that the fresh fruit cargo maintains its optimal quality and minimizes the risk of decay during transportation and storage.

In the presence of underweight concerns, measures are taken to adjust the weight whenever feasible. To address underweight issues, the cargo undergoes a careful assessment to determine whether weight modification is viable. This assessment considers factors such as the nature of the fruit, transportation constraints, and regulatory requirements. If weight modification is deemed appropriate, measures may be employed to increase the weight of the cargo to the desired standard. The weight modification aims to ensure that the fresh fruit cargo meets the required weight specifications, enhancing market suitability and preventing potential economic losses.

Once it is concluded that the quality does not meet the required standards, troubleshooting activities are initiated. On average, these activities take one shift, roughly lasting 8 hours. Nevertheless, the precise duration can vary depending on the specific process involved. It is important to highlight that not all cold storage warehouses in the Port of Hamburg engage in troubleshooting activities [B1,E].

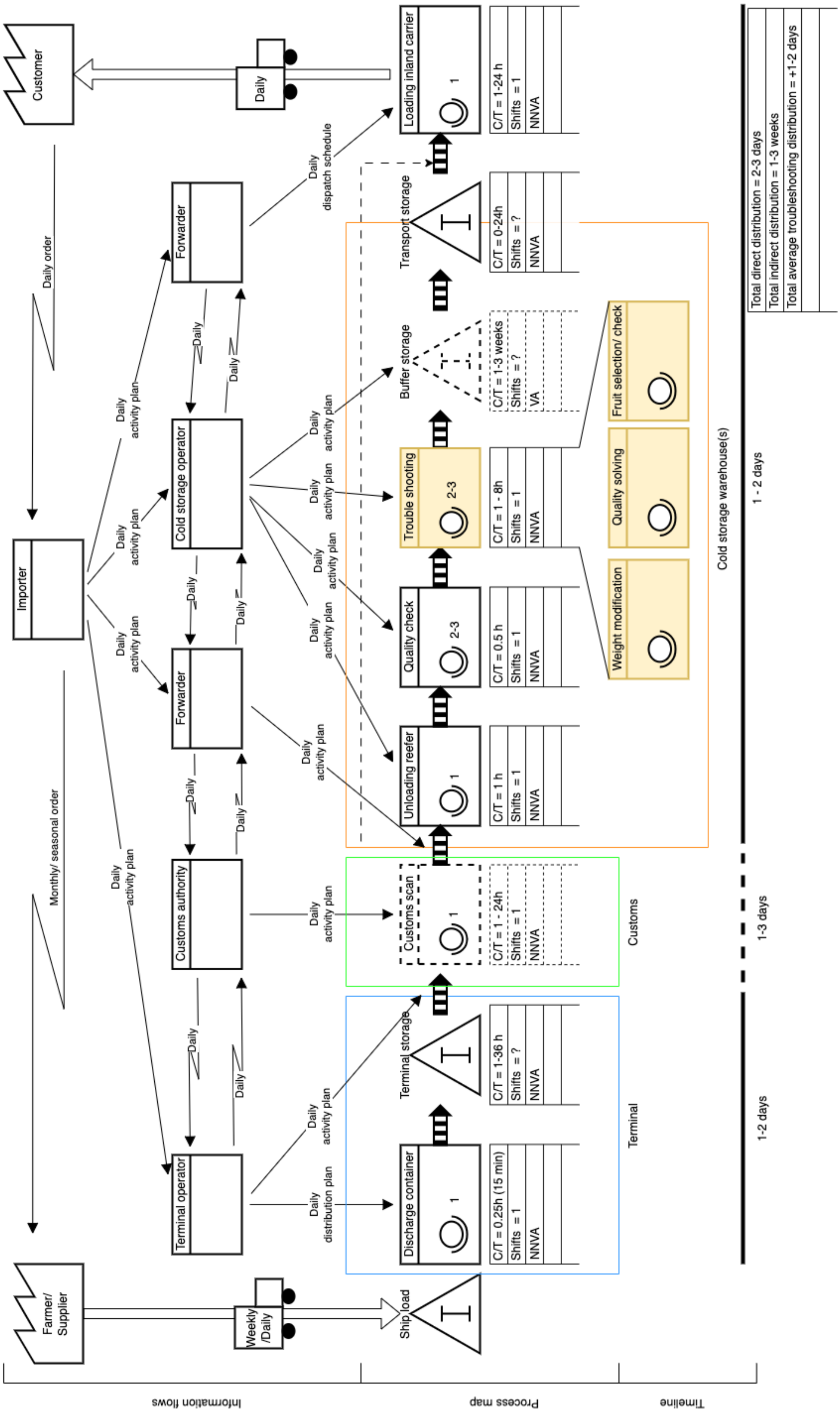

Figure 4.9.: VSM of the current GFFR cold chain distribution with troubleshooting activities value stream

4.4.4. Distribution with additional processing activities

The last identified value stream alternative is the value stream that includes additional processing activities in the GFFR cold chain, depicted in Figure 4.10. Additional processing activities include additional services and logistical services *(3 - cold storage warehouse(s))*. Depending on the fresh fruit commodity, additional processing activities are required. Additional processing activities include the following processes:

Additional service activities

- Ripening
- Packaging
- Appealing

Logistical service activities

- Repackaging
- Relabelling
- Order picking
- Repalletizing

Both services involve the packaging process, yet it is important to distinguish between them. Packaging can be considered an additional service that enhances value, whereas repackaging is a logistical requirement to ensure shelf-life and market suitability. Further clarification and elaboration on these processes are discussed in this section.

Additional service activities

3 - cold storage warehouse(s): Ripening, when applicable for a fruit commodity, is considered one of the crucial additional service activities. Within the GFFR fresh fruit context, commodities such as bananas, mangoes, avocados, and kiwis may require ripening. Although ripening is not mandatory for mangoes, avocados, and kiwis, it is generally preferred [B1,E].
In terms of volume, bananas hold a significant role in the operations of the Port of Hamburg. Consequently, the ripening cycle of bananas is discussed. Bananas are transported in sizable boxes weighing 18 kg in their green state, which is crucial for their preservation. Before being available for sale in retail stores, bananas undergo an essential ripening process [G]. A banana's ripening cycle typically spans approximately 6 to 7 days. Nonetheless, various factors, including age, origin, rainfall during growth, and other variables, can influence the precise length of this process [B2,E]. Throughout the ripening period, daily inspections are conducted to evaluate the color and temperature of the bananas, following a specific ripening protocol. This monitoring is crucial to ensure compliance with market requirements of suitability, as different markets may demand bananas of distinct colors [G].
Reefer containers, following dispatch and customs clearance, can be directly transported to inland ripening facilities, or they may remain within the port's cold storage warehouses. [G]. Leading importers like ALDI, EDEKA, LILD, and REWE have their own dedicated ripening facilities or collaborate with specialized companies. Once bananas have ripened, they are directly transferred from the ripening room to the inland depot, typically requiring around 1 to 1.5 days for transportation [B2].

Apart from ripening, packaging plays a relevant role as an additional processing activity to prepare fresh fruit for market sale. Packaging is often essential to ensure proper handling and visual appeal. Frequently, fresh fruit is transported in larger quantities than those ultimately sold to consumers. For instance, it's common for fruit to be shipped in pallets while being individually sold in nets.
As an illustrative example, the packaging of citrus fruits is discussed. While citrus fruits are usually transported as bulk cargo, approximately 80% of this cargo is eventually retailed to consumers in nets. Packaging citrus fruits in larger batches, like loose goods instead of nets, reduces the presence of air in boxes during transportation, minimizing potential issues during cargo inspections. Moreover, while supply chain planning for citrus fruits is conducted monthly, demand is evaluated daily. By packaging the citrus fruits at the destination, their freshness and quality can be better preserved [B1].
The decision to locate the packaging process at the destination's cold storage, rather than at the origin, is driven by cost-effectiveness and flexibility. Decreasing the amount of air in shipments results in cost reduction, and having packaging facilities at the destination provides greater control and planning flexibility.

The process of appealing involves the removal of the protective coating from avocados and citrus fruits [B1]. This coating contributes to the shelf-life of the fruit, but it is not meant to be sold as part of the package. Hence, it is necessary to peel off the coating before consumption. The attractiveness of this protective packaging lies in its ability to preserve the fruit's freshness and quality while also offering an aesthetically pleasing appearance that appeals to consumers.

Logistical service activities

3 - cold storage warehouse(s): Repackaging becomes essential when overseas transport damages the packaging. This process ensures that the damaged packages are addressed and the fruits are repackaged in a manner that aligns with the quality standards [B1]. By repackaging cargo, the shelf-life and market suitability of fresh fruit commodities can increase, improving their market value. Repackaging serves as an effective solution to salvage and enhance the market viability of fresh fruit commodities affected by transportation damage.

Relabelling holds significant importance within the fruit cold chain, serving as a logistical service activity for transport [B1,E]. This procedure involves the substitution or inclusion of labels on fruit packages to guarantee precise and up-to-date information. The relabelling process is crucial for preserving traceability, compliance with regulations, and consumer confidence, facilitating efficient and transparent logistics throughout the GFFR cold chain.

Order picking is a logistical service activity in the fruit cold chain that involves carefully selecting and gathering specific quantities of fruits from storage areas to fulfill customer orders. This process ensures accurate and efficient fulfillment of orders. By implementing effective order-picking processes, the GFFR cold chain can streamline operations, reduce errors, and enhance customer satisfaction by delivering fresh and correctly packaged fruits.

Repalletizing from industrial pallets to Euro-pallets may be necessary for efficient distribution, particularly in automated warehouses that specifically require Euro-pallets [B1]. This need arises because Euro-pallets do not fit optimally into reefer containers, which are only 2.20 meters wide, whereas industrial pallets, measuring 1.20 by 1 meter, are better suited for reefer containers. However, the decision to engage in repalletizing activities depends on the warehouse requirements and the preferences of cargo forwarders and distribution centers. For example, one cold storage operator in the Port of Hamburg recognized the need for repalletizing, while another one opts not to perform this process due to associated costs [B1,E,J]

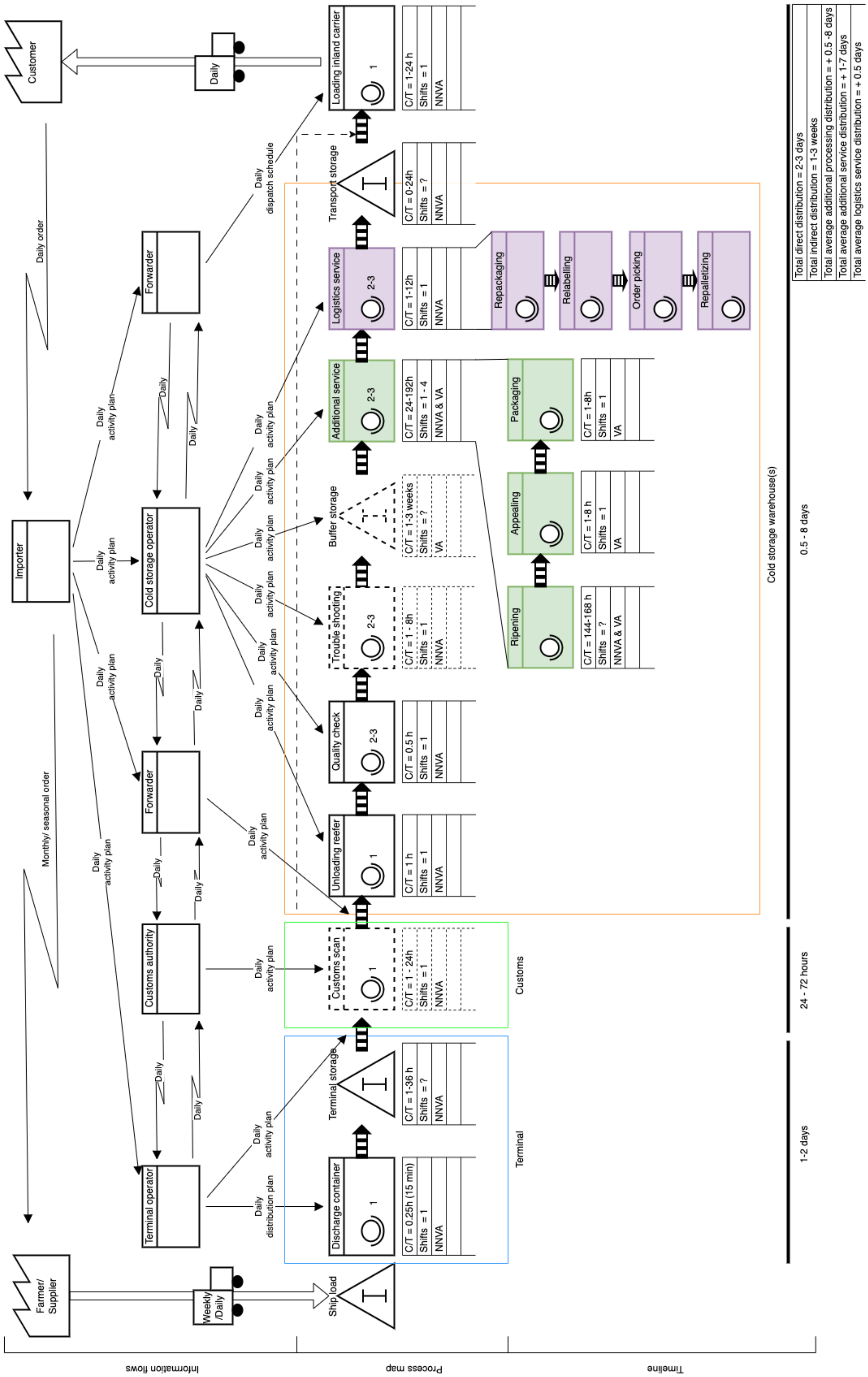

Figure 4.10.: VSM of the current GFFR cold chain distribution with additional processing activities value stream

4.5. Value stream segments

Once the activities within the GFFR cold chain have been mapped out on an organizational level, the value stream segments are assigned and discussed for each operation. Despite potential variations in the execution of operations across diverse current state alternatives, categorizing these processes remains consistent. This continuity arises from the inherent nature of the processes themselves and their unchanging contribution to the cold chain. Variations might primarily lie in the information flow, stemming from distinct data considerations necessitating sharing. However, it is important to highlight that such variations do not impact the established classification.

The classification consists of three distinct categories: value-adding (VA) streams, non-value-adding (NVA) streams, and necessary but non-value-adding (NNVA) streams. Following the initial round of interviews, variations in the interpretation of these categories among participants were observed. A precise and comprehensive definition of the associated terminology is provided to mitigate potential confusion. This is essential since one participant might characterize a process as necessary but not value-adding, while another might classify all included processes as added-value segments, considering that only indispensable processes are incorporated and funded, as excluding them would disrupt the overall flow. The perspectives of all participants have been thoughtfully considered during the assignment of categories while prioritizing the value stream perspective and terminologies. From the value stream perspective, the following definitions are used (based on (Mcmanus, 2005; Shou et al., 2019)):

- **Value-adding (VA)** - Value-adding activities and processes involve any operations that contribute to the product's form, fit, or function in the production flow that the customer requires. In the GFFR cold chain, value-adding refers to all activities and processes contributing to the shelf-life and suitability of the fresh fruit sold to the customer.
- **Non-value-adding (NVA)** - Non-value-adding activities involve any operations that could fulfill the customer's demand but not add value to the overall product or service. A customer is not willing to pay for these kinds of processes. In the GFFR, non-value-adding processes can be defined as operational waste.
- **Necessary but non-value-adding (NNVA)** - Necessary but non-value-adding activities and processes involve any operations that do not create value but are necessary for streamlining the production process to increase the value of the final product. In the GFFR cold chain, NNVA processes refer to unavoidable processes due to their critical role in maintaining a closed and good connected cold chain.

The value stream segments assigned per process are discussed in Table 4.2. As indicated in Table 4.2, all processes are classified as value-adding or necessary but non-value-adding. Non-value-adding processes were not identified at the organizational level, given the understanding that GFFR cold chain customers would not willingly invest in a process lacking value or necessity. However, these value stream segments are established at a broader organizational level. It remains plausible that a more detailed micro-level value stream map could reveal non-value-added tasks that lack necessity.

Aside from the value-adding segments identified through the value stream mapping, the GFFR cold chain at the Port of Hamburg incorporates additional value-adding aspects. Two noteworthy segments stand out in conjunction with buffer storage and additional processing activities: information and location added-value components within this cold chain system. The information-added-value segment refers to direct engagement with stakeholders throughout the cold chain, particularly for the importing stakeholder. This direct interaction ensures seamless coordination across all cold chain phases. For instance, within Hamburg's GFFR cold chain, EDEKA, as an importing stakeholder, taps into the robust network of EDEKA's Fruchtkontor to provide essential information into the cold chain's progression. This empowers the stakeholder to swiftly respond and manage unforeseen events, such as scheduling challenges, that may emerge.
The location-added-value segment refers to the current scenario where various processes within the GFFR cold chain are distributed across different close locations within the Port of Hamburg. It is important to note that cold storage-related processes are carried out at distributed cold storage facilities rather than a single centralized facility. This setup results in more advanced temperature-controlled vehicles and a higher potential for disruptions due to physical and stakeholder linkages. Additionally, this arrangement leads to extended cargo handling times. Centralizing most, if not all, processes at a single location is considered an added-value segment $_{B1,G}$.

Table 4.2.: Assigned value stream categories per GFFR cold chain process

Process	Value stream category	Description
Container handling	NNVA	The handling of a container at the terminal is necessary to provide a connection between maritime and land transport. Nevertheless, this activity does not add value to the GFFR cargo.
Terminal storage	NNVA	Reefer terminal storage serves as a necessary link connecting dedicated equipment (e.g. cranes and automated guided vehicles) for loading and discharging containers from container ships, facilitating their transfer to hinterland transport modalities. Nevertheless, while this activity supports the transport system, it does not add direct value to the GFFR cargo.
Customs scan	NNVA	Customs scans are mandatory by the customs authority and must be conducted under all circumstances (when selected). These scans help ensure cargo and food safety and quality. The customs authority sets the requirements for these scans. While customs scans do not directly add value to the GFFR cargo, they serve as protective measures and result in additional expenses. Importantly, these scans can potentially impact an importer's revenue margin, as the associated costs are not always anticipated in budgets planned well in advance [E]. This process can be classified as necessary because the cargo can not be handled if not performed.
Unloading reefer	NNVA	Unloading the cargo from a reefer is necessary to connect the cold chain. This process is needed for linking various stages and equipment within the GFFR cold chain.
Quality check	NNVA	Similar to a customs scan, a quality check is performed under all circumstances to guarantee the safety and quality of the cargo. Whenever necessary, a quality check may lead to additional necessary processes like troubleshooting activities. Nonetheless, while this process ensures a certain level of cargo quality and suitability, it does not add value.
Buffer storage	VA	Buffer storage is a value-adding process in the GFFR cold chain due to the flexibility and security this inventory provides for delivering the requested quantity of products. Buffer storage helps to cope with demand, supply, and price fluctuations in the GFFR cold chain. This flexibility and security of the inventory and GFFR cargo add value to the cargo on the market, and buffer storage is classified as value-adding. Nevertheless, it is value-adding to a certain extent because buffer storage also involves costs.
Troubleshooting activities	NNVA	Troubleshooting activities are necessary to address potential quality concerns that might arise following the overseas shipment of goods. When such troubleshooting activities are necessary, they are classified as necessary but not value-adding. This is because, without these processes, the cargo's suitability for sale or consumption could be critically compromised. Undertaking these activities incurs extra expenses for the importer, which do not add value.
Additional processing activities	NNVA & VA	Depending on the specific process and fresh fruit commodity, additional processing activities can be classified as necessary but non-value adding or value-adding. The ripening process is classified as both necessary and value-adding. For instance, the ripening of bananas is necessary due to their inedible state when green. However, for fruits like mangoes, avocados, and kiwis, ripening is not obligatory but is preferred to enhance market suitability, thereby adding value to the cargo. On the other hand, processes like packing and appealing are considered value-adding activities. While the cargo can be sold without these processes, they contribute to the presentation and form in which the cargo is marketed, aligning with customer preference. Lastly, logistical service activities are categorized as necessary, ensuring the cargo's suitability for transportation, making them crucial for the overall supply chain.
Transport storage	NNVA	Storing cargo before it is distributed to the distribution center is essential for establishing connections between various stages of the GFFR cold chain. While this storage does not add value, it can be classified as a necessary link between cold storage and the inland carrier within the cold chain.

The key insights extracted from the value stream maps and process classification highlight two critical issues within the GFFR cold chain: customs scans and quality checks. Although these activities are necessary, they do not directly contribute value and can lead to potential delays and increased costs in cargo handling. The significance of these issues is evident from their frequency in the Port of Hamburg's GFFR cold chain. Roughly 10% of all fresh fruit reefer containers undergo customs scans, while the occurrence of quality checks varies between 5% and 30% depending on the season and the quality of the fruit cargo, which is affected by weather conditions at the source. Considering the unpredictability of climate and weather patterns, it is anticipated that future production of fruits may face more quality issues due to worsening weather conditions. Increased weather fluctuations can produce more stressed fruit and plants, producing a shorter shelf-life.

Moreover, the key insights highlight aspects within the Port of Hamburg's GFFR cold chain concerning value-added components, such as buffer storage and additional processing activities, indicating opportunities for improvement. Although the frequency of buffer storage usage is unspecified, it is important to acknowledge its potential as an improvement strategy to a certain extent. At a certain point, the associated costs may outweigh the flexibility to respond to supply, demand, or price fluctuations. Additional processing, especially additional services, is not commonly performed within the cold storage facilities at the Port of Hamburg, presenting a gap in the value chain. To gain a comprehensive understanding, Chapter 5 elaborates further on these segments, emphasizing critical issues and potential improvements.

4.6. Concluding remarks value stream mapping

Conducting the value stream mapping provided essential insights into the Port of Hamburg's GFFR cold chain value streams. These insights contributed to the comprehension of the various activities and processes within this cold chain, as well as the complex interplay between these aspects. The VSM holds significant relevance in identifying specific areas for further research focus. Moreover, the VSM effectively addresses the second research question.

Research question 2 - How is the global first-mile value chain structured for the Port of Hamburg's fresh fruit reefer cold chain?

The second research question is addressed by understanding the various aspects involving the structure, activities, and flows of material and information of the GFFR cold chain in the Port of Hamburg. Moreover, the value chain's critical issues and potential improvements are presented.

The activities and processes considered for fresh fruit transported within this cold chain are defined as follows, pointed out per the operating locations terminal, customs, and cold storage warehouse(s):

- **Terminal:** discharge container & terminal storage
- **Customs location:** customs scan
- **Cold storage warehouse(s):** unloading reefer, quality check, troubleshooting activities, buffer storage, additional services, logistical services, transport storage & loading inland carrier

These activities and processes are connected by material and information flows. Various material flows can arise throughout the GFFR cold chain due to careful cargo handling according to the highest quality standards and market suitability. The differentiation of these material flows is primarily influenced by four key factors: distribution choice, the performance of customs scan, the performance of troubleshooting activities, and the performance of additional processing activities. Based on these influencing factors, a variety of material flows may occur, which are captured in four current state alternative maps:

- Direct distribution (including customs scan)
- Indirect distribution
- Distribution with troubleshooting activities
- Distribution with additional processing and logistics services activities

The information flows that facilitate the movement of cargo maintain consistency throughout the various material flows. However, the nature of information exchanged varies according to the specific processes engaged. The information flow originates from the importer, who communicates the value chain's demand. The importing stakeholder engages with the supplier through two levels of communication: monthly or seasonal supply forecasts and real-time daily updates concerning the cargo. Moreover, the importer also shares daily information with operational logistics stakeholders. These logistics stakeholders exchange daily information to ensure optimal connectivity and efficiency in maintaining the cold chain processes.

The GFFR cold chain within the Port of Hamburg involves numerous material and information flows that arise from the diverse range of processes and stakeholders engaged in the cold chain. The complexity of numerous processes, stakeholders, material flow alternatives, and information sharing within this cold chain highlights the importance of understanding the complex relationships between these elements to achieve optimal efficiency in the dynamics of the cold chain.

The classification of value stream segments reveals the critical issues and potential improvements within the cold chain. All processes are categorized as either value-adding or necessary but non-value-adding segments, grounded in the understanding that GFFR cold chain customers would not willingly invest in processes lacking value or necessity. However, it is important to note that these findings are presented at an organizational macro-level. A more detailed investigation could potentially uncover non-value-adding tasks that lack necessity.

Among the identified value-adding segments from the value stream mapping, additional services and buffer storage stand out as opportunities for improvement. Buffer storage has the potential as an improvement strategy, even though it has potential to a certain extent. At a certain point, the associated costs may outweigh the flexibility to respond to supply, demand, or price fluctuations. Furthermore, processing activities, especially additional services, are not commonly performed within the cold storage facilities at the Port of Hamburg, presenting a gap.
Moreover, two potential value-adding segments, not solely tied to individual processes but inherent in the system, emerge: the information component involving direct engagement with stakeholders across the cold chain and the location component focused on centralizing most, if not all, processes at a single location.

In addition to improvement potential, the value stream maps highlight two critical issues: customs scans and quality checks. While essential, these actions don't directly add value and can cause delays and extra costs. Their importance is evident from their frequent occurrence in the GFFR cold chain at the Port of Hamburg. These challenges, particularly associated with time-sensitive aspects, disrupt the flow of GFFR cargo and lead to handling delays.

Addressing the second research question revealed the underlying structure of the value chain and brought to light both critical issues and potential improvements within this cold chain. When combined with understanding activity and stakeholder interdependence relations derived from answering the first research question, these insights significantly enriched the ongoing research to accommodate stakeholders to improve the GFFR cold chain in the Port of Hamburg.

5. Opportunity analysis

The value stream mapping identified critical issues and potential improvements within the GFFR cold chain operations at the Port of Hamburg. This internal environmental analysis guided the identification of the GFFR cold chain core strengths and weaknesses. In addition to the internal aspects, external influences from broader global fruit cold chain dynamics and the port play a crucial role in shaping and improving operations in the Port of Hamburg. The external environmental analysis conducted via interviews identified the opportunities and threats that must be considered within this GFFR cold chain. This chapter details the conducted opportunity analysis, drawing from previous research findings and insights shared by supply chain stakeholders during interviews.

Both internal and external factors have a significant impact on the GFFR cold chain in the Port of Hamburg. Internal analysis, incorporating value stream mapping and interviews, identified the system's strengths and weaknesses, as discussed in Section 5.1. Additionally, external factors stemming from the broader fruit cold chain dynamics and port development were explored in Section 5.2. After a comprehensive assessment of strengths, weaknesses, opportunities, and threats, this research performs a SWOT analysis in Section 5.3, which leads to various strategies for enhancing the GFFR cold chain. After understanding the relevance of these strategies, Section 5.4 explores the specific improvement potentials within the GFFR cold chain in Port of Hamburg. Lastly, concluding insights on the potential analysis are presented in Section 5.5.

5.1. Internal factors

Internal factors refer to factors that are under the control of the business or, in this research context, the stakeholders engaged in the GFFR cold chain. Analyzing the internal factors reveals the strengths and weaknesses of the GFFR cold chain in the Port of Hamburg. Strengths contribute to the efficiency of GFFR material and information flows or add value to the GFFR cargo, while weaknesses hinder or even block the GFFR cargo flow. These internal factors closely align with the critical issues and improvement potentials identified through value stream mapping, as shown in Figure 5.1, where critical issues are marked in red and improvement potentials in blue. The interviews also support identifying strengths and weaknesses highlighted by the value stream mappings, including customs scans, buffer storage, additional processing activities, and the operational location segment.

It is essential to highlight that some critical issues and potentials identified through the theoretical perspective of value stream mapping are not necessarily seen as improvement strengths or weaknesses from the practical perspective obtained through interviews. This distinction underscores the divergence between academic and real-world perspectives.

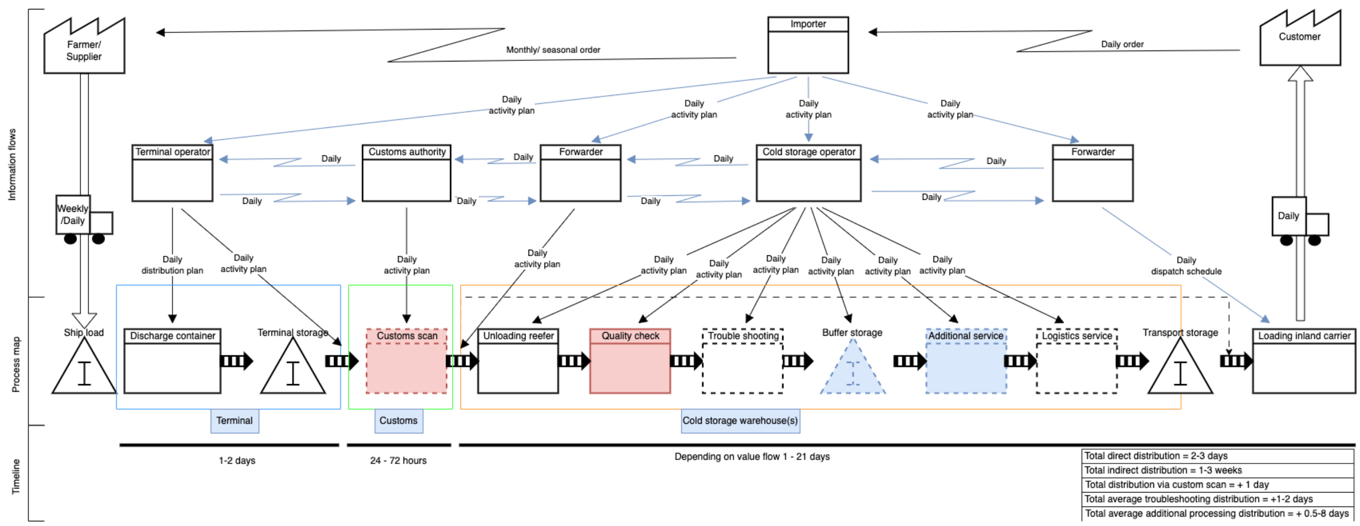

Figure 5.1.: VSM visualization critical issues (red) and improvement potentials (blue) for GFFR cold chain the Port of Hamburg

One critical issue not addressed in this SWOT analysis is the quality check. Although the quality check process itself may not introduce time-related challenges, this point of measuring GFFR cargo quality can significantly impact the GFFR cold chain. This is because additional processes may be required after the quality check to ensure that the high-quality standards of GFFR cargo are met. The interviews did not identify this aspect as a primary challenge in the GFFR cold chain but rather as a measure to ensure cargo safety and quality. Furthermore, the information segment is integrated into various aspects of the SWOT analysis rather than being discussed separately.

The strengths and weaknesses identified in this research, based on the insights of value stream mapping and interviews, are presented below.

Strengths

- Buffer storage
- Additional processing activities

Weaknesses

- Customs scan
- Groupage network
- Cold storage capacity
- Operating area
- Port area

The GFFR cold chain strengths were initially identified through value stream mapping and were further elaborated upon in interviews, mainly with cold storage operators and importers. The two strengths involve buffer storage and additional processing activities, focusing on the additional services. Addressing the strengths first by attracting additional buffer storage is a decisive step toward enhancing flexibility despite the ongoing challenge of balancing storage needs and cost considerations. Furthermore, optimizing additional processing operations, improving processes, and incorporating advanced technologies offer an approach to reducing costs, enhancing efficiency, ensuring consistent quality, and extending the shelf-life in this cold chain. However, it is essential to note that investing in specialized equipment may not be economically feasible due to fluctuations in demand caused by the seasonal nature of the cargo.

Furthermore, the GFFR cold chain in the Port of Hamburg faces several weaknesses. A major concern is the customs scanning process, which is mandatory but causes delays and increased costs. Strategic initiatives focusing on procedure streamlining, additional scanning locations, and cooperation with authorities are necessary to mitigate this weakness, ultimately enhancing efficiency and ensuring timely transportation of high-quality fresh fruits. Additionally, the limited groupage network associated with the food cluster presents a notable weakness that can be (partly) addressed through stakeholder collaboration to improve overall efficiency and reliability. Moreover, weaknesses are visible in limited cold storage capacity and reefer power plug availability, fragmented operating areas lacking direct connectivity, and the port area's competitive disadvantage due to its inland location and restricted expansion opportunities. Addressing these issues and streamlining operations is critical for enhancing the GFFR cold chain's efficiency and effectiveness in the port.

5.1.1. Strength - Buffer storage

As buffer storage provides flexibility and is categorized as value-adding to the GFFR cargo, to a certain extent, this process is considered a strength within this GFFR cold chain. While attracting more buffer storage to the port can be seen as a strength to provide flexibility to market fluctuations, it also presents challenges regarding additional costs for importers. This strength was initially identified through value stream mapping and was further elaborated upon in interviews, mainly with cold storage operators and importers.

By expanding buffer storage, the GFFR cold chain gains the advantage of greater flexibility in handling fluctuations in demand, reducing the risk of stockouts, and ensuring a consistent and reliable flow of products. Buffer storage, particularly for fresh fruits with extended shelf-life, such as apples, can add a layer of resilience to this GFFR cold chain. When utilized strategically, buffer storage can help absorb variations in supply and demand, thereby minimizing the impact of market fluctuations. This adaptability becomes especially valuable during unforeseen disruptions, such as natural disasters or transportation constraints, as it enables the GFFR cold chain to maintain a steady flow of products and respond efficiently to changing circumstances.

However, it is essential to recognize that buffer storage is not exclusively a strength, as its categorization as a value-adding process has limitations. When buffer storage becomes too extensive, it can actually be considered a non-value-adding process. While it adds value to a certain extent, importers typically aim to minimize storage due to associated costs. Nevertheless, buffer storage's benefits and flexibility in handling demand fluctuations remain considerable. Given the uncertainty of vessel scheduling, which is not entirely predictable, a degree of buffer storage is necessary.

Overall, the strength to attract additional buffer storage facilities within the GFFR cold chain at the Port of Hamburg presents a decisive step towards improving the system's flexibility. However, while a certain level of buffer storage is desirable, the overall objective for importers is to minimize it as much as possible to control costs. Achieving a balance between the need for buffer storage and cost considerations remains an ongoing challenge but can also be viewed as a strength within the GFFR cold chain at the Port of Hamburg.

5.1.2. Strength - Additional processing activities

Additional processing activities, especially additional services, are a value-adding process within the Port of Hamburg's GFFR cold chain value stream. Addressing this strength can potentially improve the cold chain in two ways: by attracting more activities to the GFFR cold chain the port and its surroundings and by improving the existing activities.

Currently, certain processing activities, such as ripening, packaging, and appealing, are not commonly performed within the cold storage facilities at the Port of Hamburg, presenting a gap in the value chain. EDEKA Fruchtkontor stands out as an exception, efficiently facilitating all processes due to its importer and cold storage operator role. However, the value stream mapping reveals an untapped potential in attracting additional processing activities and optimizing existing ones, leading to a more efficient and higher-quality GFFR cold chain system. By inviting specialized processors and service providers to set up operations within the port area, the GFFR cold chain can streamline its processes and offer a comprehensive range of value-added services to fruit importers and distributors. This creates a competitive advantage for the port, making it an attractive choice for businesses seeking an efficient and consolidated supply chain solution.

In addition to attracting processing activities, strength lies in optimizing and improving the existing processing activities, particularly regarding technology implementation. Incorporating the right technology for additional processing, such as advanced ripening techniques, can yield several advantages. Firstly, it reduces cost by automating certain processing aspects, improving overall operational efficiency. Secondly, the ripening process can be simplified and made more precise, leading to consistent and uniform fruit quality. Thirdly, with advanced ripening technology, the shelf-life of the fruits can be extended, reducing the risk of wastage and enabling better inventory management.

From the value stream perspective, attracting additional processing activities can be seen as a strength. Nevertheless, attracting these activities is not seen as a viable strength by the interview participants due to the requirement for stable volumes throughout the year to regain the investment. For instance, when importing apples and pears from overseas that need additional processing, such as packing, these products are often sent to apple packers located in Northern Germany. This approach is advantageous as the apple packers already possess the necessary machinery and equipment, and it aligns with the off-season periods of local apple companies. Consequently, no extra investment in equipment is required. Another example, regarding citrus fruits, packing operations only take place from May to November, while during other months, the cargo is packed directly at the farm in southern Europe, with the importer receiving the final product from them Investing in specialized equipment for additional processing activities in the port is economically unfeasible due to the fluctuating demand and limited necessity, which limits the potential strength for such investments.

Overall, addressing the strength of additional processing, specified to additional service activities, has the potential to enhance the GFFR cold chain in the Port of Hamburg by attracting more activities and improving existing processes. While investment in specialized equipment may not be economically feasible, optimizing operations and incorporating advanced technologies, such as automated ripening techniques, can lead to cost reduction, improved efficiency, consistent quality, and extended shelf-life. Strengthening existing processes and attracting specialized service providers are key strategies for enhancing the GFFR cold chain in the Port of Hamburg.

5.1.3. Weakness - Customs scan

As highlighted by the value stream mapping and in most interviews, the primary weakness faced within the GFFR cold chain value stream is the customs scan process. This weakness originates from the critical role of the customs scanning process in the overall value stream, given its mandatory nature, which often leads to significant delays in cargo handling and an increase in cargo handling costs. On average, customs scans cause an additional 1 to 3 days of handling time, impacting the efficient flow of GFFR cargo. Such delays can have far-reaching implications in a time-sensitive system like the GFFR cold chain, where rapid and seamless transportation is crucial to maintaining product quality. Furthermore, customs scans increase transportation and operational costs for GFFR cargo, posing financial burdens on the stakeholders involved, especially the importing stakeholder. The container's profit margin is compromised when customs scans are required, as the additional costs are not always considered in the budget prepared a year in advance. The financial impact varies depending on the number of scans conducted and whether those costs are considered in the budget planning process.

Over the last few years, there has been a notable increase in the number of customs scans conducted specifically on fresh fruit cargo, affecting the Port of Hamburg and various ports globally. The increase in customs scans is especially noticeable in examining shipments containing bananas and exotic fruits sourced from Central and Latin America. The increased amount of customs scans is targeted explicitly at countering the drug trade, as traffickers often take advantage of the perishable nature of fresh produce to conceal narcotic substances, reflecting the need for increased inspections due to the rise in drug trafficking.

Moreover, regarding customs scans, the Port of Hamburg faces a notable competitive disadvantage compared to the other ports, such as the Port of Rotterdam, as it has only one scan location while Rotterdam has multiple locations. The Port of Rotterdam has at least one scan location per terminal at the Maasvlakte 2. Having just one scan location adds to the challenges faced by the GFFR cold chain at the Port of Hamburg, hindering its ability to maintain streamlined operations and competitive advantages. However, despite the higher amount of scan locations in the Port of Rotterdam, Rotterdam's investment in scanning facilities necessitates a higher percentage of scans to ensure a return on investment. Striking the right balance between required and performed scans is crucial to managing costs, as exceeding the predetermined percentages would increase expenses and potentially lead importers to redirect their volumes.
Finding the right balance becomes challenging due to conflicting interests between customs authorities and forwarding/importing stakeholders, as noted during interviews with these stakeholders. An interviewee mentioned their engagement with customs authorities regarding the need for additional customs scan locations. Unfortunately, the existing facility at Walterhof in the Port of Hamburg frequently experiences technical difficulties and unavailability. A recommended approach would involve expanding scan locations, such as establishing one at the fruit terminal to streamline operations within the cold chain. However, the customs authority currently holds the opinion that investing in more locations is unnecessary due to perceived sufficient capacity.

In conclusion, the customs scanning process poses a significant weakness to the GFFR cold chain value streams at the Port of Hamburg. The mandatory nature of scans, along with their impact on handling time and costs, requires strategic measures. It is crucial to explore solutions that streamline customs scanning procedures, consider the feasibility of additional scanning locations, and collaborate with relevant stakeholders to balance security concerns and the smooth flow of GFFR cargo. By effectively addressing the customs scan challenge, the GFFR cold chain can enhance overall performance, minimize delays, and ensure the timely and cost-efficient delivery of high-quality fresh fruits to global markets.

5.1.4. Weakness - Groupage network

As highlighted by the interviews, the second major weakness of the fruit cold chain in the Port of Hamburg is the limited groupage network associated with the limited food cluster. Firstly, to understand this issue, an understanding of groupage is relevant. In the context of logistics, groupage refers to combining smaller shipments from multiple suppliers into larger, consolidated shipments for transportation. It helps optimize transport efficiency, reduce costs, and improve logistics operations by maximizing available transportation space. By bundling shipments together, groupage offers a cost-effective solution and enhances the overall efficiency of the cold

The weakness faced by the Port of Hamburg (PoH) compared to the Port of Rotterdam (PoR) lies in the lack of food cluster and groupage capabilities. PoH struggles with its hinterland connection and demand for fresh fruit and other food products. The groupage bundling of pallets for efficient hinterland transportation is currently limited in PoH, while PoR benefits from a vast hinterland connection that allows for the combination of various fruits and other commodities, making them more flexible in transporting small batches to the hinterland. Rotterdam's history of greenhouse agriculture and its focus on groupage have contributed to developing a strong cluster. The Dutch logistics capabilities are highly regarded, and the Rotterdam cluster has a wide-reaching network that enables efficient distribution throughout Europe. In contrast, the food cluster in the Port of Hamburg seems to be lacking. This could be attributed to the historical evolution of the port and its limited supply within the food cluster.

5.1.5. Weakness - Cold storage capacity

A notable weakness emphasized in several interviews with importers and forwarders refers to the limited cold storage capacity available for fresh fruit. Currently, importers have restricted cold storage options, primarily relying on HHLA facilities or smaller nearby facilities managed by small cold storage operators.

Furthermore, in addition to the existing capacity limitations, the Port of Hamburg is experiencing a reduction in overall cold storage capacity. Investments aimed at expanding storage facilities have decreased, potentially attributed to the fluctuating volumes and seasonal nature characterizing this cold chain's overseas business operations. The GFFR cold chain operates in a highly seasonal manner, with peak periods experiencing a surge in volume and off-season times witnessing reduced volume. This situation presents challenges in effectively storing, tracking, and unloading GFFR cargo. For instance, if a large vessel arrives with a hundred containers and only a small warehouse with limited entrances is available, as seen in the current case with a forwarder facility featuring just two entrances, only 15 containers can be unloaded per shift. Consequently, demurrage costs accrue as the containers await unloading at the gate.

5.1.6. Weakness - Operating area

The operating area within the GFFR cold chain in the Port of Hamburg represents a weakness, stemming from the separation of cold chain operation locations and the challenges associated with providing power to reefer containers. The value stream mapping and interviews conducted with cold storage operators and forwarders highlighted this division of the operating area as an obstruction to the efficiency of the GFFR cold chain, and in some cases, it disrupts the cargo flow. Currently, various processes within GFFR cargo flow are distributed across numerous small warehouses throughout the port and its surroundings. This separation requires the transportation of goods between these locations, which hinders the creation of a seamless and efficiently connected GFFR cargo flow. A more advantageous and efficient approach would involve centralizing the processes of unloading, storage, quality checks, troubleshooting, and additional processing activities within a single facility. Such consolidation would eliminate the need to transfer containers to external warehouses, potentially reducing freshness loss by 2 to 3 days when external packing stations are used.

In the Port of Hamburg, EDEKA is addressing this weakness by constructing its new cold storage facility. This initiative aims to shorten the cold chain, increase cold storage capacity, and eliminate the need for additional transportation by enabling the direct transfer of larger volumes to hinterland regions. Furthermore, future plant inspections are intended to take place at the warehouse itself, although certain commodities may still require inspections at separate locations, where all cargo of that particular commodity needs to be checked.

Additionally, interviews with the port authority and a forwarder highlighted a challenge and, consequently, a weakness concerning the limited availability of plugs for reefer containers at terminals, which can lead to missed reefer connections. These plugs are crucial to ensuring the power supply to reefer containers when stored temporarily at the terminal, thereby impacting the quality of transport and the GFFR cargo. However, whether there is a genuine desire for additional plugs to address this weakness remains unclear, as does the extent of its impact.

In conclusion, the division of operational locations and reefer container power supply challenges in the GFFR cold chain at the Port of Hamburg represent a significant weakness. Addressing this weakness has the potential to streamline processes, minimize transportation requirements, and enhance overall efficiency. Although some challenges may remain for certain commodity inspections, addressing this weakness offers a promising avenue for optimizing the cold chain and improving its performance.

5.1.7. Weakness - Port area

Another weakness identified in the GFFR cold chain is related to the port area of the Port of Hamburg. Being situated further inland without direct access to the North Sea poses a competitive disadvantage due to higher operational costs. In contrast, the Port of Rotterdam, benefiting from its open North Sea connection, avoids issues like traffic congestion on the Elbe River in Hamburg. Consequently, the operational costs in the Hamburg port area are higher, impacting GFFR cargo importers financially. Moreover, the port faces limitations in terms of port area expansion opportunities. These limitations place the Port of Hamburg at a competitive disadvantage compared to rival ports within the Hamburg-Le Havre range, where more extensive expansion opportunities are available.

5.2. External factors

The cargo flow and operations of the GFFR cold chain in the Port of Hamburg are not only affected by internal factors but also by external factors involving opportunities and threats that encompass the broader dynamics of the overall fruit cold chain and the Port of Hamburg. Opportunities refer to external factors that stakeholders can not directly control but could benefit the GFFR cold chain. On the other hand, threats in the GFFR cold chain at the Port of Hamburg encompass factors beyond stakeholders' control, potentially reducing the efficiency of GFFR cargo flow. It is worth noting that while individual stakeholders of this cold chain lack control over these external factors, their collective influence may have some impact on these factors and so on the system.

Opportunities

- Improve food cluster
- Investment in port infrastructure
- Attract more container volume

Threats

- Vessel scheduling
- Operation costs
- Connectivity to shipping lines
- Climate change

The GFFR cold chain in the Port of Hamburg presents significant opportunities when addressing its underlying threats. For instance, improving connectivity to shipping lines and enhancing the food cluster within the port can significantly boost volume throughput and efficiency. Additionally, investing in the port's infrastructure emerges as a valuable opportunity, enhancing not only cold chain operations but also overall port competitiveness.

However, the GFFR cold chain faces several threats in the Port of Hamburg. The reliability and scheduling of vessels pose a primary threat, causing disruptions in cargo flow, transit times, and container handling coordination. The port's position in vessel scheduling and the increasing vessel sizes contribute to extended transit times and operational challenges. Limited connectivity to shipping lines reduces capacity and prolonged transit times for fresh fruit cargo. Moreover, operational costs associated with maintaining temperature-controlled systems present a persistent threat to cold chain operations in the port. Lastly, climate change presents a threat by impacting the GFFR cargo in a way that the cold chain becomes more sensitive and fragile.

5.2.1. Opportunity - Improve food cluster

The approach of improving the development of a food cluster in the Port of Hamburg, revealed by interviews, presents an opportunity to accommodate the GFFR cargo flow. It is worth noting that this food cluster encompasses various food commodities beyond fresh fruit. Improving the food cluster will lead to increased imports of food cargo, including fresh fruit and other commodities. This heightened demand for fresh fruit can benefit the GFFR cargo flow, particularly by increasing the demand and thereby better facilitating the transport of small batches. Moreover, the groupage network of the GFFR cargo flow can profit from this heightened food import flow. It is essential to emphasize that enhancing the groupage network specifically for fresh food is crucial because fresh fruit cannot be combined with frozen cargo.

Initiating the development of the food cluster might involve considering the establishment of a Greenport food hub, similar to what exists in the Port of Rotterdam and its surrounding regions. This hub could focus on attracting production facilities and refining processing operations to increase cargo volumes and add value to the port. Additionally, building a robust cluster in Hamburg would require a strong network and a deep commitment to clients, potentially attracting shipping agencies, and stimulating growth in the cold chain industry.

However, building a successful cluster in Hamburg comes with certain challenges, as it historically has been less inclined to commit and take risks compared to Rotterdam. Offering daily groupage services involves the risk of underutilized truck capacity and transporting only a few pallets, potentially leading to revenue loss. In contrast, the Dutch have strategically developed a substantial truck fleet and a diverse range of combinable products, including fresh food, flowers, pharmaceuticals, and frozen goods. While some German companies, especially forwarding and fruit-importing stakeholders, are striving to establish a daily network in Hamburg, more coordinated efforts are necessary.

Global logistics providers in Hamburg and its surroundings have expressed interest and effort in enhancing the cluster. Nonetheless, they have encountered obstacles because of the competitive nature of the fruit and vegetable market. Container sharing and cargo supply remain key areas of focus for importers, and attracting shipping agencies is not their primary interest.

Overall, improving the GFFR cold chain in the Port of Hamburg requires carefully considering securing business and customer satisfaction. Collaborations between stakeholders, including importers and forwarders, play a vital role in enhancing the efficiency and reliability of the food supply chain in the region.

5.2.2. Opportunity - Investment in port infrastructure

Another opportunity for the GFFR cold chain lies in investing in the infrastructure of the Port of Hamburg. Currently, the port faces challenges with its infrastructure, particularly regarding its connection to the North Sea. This raises concerns about the port's future feasibility and ability to address industry demands, both on the water- and land-side connection.

Furthermore, the infrastructure within the Port of Hamburg itself, including the flow of goods, container handling, and transportation to and from the port, creates bottlenecks that disrupt efficient operations. One specific issue under discussion is the state of the current bridge, which presents a political challenge that needs resolution. These bottlenecks can be mainly addressed by involving the port authority and stakeholders, such as terminal operators, cold storage operators, and forwarders, to find solutions collectively.

Investing in the infrastructure of the Port of Hamburg would not only enhance the GFFR cold chain operations but also improve the overall efficiency and competitiveness of the port. Collaborative efforts among various stakeholders are crucial in overcoming these infrastructure challenges and ensuring smooth operations within the cold chain industry.

5.2.3. Opportunity & Threat - Attract more container volume & Connectivity to shipping lines

As highlighted in most interviews, another opportunity is to attract more container volume throughput, which will also address the threat of direct connectivity to shipping lines in the Port of Hamburg. Due to its lack of direct connections to major shipping lines, Hamburg often serves as the final destination for cargo in Northern Europe. This positioning can lead to limited capacity and longer transit times, affecting the overall efficiency of the GFFR cold chain in the port. To address this threat, optimizing connectivity and addressing the potential of increasing volume throughput becomes crucial for the Port of Hamburg to enhance its role in the cold chain network and improve operational performance.

To improve the GFFR cold chain at the Port of Hamburg, importers and the port itself must focus on making themselves appealing to shipping lines. This can be achieved by forming clusters of importers and forwarders to consolidate their demand, thereby demonstrating a higher volume potential to shipping lines. By fostering stakeholder collaboration, efforts can be made to persuade shipping lines to establish new services or include Hamburg earlier in their existing routes. This comprehensive approach involving all key stakeholders is essential to address the challenge and enhance the fruit cold chain in the Port of Hamburg.

Addressing the threat of limited connectivity between the Port of Hamburg and shipping lines presents an opportunity to attract greater cargo volumes, potentially benefiting the GFFR cold chain in the Port of Hamburg. However, realizing this potential is complex due to the port's inability to accommodate modern vessel sizes, especially compared to other North European ports. Despite the appeal of around 1000 containers per vessel for shipping lines, the current market size in Hamburg is insufficient to handle such volumes efficiently [B1]. Therefore, it's not only essential to attract shipping lines and increase volume but also crucial for the port and its associated supply chains to enhance their capabilities to meet heightened container demands.

5.2.4. Threat - Vessel scheduling

One of the primary threats to the cold chain relates to the reliability of vessel timing and scheduling, which has a profound impact on the GFFR cold chain's operations in the Port of Hamburg. Interviewees across all stakeholder categories consistently highlight this threat as a significant challenge for ensuring the efficient flow of GFFR cargo. Efficient vessel scheduling is crucial in coordinating the various processing activities involved in container handling, from when it arrives at the destination port to its final delivery. However, fluctuations in vessel scheduling can lead to unpredictable handling requirements, ultimately increasing transit times.
Considerable delays may significantly impact overall operations. For instance, consider a situation where a week-long promotion is planned at retail stores. The promotion cannot be skipped or postponed if a vessel carrying the necessary goods is delayed. As a result, the company responsible must purchase products from the fruit market at a higher cost to fulfill the promotion requirements. Subsequently, the originally planned goods arrive, but their demand has already diminished, leading to financial losses. This situation highlights the core difficulty in scheduling vessels within the cold chain industry.

Furthermore, the Port of Hamburg faces a disadvantage in the vessel scheduling framework. Hamburg typically serves as the final destination in Northern Europe, whereas Rotterdam or Antwerp are the primary ports of call. Consequently, cargo bound for Hamburg experiences longer transit times than cargo destined for Rotterdam or Antwerp. This can lead to an additional transit time of 10 to 12 days at the Port of Hamburg compared to the initial ports of call. Moreover, the growing size of vessels contributes to extended transit times. Larger vessels can accommodate more cargo and incorporate multiple ports into their schedules, increasing the overall transit time.

In conclusion, disruptions or delays in vessel scheduling can have a disruptive impact on the cold chain sector, including the GFFR cold chain in the Port of Hamburg. This can result in operational disruptions and extended transit times. These factors highlight the crucial importance of adopting efficient scheduling practices and strategic decision-making to optimize overall supply chain efficiency and performance.

5.2.5. Threat - Operation costs

Another threat identified by cold storage operators, forwarders, and importers is the issue of operation costs. Maintaining the correct temperatures for perishable goods, such as the GFFR cargo, through transport and cold stores requires a substantial amount of energy, significantly impacting operation costs compared to other container cargo. Cold storage costs have significantly increased with the rising energy prices in the past 12 months. Although electricity prices have somewhat stabilized nowadays, they remain twice as high as they were before the COVID-19 pandemic, impacting the overall cargo expenses.

Another aspect that influences the operation costs is the sea freight costs. Especially in the last year, sea freight costs were extremely high. On average, the costs are 1,500 dollars per container shipment, while over the last year, it was ten times so high. Even when these prices have started to normalize, the impact on the operation costs should be considered a challenge. Regarding operation costs, the Port of Hamburg faces a drawback compared to other ports, as the absence of intense inter-port competition prevents significant price reductions within the port. This is primarily due to the limited number of competitors in the port compared to Rotterdam and Antwerp, where the dynamics are different, and competition plays a more influential role.

In conclusion, the considerable rise in cold storage expenses and the unpredictable fluctuations in sea freight costs present substantial threats to the GFFR cold chain. Finding cost-effective solutions and adapting to evolving market conditions is crucial for businesses operating in this sector.

5.2.6. Threat - Climate change

The final threat recognized is climate change, which affects the GFFR cold chain at the Port of Hamburg by influencing the quality of fresh fruit cargo. Given the unpredictable nature of climate and weather patterns, it is expected that future fruit production may encounter more quality issues due to worsening weather conditions. Heightened weather fluctuations can lead to increased stress on fruits and plants, resulting in a reduced shelf-life. These effects on GFFR cargo will make the cold chain more sensitive and fragile.

5.3. SWOT analysis

To evaluate the potential for improvement in the GFFR cold chain at the Port of Hamburg, it is essential to comprehensively understand various improvement strategies. This involves assessing how the strengths and weaknesses align with the emerging opportunities and threats. To facilitate this evaluation, a SWOT analysis is conducted. The SWOT analysis conducted in this research include the elaboration on the SWOT matrix and improving strategies Section 5.3.1, the utilization of key drivers for assessing the significance of SWOT strategies in Section 5.3.2, and the evaluation of these strategies in Section 5.3.3.

5.3.1. SWOT matrix

Utilized as a strategic planning tool, the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis combines internal and external assessments to reveal alternative business strategies in a SWOT matrix (Lee & Sai on ko, 2000; Valentin, 2001; Wang, 2007; Weihrich, 1982; Benzaghta et al., 2021). The SWOT matrix serves as a structured framework, shedding light on how an organization's strengths and weaknesses align with emerging opportunities and threats. Decision-makers, in light of these internal and external dynamics, can formulate four distinct strategies: SO (Strengths - Opportunities), ST (Strengths - Threats), WO (Weaknesses - Opportunities), and WT (Weaknesses - Threats) (Bayram & Üçüncü, 2016; F. David et al., 2019; Thomas et al., 2014; Benzaghta et al., 2021). The SO strategy takes advantage of opportunities, while the ST strategy focuses on reducing threats. The WO strategy aims to address weaknesses to create new opportunities, and the WT strategy aims to mitigate threats by reducing weaknesses.

The SWOT matrix illustrated in Figure 5.2 provides a comprehensive overview of the strengths, weaknesses, opportunities, and threats associated with the GFFR cold chain in the Port of Hamburg, linked to the four corresponding strategies for its enhancement.

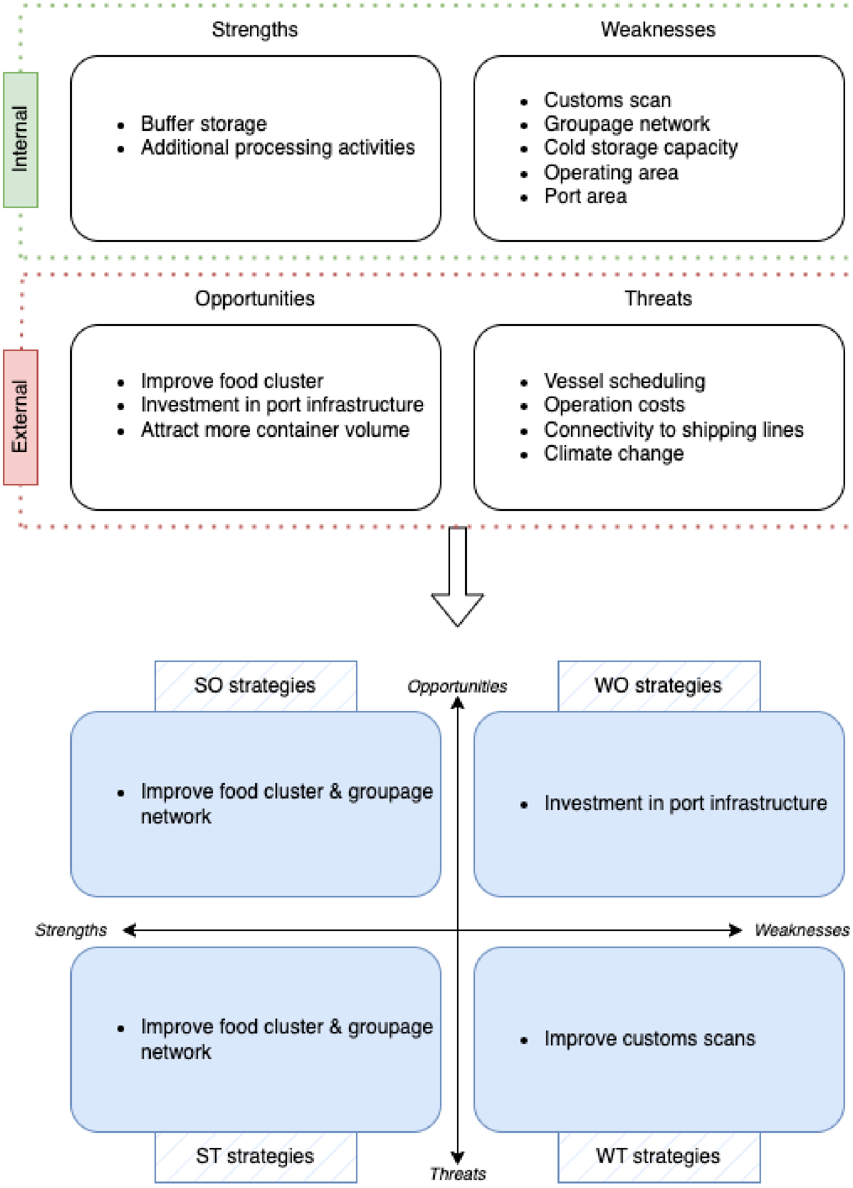

Figure 5.2.: SWOT matrix GFFR cold chain Port of Hamburg

- **SO - Improve food cluster and groupage network**
  Enhancing the food cluster and groupage network presents a strategic opportunity to strengthen the integration of the GFFR cold chain with the Port of Hamburg. The growing food industry, marked by increased economies of scale in supply chain operations (Klopott, 2019), combined with the collaborative efforts of Hamburg authorities to strengthen the region's food cluster (Meier et al., 2022), presents an opportunity for its integration and enhancement. This combination of factors highlights the compelling strategy of optimizing and connecting the food cluster with the GFFR cold chain in the Port of Hamburg. This approach aligns with the evolving dynamics of the food industry, offering a promising pathway for improved efficiency and competitiveness in the handling of fresh fruits and related products at the port.

- **ST - Improve food cluster and groupage network**
  Strengthening the food cluster and groupage network also serves as a strategic approach to (partly) avoid threats and weaknesses, primarily the existing limitations within the food cluster and groupage network of the GFFR cold chain in the Port of Hamburg. Furthermore, this approach can potentially diminish the threat of limited connectivity to shipping lines by attracting shipping lines by establishing a more robust network and potentially boosting demand. This strategy will also address the operational strength of the flexibility of buffer storage and attracting and improving additional processing activities.

- **WO - Investment in port infrastructure**
  Investing in port infrastructure presents an opportunity to address the identified weakness of the port's operating area, as indicated by the value stream mapping and interviews. The current operating area of the Port of Hamburg has been identified as a hindrance affecting the efficiency of the GFFR cargo flow. Through infrastructure investment, this weakness can be reduced, leading to improved connectivity and smoother operations within the GFFR cold chain. This approach could potentially benefit other segments within the cold chain as well.
- **WT - Improve the customs scan process**
  Minimizing delays and additional costs resulting from inefficient customs scans could help reduce the threat of high operation costs to some extent. Currently, customs scans add 1 to 3 days to GFFR cargo handling, disrupting the overall cargo operations and increasing costs due to reduced connectivity in the GFFR cold chain. Enhancing the capacity of the customs scanning process in the Port of Hamburg may benefit the impact of customs scans on the GFFR cargo handling flow. This strategy aims to reduce weakness and thereby partially reduce the threat of high operation costs.

5.3.2. GFFR cold chain key drivers

The drivers of the GFFR cold chain in the Port of Hamburg are essential in underlining the significance of the identified strategies to accommodate strengths, weaknesses, opportunities, and threats of improving this cold chain. These drivers help contextualize the indicators for potential improvements, offering valuable insights into the areas that require focused attention. By understanding the impact of the drivers associated with the potentials, stakeholders can better strategize and enhance the efficiency and effectiveness of cold chain operations. In the GFFR cold chain, three main drivers for development are identified:

- Operation costs
- Quality and safety of fresh fruit
- Lead time

These key drivers play a crucial role in shaping the functioning and efficiency of the GFFR cold chain system in the Port of Hamburg. Firstly, operation costs emerge as a significant driver due to the direct influence of customer demand. The costs associated with cold chain operations substantially impact customer demand. Since the GFFR cold chain originates from customer demand, operation costs are one of the most critical drivers of this specific cold chain. The demand is dependent on the costs in a specific way. The higher the costs, the lower the demand may be expected. Additionally, highlighted in an interview, it is indicated that the Port of Hamburg incurs higher costs than Rotterdam due to expensive terminal operations, harbor fees, and additional transportation costs. This observation is particularly significant in Germany, where cost is crucial in the food market. German consumers are known to be price-sensitive regarding food, leading to a highly competitive market and lower prices than other countries.

The second driver is the quality and safety of fresh fruit. Regulations and industry standards are implemented throughout the cold chain to maintain the quality and safety of food products. It is found that there occur over 200 standards for cold chain food logistics such as processes of production, handling, storage, and transportation of agricultural products (Zhao et al., 2018; Dong et al., 2020). In the Port of Hamburg, the handling of GFFR cargo considers not only the standard requirements but also incorporates additional specifications from the customs authority and importers. Ensuring the quality and safety of fresh fruit is essential, and it directly impacts the effectiveness of the GFFR cold chain.

The third driver is the lead time of the GFFR cold chain, which is closely linked to the quality and safety of fresh fruit, as well as the operation costs. The lead time of reefer and cargo handling is a crucial factor in the overall efficiency of the cold chain. Timely transportation and handling of fresh fruit are essential to maintain its quality and safety throughout the supply chain. Therefore, minimizing lead time is critical to the GFFR cold chain.

These drivers are interconnected and influence each other. For instance, ensuring fresh fruit quality and safety requires proper refrigeration technology associated with reliable electricity sources and high energy costs. Moreover, the involvement of various stakeholders in the GFFR cold chain demonstrates the interconnection among these drivers. Without establishing and maintaining these connections, achieving the desired outcomes and goals in the GFFR cold chain would be challenging.

In conclusion, the GFFR cold chain is driven by several factors, including the key drivers of operation costs, quality and safety of fresh fruit cargo, and lead time. These drivers are interconnected and mutually influence each other, shaping the effectiveness and efficiency of the cold chain system. Managing costs, ensuring fresh fruit quality and safety, and minimizing lead time is crucial for successfully operating the GFFR cold chain.

5.3.3. SWOT evaluation

To assess the potential of strategies accommodating the GFFR cold chain in the Port of Hamburg, it is crucial to consider the perspectives and interests of supply chain stakeholders to accommodate the potential effectively, next to the value stream mapping insights. These stakeholders play a significant role in shaping the direction and growth of this cold chain. Interviewees hold contrasting perspectives regarding the potential of the Port of Hamburg and the GFFR cold chain. While some see limited growth prospects under the current circumstances, others believe in its potential. However, the port faces fierce competition from other ports, which adds to the challenges. To fully explore the potential in the focus of this research, a comprehensive discussion considering the SWOT matrix strategies mentioned earlier is essential.
Moreover, when evaluating the potential for improvement in the GFFR cold chain, it is essential to consider the key drivers: cost, quality, and lead time. These drivers heavily influence the decision-making processes of stakeholders and provide insights into the areas where improvements can be made. By addressing critical issues, strengthening improvement potentials, and aligning with the drivers, the potential of the GFFR cold chain in the Port of Hamburg can be better understood and harnessed.

The qualitative evaluation of the potential of the improvement strategies outlined in Table 5.1 draws from the insights gathered during the value stream mapping, interviews with various stakeholders, and the anticipated impact on the key drivers of the GFFR cold chain. The insights from interviews reflect the stakeholders' collective and general perspectives on challenges and opportunities in the GFFR cold chain in the Port of Hamburg.

Strategy	**Evaluation**		
	Value stream mapping	**Interviews**	**Key drivers**
SO - Improve food cluster & groupage network	-/+	+	+
ST - Improve food cluster & groupage network	-/+	+	+
WO - Investment in port infrastructure	+	-/+	-/+
WT - Improve customs scan process	+	+	+

Table 5.1.: Evaluation SWOT improvement strategies GFFR cold chain Port of Hamburg

Improve food cluster & groupage network (SO & ST strategy)

The strategy of enhancing the food cluster and groupage network within the GFFR cold chain at the Port of Hamburg is not expected to have a significant positive or negative impact on the value stream in either the SO or ST segments of this strategy. This can be attributed to the fact that improving the food cluster will not fundamentally change the operational structure but will affect the volume of GFFR cargo flow. Enhancing the food cluster must consider the existing operational structure to ensure a seamless transition without disrupting the GFFR cargo flow. However, these changes associated with implementing this strategy are not guaranteed to result in improved value streams and related operations as mapped out.

Furthermore, the interviews underscore the competitive advantage of the well-developed food cluster in the Port of Rotterdam, particularly in comparison to the lacking or even missing food cluster in the Port of Hamburg. Therefore, implementing this strategy is assessed as having a positive impact on enhancing the GFFR cold chain.

Finally, the key drivers assess this strategy as having a positive impact, primarily because it leads to a more connected and integrated GFFR cold chain, which in turn improves lead times and enhances the quality and safety of GFFR cargo.

Investment in port infrastructure (WO strategy)

Value stream mapping analysis suggests that the WO strategy of investing in port infrastructure could have a positive impact on enhancing the operational structure of the GFFR cold chain in the Port of Hamburg. By investing in port infrastructure, there is potential for improved connectivity and more streamlined operations within the GFFR cold chain. This approach may also address the weaknesses of the location and operating area components identified in the value stream mapping analysis.

Nevertheless, while the operational structure and infrastructure of the port were mentioned in a few interviews, they were not emphasized as standalone factors that could significantly positively or negatively enhance the GFFR cold chain in the Port of Hamburg. Instead, this strategy is viewed as an approach that might be incorporated into other strategies or improvement initiatives, such as the development of the food cluster or the establishment of customs scan locations.

Furthermore, it is anticipated that this approach will not have a significant positive or negative impact on the key drivers. This is primarily because this strategy is likely to influence the GFFR cold chain when combined with other strategies or initiatives rather than on its own.

Improve customs scan process (WT strategy)

The value stream mapping analysis highlights the significance of enhancing the customs scanning process as a relevant strategy. This strategy addresses the critical issue of GFFR cargo flow disruption caused by customs scan delays at the Port of Hamburg. Embracing this strategy, as value stream mapping indicates, leads to an improvement in the GFFR cold chain operations.

This strategy is also assessed positively, largely due to the unanimous recognition among interviewees regarding the significant challenges associated with the customs scanning process within the GFFR cold chain at the Port of Hamburg.

Lastly, improving this process may not only reduce lead times but also lower operation costs while potentially improving the overall quality and safety of fresh fruit. Consequently, this approach is highly relevant and aligns with the key drivers of the GFFR cold chain.

In conclusion, based on the SWOT analysis and evaluation, two primary potential strategies for improving the GFFR cold chain in the Port of Hamburg have been identified: customs scans and the food cluster. These opportunities will be further explored in detail in section Section 5.4.

5.4. Port of Hamburg's potential

This section further elaborates on two key potential strategies identified in the SWOT analysis: the customs scan and the food cluster, discussed in Section 5.4.1 and Section 5.4.2.

5.4.1. Potential - Customs scan

Improving the customs scanning process is a potential for supply chain stakeholders to effectively accommodate the GFFR cold chain in the Port of Hamburg, specifically in addressing the weakness of customs scans highlighted previously in this chapter. There are several reasons why this improvement can be seen as a potential. Firstly, the mandatory nature of customs scans often leads to significant delays in cargo handling and increased handling costs, negatively impacting the efficient flow of GFFR cargo. The average additional handling time of 1 to 3 days causes delays that have far-reaching implications in a time-sensitive system like the GFFR cold chain, where rapid and seamless transportation is crucial to maintaining product quality. Moreover, customs scans result in increased transportation and operational costs, posing financial burdens on stakeholders, as these costs are not always considered in advance budget planning.

When considering the potential of improving customs scans in the GFFR cold chain, it is crucial to consider the side notes and effects. The Port of Hamburg faces a notable competitive disadvantage compared to other ports, like Rotterdam, due to its limited number of scan locations. Finding the right balance between required and performed scans is crucial to address the delays and costs associated with customs scans and maintain streamlined operations and competitive advantages. Two main aspects should be considered in achieving this balance: the number of customs locations, including their capacity, and the location in the port. Currently, the delays in conducting customs scans present an opportunity to improve the process by either adding an additional customs scan location or increasing the capacity of the existing one. However, it is essential to ensure that increased capacity leads to faster handling times and improved efficiency. The case of the Port of Rotterdam serves as an example, where increased capacity resulted in a higher percentage of customs scans but without a corresponding improvement in handling time and costs. Striking the right balance is vital to managing the time-sensitive handling process and associated costs effectively. Furthermore, there is potential to enhance the GFFR cold chain in the Port of Hamburg by locating customs scan facilities near the cold storage facilities. This would reduce the need for additional transfers, as most GFFR cold storage facilities are concentrated in the Kleiner Grasbrook area. Constructing a new customs scan location close to this area would improve handling time, mainly focusing on transportation time efficiency. Moreover, considering a customs scan area prioritizing perishable or sensitive goods, such as fresh fruit, could further enhance the GFFR cold chain's effectiveness in the Port of Hamburg.

To effectively address the potential improvement of customs scans, the involvement of various stakeholders is crucial. While customs authorities are the main stakeholders responsible for determining the number and location of customs scan locations, collaboration with forwarders and importers is also vital. The decision regarding establishing additional scan locations, such as one at the fruit terminal, lies within the responsibility of customs authorities. Therefore, engaging in dialogue with customs authorities is essential to express the need for improved customs scanning procedures. In addition, collaborative efforts between customs authorities, port authorities, cold storage operating, forwarders, and importing stakeholders are necessary to balance security concerns and the efficient flow of GFFR cargo. Engaging in dialogue with customs authorities regarding the need for additional scan locations, such as establishing one at the fruit terminal, can streamline operations within the cold chain. This collaboration is essential to optimize customs scanning procedures, manage costs effectively, and ensure high-quality fresh fruits' and cost-efficient delivery to global markets.

By recognizing and addressing the potential of improving customs scans, supply chain stakeholders in the GFFR cold chain can overcome the challenges associated with customs scans, enhance overall performance, minimize delays, and create a more efficient and robust GFFR cold chain in the Port of Hamburg.

5.4.2. Potential - Food cluster

A food cluster is a specialized ecosystem within a region or port dedicated to efficiently handling, storing, and distributing food products, including perishables like fresh fruits. These clusters are strategically designed to streamline the entire food supply chain, from the arrival of goods at the port to their distribution to consumers. Improving the development of a food cluster presents a potential for supply chain stakeholders to effectively accommodate the GFFR cold chain in the Port of Hamburg. This approach can potentially address the threats of a limited food cluster and groupage network, as well as the threats and opportunities of connectivity to shipping lines and associated volume throughput. In a food cluster related to the GFFR cold chain in the Port of Hamburg, various stakeholders collaborate closely, including importers, terminal operators, forwarders, cold storage providers, and regulatory authorities. This collaboration ensures seamless operations, minimizes delays, and maintains the integrity of temperature-sensitive cargo like fresh fruits.

The establishment of a food cluster offers several benefits. Firstly, clustering importers can increase the demand volume and attract shipping lines by demonstrating a higher potential for consolidated cargo. This collaborative approach merges demand and presents a more robust market presence, enhancing Hamburg's attractiveness as a preferred destination for shipping lines. Secondly, clustering importers and stakeholders within the food cluster optimizes transportation space and reduces costs. This approach enhances shipping efficiency and logistics operations, aligning with cost, quality, and lead time drivers. By leveraging the power of collaboration, stakeholders can collectively overcome challenges and streamline operations within the GFFR cold chain.

However, there are side notes and effects to consider. The fresh fruit market is highly competitive, posing challenges to forming a successful cluster. To mitigate this, it may be necessary to focus on clustering importers from non-competing markets to reduce competition. Moreover, the transportation of increased volumes from the food cluster should be considered. This requires the involvement of forwarding companies to handle the additional throughput effectively. Collaboration with importers, forwarding companies, and other stakeholders is crucial to ensuring the smooth flow of pallets and maintaining the efficiency of the cold chain.

Various stakeholders should be involved to tap into the potential of the food cluster. Importers, shipping lines, terminal operators, forwarding companies, and other supply chain participants must collaborate to establish and sustain a strong cluster. Additionally, close collaboration with customs authorities and cold storage providers is essential to streamline operations and address regulatory requirements. By effectively leveraging the potential of a food cluster, the GFFR cold chain in the Port of Hamburg can improve its connectivity to shipping lines, increase volume throughput, and enhance operational efficiency. This collaborative approach helps accommodate the needs of stakeholders, optimize the cold chain network, and ensure the timely and cost-effective delivery of fresh fruits to global markets.

5.5. Concluding remarks opportunity analysis

Performing the opportunity analysis involving a SWOT matrix provided insights into the Port of Hamburg's strengths, weaknesses, opportunities, and threats for improving the cold chain. These insights contributed to understanding the potential of enhancing the GFFR cold chain in the Port of Hamburg, supporting decision-makers in accommodating this cold chain. Moreover, the opportunity analysis addresses the third research question.

Research question 3 - What are the potentials of improvement for supply chain stakeholders to effectively accommodate the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?

The third research question is addressed by understanding the internal and external factors encompassing the GFFR cold chain in the Port of Hamburg. The internal factors, referring to the value chain operations, encompass strengths like buffer storage and additional processing activities, alongside weaknesses such as customs scans, groupage network, cold storage capacity, operating area, and port area.

Among strengths, one involves expanding buffer storage facilities, enhancing flexibility despite the challenge of balancing storage needs and costs. Moreover, optimizing additional processing operations, refining processes, and adopting advanced technologies can reduce expenses, enhance efficiency, ensure consistent quality, and extend shelf-life. However, due to demand fluctuations due to the cargo's seasonal nature, investing in specialized equipment might not always be financially feasible.

Mandatory customs scanning poses a major weakness, causing delays and increased costs. Overcoming this requires streamlined procedures, exploring new scanning locations, and collaborating with authorities for better performance, ensuring improved performance, reduced delays, and efficient delivery of fresh fruits to global markets. Additionally, the limited groupage network associated with the food cluster presents a notable weakness that can be (partly) addressed through stakeholder collaboration to improve overall efficiency and reliability. Moreover, weaknesses are visible in limited cold storage capacity and reefer power plug availability, fragmented operating areas lacking direct connectivity, and the port area's competitive disadvantage due to its inland location and restricted expansion opportunities. Addressing these issues and streamlining operations is critical for enhancing the GFFR cold chain's efficiency and effectiveness in the port.

The Port of Hamburg faces several threats in the GFFR cold chain, stemming from broader dynamics of the overall fruit cold chain and the port itself. Primary among these is the reliability and scheduling of vessels, affecting overall cold chain operations, transit times, and container handling coordination. Furthermore, the port faces significant threats related to its positioning within the vessel scheduling framework, coupled with growing vessel sizes, increasing transit times, and operational complexities. Insufficient connectivity to shipping lines and limited volume throughput capacity further extend transit times and constrain the handling of fresh fruit cargo.
Moreover, the operational expenses of maintaining temperature-controlled systems pose a notable hurdle for the port's cold chain operations. Lastly, climate change presents a threat by impacting the GFFR cargo in a way that the cold chain becomes more sensitive and fragile.

Among the threats, certain opportunities have been identified. These opportunities stem from strategies to address external challenges, such as enhancing volume throughput by improving shipping line connectivity and advancing the food cluster within the port. Additionally, the prospect of enhancing the port's infrastructure is emphasized. Investing in the infrastructure of the Port of Hamburg would not only optimize cold chain operations but also elevate the overall efficiency and competitiveness of the port, including its GFFR cold chain.

Assessing the potential for improvement in the GFFR cold chain at the Port of Hamburg necessitates a comprehensive understanding of various improvement strategies. This involves assessing how the strengths and weaknesses align with the emerging opportunities and threats. The SWOT matrix revealed three improvement strategies:

- Improve food cluster & groupage network
- Investment in port infrastructure
- Improve customs scan process

After evaluating these strategies, the potential impact on the GFFR cold chain, as assessed through value stream mapping, interviews, and key drivers, revealed two primary areas of potential improvement: customs scans and the development of the food cluster.

Improving the customs scanning process can potentially address the weakness associated with customs scans. These mandatory scans often result in significant delays of 1 to 3 days and increased handling costs for reefer containers, impacting the efficient flow of GFFR cargo. Achieving a balance between necessary scans and their impact on operations is crucial to reducing delays and costs effectively. Key considerations for achieving this balance include the number and capacity of customs locations, as well as their strategic placement within the port. Increasing scan capacity should lead to faster handling and improved efficiency, qualifying as an enhancement. Additionally, establishing a new scanning location close to the GFFR cargo handling area, such as in the Kleiner Grasbrook area of the Port of Hamburg, could improve cargo handling, especially transportation efficiency. Moreover, prioritizing perishable or delicate goods, like fresh fruit, could further optimize the effectiveness of the GFFR cold chain at the Port of Hamburg. To effectively address this potential, the involvement of the leading stakeholder responsible for this process, the customs authority, in collaboration with forwarders and importers is essential. Moreover, collaborative efforts between customs authorities, cold storage operators, forwarders, and importing stakeholders are necessary to balance security concerns and the efficient flow of GFFR cargo.

Enhancing and expanding the food cluster within the Port of Hamburg offers a solution to threats and opportunities related to connectivity with shipping lines and volume throughput, as well as the limitation of the existing food cluster and groupage network. This potential holds several advantages for the GFFR cold chain at the port. Firstly, it can boost demand volume, potentially attracting shipping lines through a more robust market presence. Secondly, it may streamline the groupage network, leading to cost reductions. However, given the competitive nature of the fresh fruit market, careful consideration should be given to clustering importers from non-competing markets. To effectively harness this potential, collaboration among importers, forwarders, shipping lines, and other supply chain stakeholders is essential to establish and maintain a robust food cluster.

Addressing the third research question revealed the underlying improvement strengths, weaknesses, opportunities, and threats of the GFFR cold chain in the Port of Hamburg, pointing out its potential. When combined with understanding the cold chain's operations, stakeholder interdependence relations, underlying structure, critical issues, and potential improvements derived from answering the first two research questions, the main research question is answered.

6. Conclusion, Discussion & Recommendations

This chapter finalizes the research by presenting the conclusion in Section 6.1. Following this, the upcoming sections discuss scientific and practical implications, followed by a consideration of limitations in Section 6.2, engaging in a discussion in Section 6.3. Finally, this chapter concludes with recommendations for future research in Section 6.4.

6.1. Conclusion

This research aimed to identify and analyze the transparent process and value structures of the Port of Hamburg's global first-mile fresh fruit reefer (GFFR) cold chain. This was achieved by exploring and providing insights into its value stream integration to identify strengths, weaknesses, opportunities, threats, and potential for improvement within this cold chain. The following research question guided this research:

"How can supply chain stakeholders effectively accommodate the global first-mile reefer cold chain, with respect to the fresh fruit food segment in the Port of Hamburg?"

To address this research question, three supporting sub-questions were formulated. Each sub-question focused on a distinct research aspect, which, when combined, answered the main research question. These three sub-questions were as follows:

1. How are supply chain stakeholders involved in the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?
2. How is the global first-mile value chain structured for the Port of Hamburg's fresh fruit reefer cold chain?
3. What are the potentials of improvement for supply chain stakeholders to effectively accommodate the global first-mile fresh fruit reefer cold chain in the Port of Hamburg?

A comprehensive approach encompassing a case study involving a background study, value stream mapping, and opportunity analysis was undertaken to address the main research question. Based on the literature review and interviews, the background study clarified the five main stakeholder categories shaping the GFFR cold chain in the Port of Hamburg: (port and customs) authorities, terminal operators, cold storage operators, forwarders, and importers. These stakeholders nurture interdependent connections across diverse supply chain stages and operations, highlighting the complexity of this cold chain. A deeper understanding of the inherent interdependencies and complexities within the GFFR cold chain was achieved through value stream mapping, straightening out the material and information flows occurring through operations and involving various stakeholders.

Based on the background study insight and interviews, value stream mapping illustrated the operations involved in the GFFR cold chain, pointed out according to their operating locations:

- Terminal: discharge container & terminal storage
- Customs location: customs scan
- Cold storage warehouse(s): unloading reefer, quality check, troubleshooting activities, buffer storage, additional services, logistical services, transport storage & loading inland carrier

Various material flows were identified among these operations, as depicted in four alternative current state maps: direct distribution (including customs scans), indirect distribution, distribution with troubleshooting activities, and distribution with additional processing and logistics services activities. Moreover, the information flows illustrated the facilitation of cargo movement across the material flows. Stakeholders exchange information daily, linking the operations together. The GFFR cold chain in the Port of Hamburg involves numerous material and information value streams stemming from diverse processes and stakeholders. The complexity of connecting these elements highlights the importance of managing relationships to achieve optimal efficiency in the dynamics of the cold chain. Value stream mapping revealed the value chain's structure, highlighting critical issues such as customs scans and quality checks, as well as potential improvements such as additional services, buffer storage, information exchange, and location strategy. These insights guided the focus on specific GFFR cold chain aspects during the opportunity analysis.

Drawing insights from value stream mapping, background study, and interviews, the opportunity analysis addressed internal and external improvement strengths, weaknesses, opportunities, and threats of the GFFR cold chain in the Port of Hamburg, revealing improvement potentials. The internal aspects, focusing on value chain operations, revealed strengths like buffer storage and additional processing activities, while also highlighting weaknesses like customs scans, the cold chain's groupage network, cold storage capacity, operating area, and port area. Regarding external opportunities and threats, the Port of Hamburg encounters various influences by the broader dynamics of the fruit cold chain and the port itself. These include threats related to vessel scheduling, high operation costs, shipping line connectivity, and climate change. Among these threats, opportunities emerge, such as enhancing the food cluster, investing in port infrastructure, and increasing container volume throughput.

Assessing the potential of the GFFR cold chain in the Port of Hamburg involved the evaluation of identified improvement strategies by insights from the value stream mapping, supply chain stakeholders' perspectives, and key drivers of this cold chain. Within this context, two leading potentials emerged: improving the customs scanning process and enhancing and expanding the food cluster within the Port of Hamburg.
Improving the customs scan process addresses the weakness associated with customs scans, which cause significant delays of 1 to 3 days and increased handling costs, disrupting the efficient flow of GFFR cargo. To reduce this weakness, balancing the number of necessary scans and their impact on the GFFR cargo flow is essential, resulting in faster cargo handling and improved efficiency. The key considerations for achieving this enhancement involve increasing the number and capacity of customs locations, prioritizing perishable or sensitive goods, and strategically allocating locations within the port. For instance, establishing an additional custom scan facility close to the GFFR cargo handling area, such as in the Kleiner Grasbook area of the Port of Hamburg. Effectively realizing this potential requires active engagement from the responsible stakeholder, the customs authority, in collaboration with forwarders and importers. Moreover, a collective effort involving customs and port authorities, cold storage operators, forwarders, and importers is crucial to balance security considerations and the streamlined movement of GFFR cargo.
Enhancing the food cluster in the Port of Hamburg addresses weaknesses, threats, and opportunities related to the current limitations of the groupage network for GFFR cargo, shipping line connectivity, and volume throughput. This potential offers significant benefits for the GFFR cold chain, as it can increase demand volumes and potentially attract shipping lines by establishing a more robust market presence. Moreover, it can optimize the groupage network, resulting in cost efficiencies. However, in the competitive fresh fruit market, it is essential to carefully consider importer clustering, possibly focusing on grouping importers from non-competing markets. To effectively realize this potential, collaborative efforts among importers and forwarders, are essential. Additionally, the collaborative efforts of other supply chain stakeholders are also crucial to establishing a robust food cluster and GFFR cold chain.

In essence, the primary focus for supply chain stakeholders to effectively accommodate the improvement of the global first-mile fresh fruit reefer cold chain lies within maintaining and enhancing the complex relationships between the cold chain's operations and stakeholders. Moreover, the GFFR cold chain in the Port of Hamburg may benefit from improving its potential concerning customs scans and establishing a comprehensive food cluster.

6.2. Implications

This section elaborates on this research's scientific and practical implications for identifying, analyzing, and improving a global fresh fruit cold chain. One scientific implication is that no prior studies have used the value stream mapping methodology to explore the global food cold chain's organizational level connectivity and potential, encompassing diverse operations and stakeholders. Previous research primarily concentrated on a broader organizational level, addressing the structure of supply chain stages without further research into the operations and their complex interconnections at both the material and information levels. Value stream mapping is a commonly employed technique for comprehending organizational processes, enabling the exploration of interconnected segments within operations, organizations, or systems. This study demonstrated that applying the value stream mapping methodology led to a comprehensive analysis, highlighting operational and information structures, critical challenges, and opportunities for improvement over the food cold chain import segment, also influencing the entire food cold chain. These findings are particularly relevant in highlighting this cold chain's complexity and interdependence.

Another noteworthy scientific implication of this research is the combined application of the value stream mapping (VSM) methodology with a SWOT analysis. While some prior studies have employed the combination of SWOT and VSM to conduct in-depth system analysis, this research takes a unique approach by utilizing VSM to elaborate on the SWOT analysis. By highlighting focus areas identified through VSM, this approach shifts the perspective from an external-inside view to an inside-outside view. This shift adds depth to the understanding of a system's complexity and operations, offering more than just a strategic viewpoint. Moreover, in my personal reflection on this approach, I find that evaluating strengths, weaknesses, opportunities, threats, and improvement strategies is more effectively substantiated when considering their fundamental understanding and impact on a system rather than solely from a strategic standpoint. Through this approach, certain strengths and weaknesses were noticed that have a subtle influence on the system, aspects that might have gone unnoticed with an external-inside perspective.

Furthermore, research on the food cold chain often centered on examining the entire cold chain process, lacking a specific orientation towards the complex nature of import logistics value processes. This emphasis can be explained by the crucial role of transparent operations of the entire supply chain, from harvest to end-consumer distribution. This study underscores this scientific implication by highlighting connectivity throughout the supply chain and within the integration into port logistics. By identifying and analyzing operations within this specific context, a clearer understanding of potential improvements to the importing food cold chain flows can be achieved, benefiting the overall food cold chain. Notably, fresh fruit operations, characterized by increased time-sensitivity and quality preservation demands compared to frozen fruit, contribute to comprehending these complex and sensitive systems. This comprehension may extend to enhancing less time-sensitive segments of the cold chain. Importantly, this focused approach represents a cold chain perspective not yet presented in scientific literature.

In terms of practical implications, this research provides a comprehensive understanding of the imported fresh fruit reefer cold chain in the Port of Hamburg accessible to all stakeholders, regardless of their specific expertise. This level of understanding is crucial for recognizing the interconnections and significance of this cold chain, thereby fostering stronger relationships and information exchange among the diverse stakeholders involved. Such enhanced collaboration can lead to improved cold chain efficiency. When the operations and interdependencies are transparent, stakeholders who may not be directly involved in a particular operation but are connected can make informed investments to strengthen these relationships. This, in turn, contributes to a more streamlined and efficient cold chain.

Furthermore, this research not only emphasizes the interplay of relationships and operations but also clarifies the associated challenges and opportunities. As indicated, the potential enhancement of this cold chain's critical issues and opportunities requires a collaborative effort involving multiple stakeholders. Stakeholders with a deeper understanding are likely more willing to invest in strengthening operations that may not fall solely under their responsibility but can still contribute to their own venture.

6.3. Discussion

While the conclusion and implications follow directly from the results of the research elements, a research reflection is given in this discussion. Throughout the development of this research, multiple decisions have been made that impacted the research results. The following paragraphs briefly discuss the chosen methodologies, followed by an exploration of the design approach, and critically reflect on the developed designs.

To start, due to the qualitative approach of this research, the results might be over-ambitious and not very straightforward. The interpretations and presentations of the findings are influenced by the perspectives and priorities of supply chain stakeholders, lacking quantitative data support. This scenario could misrepresent the accurate illustration of the significance and goals concerning the enhancement of potentials within this cold chain. Further research into quantitative data linked to this research's results emphasizes the findings' objective significance.

Moreover, the approach of semi-structured interviews introduces certain limitations regarding the non-generalizability of interview outcomes due to the incomplete involvement of all stakeholders. It would be particularly valuable to include the German customs authority's perspective to comprehend the potential for enhancing customs scan processes at the Port of Hamburg. Additionally, while leading stakeholders from each category participated in this research, providing insights into the primary strategies and interests of operations, it leaves out the perspectives of smaller yet relevant operating stakeholders. Including a broader range of stakeholders would increase the relevance and practicality of this cold chain research findings.

This research was conducted under specific assumptions regarding its scope. The scope starts with the arrival of a reefer container at a terminal in the Port of Hamburg, excluding the transportation of GFFR cargo to the port and the associated processes within and affecting the GFFR cold chain. Consequently, shipping agencies were excluded, although this stakeholder category was addressed as an essential influence in overcoming the volume throughput challenges at the port. Incorporating this stakeholder would enhance the research by offering additional insights and improvement strategies.

A further point of discussion is that the analysis focused on the material and information value stream flow of reefer fresh fruit cargo, neglecting other activities and entities such as financial, legal, IT support, and administrative transactions contributing to container movements. Although these transactions might impact decision-making, they were not considered in this research. Further investigation into these transactions and their relationship to material and information flows could provide a more comprehensive understanding of the cold chain dynamics.

Finally, while value stream mapping was employed to map the current state for each material flow alternative, the process did not extend to creating a future state map. To address this, further research is required to explore strategic and structural gaps and assess the potential impact of improvements in developing a future state value map. This map would serve as a strategic framework for implementing tactical improvements. Demonstrating the impact of the potentials identified in this research enhances the decision-making process and facilitates practical adaptations to the cold chain.

6.4. Recommendations

This research suggests potential areas for further investigation, building upon the results presented in this research. The recommendations encompass both further research directions (Section 6.4.1) and specialized directions customized to the context of the Hamburg Port Authority (Section 6.4.2.

6.4.1. Recommendations research

The first research suggestion focuses on an extended analysis of the potentials highlighted in this research. Given the limited time and data available, this research did not incorporate the analysis of implementing these potentials. The competitive environment of the GFFR cold chain, particularly among stakeholder categories, prevented the sharing of quantitative data, resulting in the absence of clarity regarding the quantitative effects on variables like operational costs, quality, or lead time. Assessing the impact of these key drivers of the cold chain would significantly enhance the decision-making process. Moreover, further research into the potential could indicate challenges and opportunities previously highlighted but not fully considered as potential aspects. A comprehensive comparison of these factors across various criteria would make their underlying potential for enhancing the cold chain evident. This process can lead to a more thorough and critically evaluated improvement strategy.

The second research suggestion involves incorporating shipping agencies within the scope. Interviews and identified potentials highlight their relevance in cold chain operations, particularly in the strategic context. Examining the internal perspective of shipping agencies' impact, interests, and connectivity to operations enhances the cold chain understanding, potentially revealing further critical issues and approaches for improvement.

The third and final research suggestion involves examining the competitive landscape of the GFFR cold chain in the Port of Hamburg compared to other ports like Rotterdam and Antwerp. This research has already highlighted various external challenges and opportunities related to the competitiveness of the Port of Hamburg. Given the comprehensive insight into cold chain operations, examining the operational competitiveness of alternative ports becomes relevant to value the necessity for improvement. Assessing insights from other port operations could potentially address internal challenges and opportunities. Furthermore, the external challenges primarily stem from the Port of Hamburg's competitive positioning, involving aspects like its attractiveness to shipping lines, the food cluster and groupage network, and operational costs.

6.4.2. Recommendations Hamburg Port Authority

Since the Hamburg Port Authority (HPA) is not directly engaged in the physical cargo movement of the GFFR cold chain at the Port of Hamburg, the main recommendation focuses on the cluster management role that the port authority can undertake. This research highlights the potential to enhance the food cluster and groupage network. Benefiting from its neutral position within the competitive dynamics of the fresh fruit market, HPA can facilitate cold chain improvement through effective cluster management. By coordinating and uniting stakeholders, HPA can significantly elevate the cold chain. Notably, facilitating collaboration among importers in clusters, potentially by grouping importers from non-competing markets, could yield significant benefits. Another potential example involves HPA's impartial role in facilitating a link between customs authorities, forwarders, and cold storage stakeholders to enhance the customs scanning process. Though conversations are already underway among stakeholders, the power imbalance of the customs authority might hinder collaborative efficiency with the other stakeholders.

Moreover, given the insights into the cold chain provided by this research, HPA could pursue additional research into the connectivity of the cold chain. Certain interviews indicated that some stakeholders perceive a lack of inclusion or consideration when making decisions potentially impacting cold chain structure. Establishing more frequent communication channels could yield more current information about interests, evolving dynamics, and preferred strategies that can be employed to enhance the cold chain.

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A.Appendix A - Scientific paper

Value stream mapping for analyzing cold chain dynamics into fresh fruit imports

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Keywords: Value stream mapping, VSM, reefer, cold chain, fresh fruit

September 11, 2023

Abstract

This paper explores how ports, such as Hamburg, are adapting their logistics to enhance supply chain efficiency, with a specific focus on the evolving global first-mile fresh fruit reefer (GFFR) cold chain. It discusses the use of value stream mapping (VSM) from an inside-out perspective to analyze operations, challenges, and opportunities for improvement. Through VSM and opportunity analysis, it identifies key issues and opportunities, stressing the need to improve customs scanning and establish a food cluster network at the Port of Hamburg. In summary, this study underscores the significance of effectively managing GFFR cold chain relationships, with proposed improvements addressing weaknesses and capitalizing on opportunities for competitiveness.

1 Introduction

Ports operations play a crucial role within maritime transportation and international supply chains, effectively facilitating the seamless flow of information, commodities, and financial resources (Tongzon, Chang, and Lee, 2009; Bo and Meifang, 2021; Song, 2021). Over the past few decades, the landscape of supply chain operations has undergone significant transformations, driven by structural and strategic shifts, with ports adopting a corporate approach to streamline their logistics. The wave of the corporatization of port authorities in Europe reflects the increasing business and market-oriented approach to port management and logistics (Notteboom, 2017). This transformation has the potential to change the dynamics of logistics and value-driven activities, as well as the effectiveness of supply chains (Notteboom, 2017; Md ibrahim and Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020). Moreover, this change highlights the critical importance of logistics efficiency to port competitiveness (Alavi et al., 2018; Stock, Greis, and Kasarda, 2000).

Alongside this shift towards a corporate approach, the dynamic nature of supply chain operations has been shaped by increases in demand in various industries. Which has led to expanding global supply chain operations. Notably, the global food trade, particularly in fresh fruit, has witnessed substantial growth (Klopott, 2019). This supply chain stands out as sensitive and vulnerable due to the significant impact on human health standards (Unurjargal, 2019; World Health Organization, 2018), the perishable characteristics of the products involved, and the specialized refrigerated equipment facilitating the global fresh fruit reefer cold chain (Unurjargal, 2019; Klopott, 2019; Jedermann et al., 2014; Arduino, Carrillo Murillo, and Parola, 2015; Mercier et al., 2017; Castelein, Geerlings, and Van Duin, 2020). An interesting observation in this evolving cold chain landscape is the varying readiness of different segments to capitalize on the increased demand for fresh fruit trade, as demonstrated in the case of the Port of Hamburg. Motivated by this operational gap, the Hamburg Port Authority investigated improvement strategies to enhance the port's competitive position.

Focused on a case study at the Port of Hamburg, the objective of this research is to explore process and value structures, identifying challenges and opportunities for improvement. This aims to support supply chain stakeholders in accommodating the improvement potential within the Port of Hamburg.

This paper continues with a literature review in Section 2. In Section 3, the value stream mapping (VSM) approach is discussed as the primary methodology employed, crucial for exploring process and value structures and identifying areas for improvement. Section 4 outlines the practical application of VSM, which played an essential role in shaping this research and driving both direct and indirect outcomes. Section 5 presents the research findings, reflecting how VSM guided this study, leading to various outcomes. The paper concludes in Section 6, offering a conclusion, highlighting future research recommendations, and providing a reflection on the implication of the VSM methodology.

2 Literature review

The literature review served to understand the different aspects of the explored global first-mile fresh fruit reefer (GFFR) cold chain and how these aspects are connected.

2.1 Fresh fruit supply chain

The fresh fruit supply chain shares similarities with the general food supply chain, encompassing the physical movement from farmers to end-consumers (Xu et al., 2020; Zhang et al., 2022). However, it requires temperature control, typically achieved through refrigeration technology (Chen and Yang, 2022; Han et al., 2021; Zhao et al., 2018), to maintain the proper temperature range and extend the shelf-life while ensuring food safety and quality for consumers (Li et al., 2021). Temperature and humidity are critical factors influencing fresh fruit quality and longevity (Abeles, Morgan, and Saltveit, 1992; Behdani, Fan, and Bloemhof, 2019; Hamburg Süd, 2019; Van Duin et al., 2019; Kumar, Singh, and Layek, 2020), with a standard temperature range of fresh fruit typically set above -5°C and an accepted deviation of +/- 1°C of its set point temperature during transportation (Van Duin et al., 2019).

2.2 Reefer cold chain

Cold chain refers to temperature-controlled transportation for perishable products, primarily facilitated by refrigerated containers, or reefers, which hold over 80 % of the market share (Jedermann et al., 2014; Arduino, Carrillo Murillo, and Parola, 2015; Mercier et al., 2017; Castelein, Geerlings, and Van Duin, 2020). A reefer provides cost-effective logistics and adaptable temperature management throughout the supply chain (Rodrigue and Notteboom, 2017; Goedhals-Gerber, Stander, and Van Dyk, 2017). Reefer containers cool the circulated air using two fans and direct the cooled air through and around the cargo (Castelein, Geerlings, and Van Duin, 2020; Hamburg Süd, 2019; Fefelova, 2018). Notably, chilled cargo's cooled airflow passes through the content, while frozen cargo's airflow goes around it (Fefelova, 2018). Fresh fruit is typically transported as chilled cargo, although the preferred temperature varies by fruit type.

2.3 Global first-mile fresh fruit (GFFR) cold chain

The GFFR cold chain explored in this research encompasses various stages. It begins with the global fresh fruit (GF) supply chain, which includes processes like harvesting, processing, packaging, storing, transportation, and retailing, all while maintaining the desired temperature range (Acciaro et al., 2018; Unurjargal, 2019; Behdani, Fan, and Bloemhof, 2019; Shabani, Torabipour, and Saen, 2015; Mercier et al., 2017; Kitinoja, 2013). The cold chain aspect initiates during transportation when products are containerized in reefers. This GF cold chain, containerized in reefer containers, is referred to as the global fruit reefer (GFR) cold chain. After the GFR cargo completes its long-range international journey from the port of origin to the destination port, which often takes several weeks, the products must be unloaded from the ship and stored in cold storage facilities. They remain in cold storage until they are ready for transport to distribution centers in the hinterland (Behdani, Fan, and Bloemhof, 2019; Castelein, 2021). This research focuses on the movement of cargo from its arrival at the importing port terminal to the distribution centers in the inland area, the first-mile importing flow of the global fresh fruit reefer cold chain, which is referred to as the GFFR cold chain.

2.4 GFFR cold chain analysis

While academic research extensively covers topics related to the food reefer cold chain (Acciaro et al., 2018; Unurjargal, 2019; Behdani, Fan, and Bloemhof, 2019; Shabani, Torabipour, and Saen, 2015; Mercier et al., 2017; Kitinoja, 2013) and restructuring of port logistics (Notteboom, 2017; Sletmo, 1999; Pallis et al., 2011; Mangan, Lalwani, and Fynes, 2008; Md ibrahim and Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020; Alavi et al., 2018), there exists an empirical research gap concerning the integration of supply chain logistics within the food cold chain.

Current port logistics analyses often overlook supply chain structures, resulting in this research gap. Most studies on food cold chain logistics concentrate on the entire cold chain without specific attention to the import logistics value processes, potentially neglecting the efficiency of individual components like import first-mile processes. Consequently, there is a notable absence of an operational structure for the import-oriented reefer cold chain in the fresh fruit segment, a lack of substantiated value chain structure, and a limited understanding of the primary challenges and opportunities for integration and improvement in these systems. Addressing these research gaps by exploring opportunities for improvement could enhance the port's competitive position.

3 Methodology

Focused on the Port of Hamburg, a case study was conducted involving several research elements, including a literature and background review, value stream mapping (VSM), and opportunity analysis. These research elements were also supported by interview and SWOT methodologies. By combining the findings from these research elements, the research presents the improvement potentials within the Port of Hamburg. As VSM played an essential role in shaping this research and driving both direct and indirect outcomes, this methodology is highlighted.

The value stream mapping methodology makes a valuable contribution to supply chain analysis by facilitating an inside-out perspective in the opportunity analysis. Unlike the traditional approach of first identifying strengths, weaknesses, opportunities, and threats and then focusing on these aspect structures, this methodology focuses on GFFR cold chain improvement potentials from the value chain structure. It offers an alternative perspective to the main strategic viewpoint typically employed. By doing so, it aids in uncovering competitive aspects and insights that might otherwise be overlooked, providing a deeper understanding of opportunities for improvement from a different angle.

Value Stream Mapping (VSM) is a methodology developed to collect all actions (both value-added and non-value-added) required in a supply chain to bring a product through its essential main flows (Rother and Shook, 2003). VSM provides a transparent, unbiased, fact-based insight into how processes should be managed to achieve and sustain high-performance levels (Deming, 2000; Martin and Osterling, 2014). VSM's broader outlook encompasses both individual processes and the entire process overview, crucial for considering relationships with various business partners along the same supply chain (Dinesh et al., 2007; Rother and Shook, 2003). Given the complex nature of the GFFR cold chain involving numerous stakeholders, this holistic approach proves relevant and valuable.

The VSM approach in this research involves strategically reviewing the supply chain's activities and mapping these processes. Within the context of this research, the representation of physical and information flows of the global fresh fruit reefer container cold chain is created by the following six steps (partly based on (Rother and Shook, 2003)):

1. Identification specific value stream to be reviewed (scope)
2. Identify material flow
3. Identity information flow
4. Analyze flow categories
5. Analyze critical issues
6. Identify improvement potentials

4 Application VSM

The application of value stream mapping (VSM) in this research serves to comprehensively analyze the current state of operations, revealing critical issues and areas with potential for improvement. Notably, this VSM provides an integral view of the system, encompassing multiple stakeholders involved in the handling of GFFR cargo. This approach extends beyond operational aspects, focusing on the organizational aspects of material and information flows related to GFFR cargo.

The current state map is constructed starting from end-customer processes and services, and then moving upstream. This approach aligns with the principle that product flow should be driven by customer demand (Chen and Cox, 2012). To gather relevant data, interviews were conducted in the same order, commencing with importing stakeholders and concluding with terminal operators. This sequential approach was crucial in understanding the specific focus areas of the value stream maps.

Initially, the activities and processes within the GFFR cold chain were categorized according to their respective operating locations. This categorization aimed to provide insights into the diverse influences of various stakeholders. Subsequently, these activities and processes were interconnected through material and information flows. However, before focusing on the material and information flows of GFFR cargo handling, it was essential to identify the various value streams that could emerge. Seven distinct value streams were identified, primarily shaped by four key factors: distribution choices, the efficiency of customs scans, the effectiveness of troubleshooting activities, and the proficiency of additional processing activities. Based on these seven value streams, four alternative current state maps were created, each focusing on a specific aspect of the reference current state map, presented in Figure 1. Developing the reference map played an essential role in maintaining a holistic perspective of the system rather than limiting the viewpoint to specific aspects.

The VSM revealed numerous material and information flows stemming from the diverse range of processes and stakeholders involved in this cold chain. However, the significance of these operations, material flows, and information flows remains undetermined by solely mapping them out. The segmentation of value streams serves to highlight critical issues and areas with potential for enhancement within the cold chain. The classification consists of three distinct categories: value-adding (VA) streams, non-value-adding (NVA) streams, and necessary but non-value-adding (NNVA) streams. Based on this classification and interviews, critical issues and improvement potentials were identified, as illustrated in Figure 2 in red and blue.

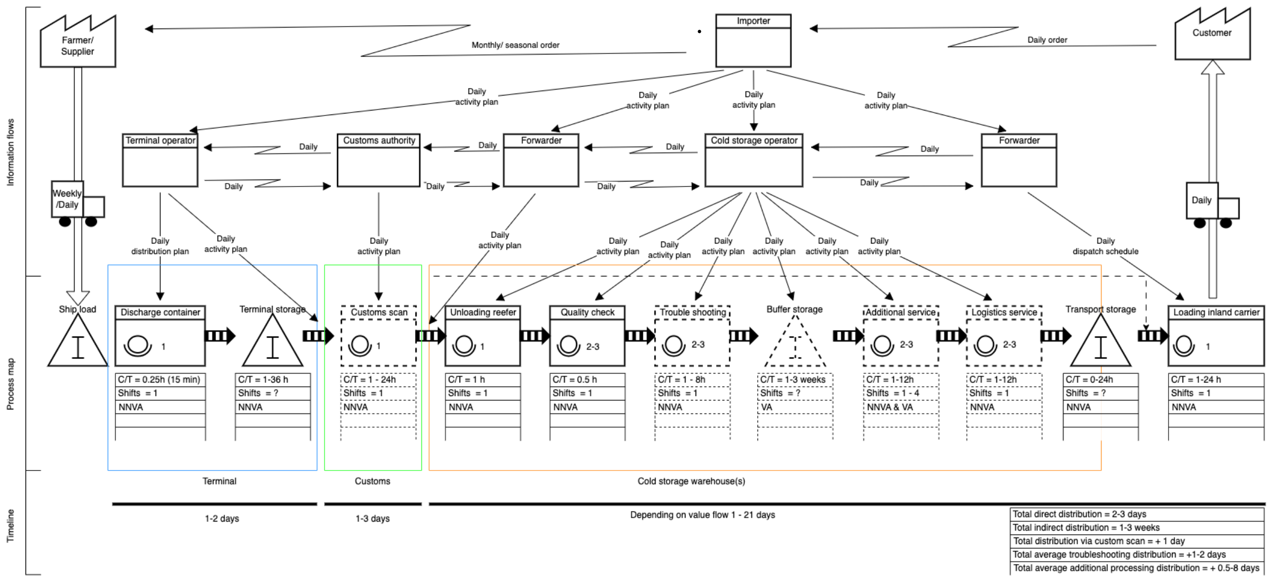

Figure 1: *VSM reference current state map GFFR cold chain Port of Hamburg*

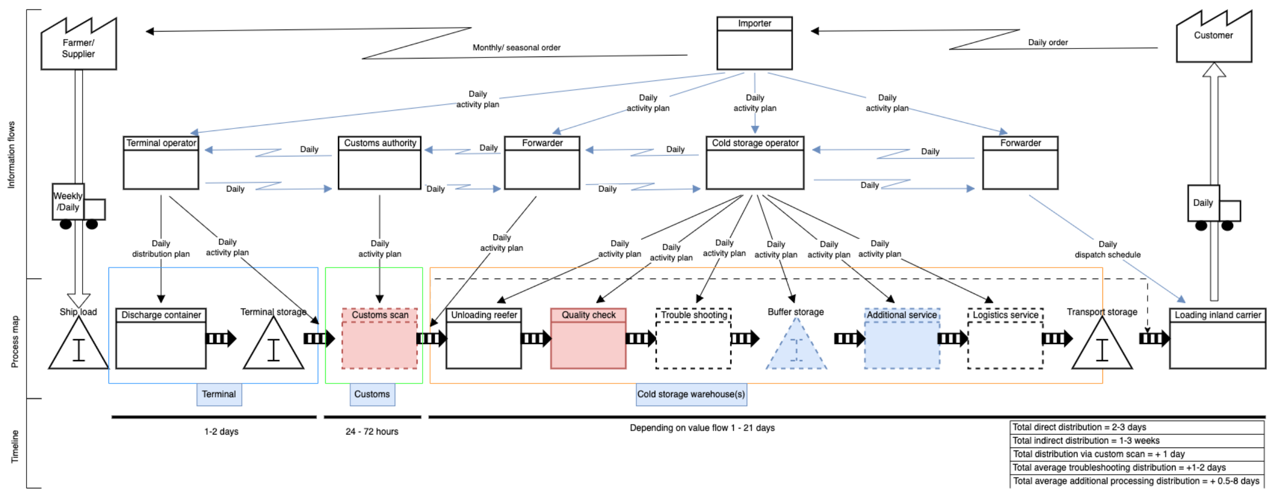

Figure 2: *VSM visualization critical issues (red) and improvement potentials(blue) for GFFR cold chain in the Port of Hamburg*

The complexity of numerous operations, stakeholders, material flow alternatives, and information sharing within this GFFR cold chain underscores the significance of understanding the complex relationships between these elements to enhance efficiency and improve the dynamics of the cold chain.

The utilization of VSM in the SWOT analysis, which is part of the opportunity analysis, is particularly valuable in identifying critical issues and potential areas for improvement. Furthermore, the VSM perspective is applied to assess the SWOT strategies. This latter application of VSM contributes significantly to understanding the relevance of improvement opportunities for the GFFR cold chain.

5 Results

Through literature review and interviews, the background study categorized five key stakeholder categories influencing the GFFR cold chain at the Port of Hamburg: (port and customs) authorities, terminal operators, cold storage operators, forwarders, and importers. These stakeholders nurture interconnections across diverse supply chain stages, highlighting this cold chain's complexity. Value stream mapping provided deeper insight into these interdependencies, revealing the material and information flows that cross operations and stakeholders.

Various material flows were identified by the value stream mapping, and categorized into four alternative current state maps: direct distribution (including customs scans), indirect distribution, distribution with troubleshooting activities, and distribution with additional processing and logistics services activities.

Information flows facilitated cargo movement across these material flows, with stakeholders exchanging information daily to link operations together. The GFFR cold chain in the Port of Hamburg features numerous material and information value streams originating from diverse processes and stakeholders. The complexity of connecting these elements highlights the importance of managing their relationships for optimal cold chain efficiency. Value stream mapping revealed the underlying structure of the value chain, highlighting critical issues like customs scans and quality checks, as well as potential improvements such as additional services, buffer storage, information exchange, and location strategy. These insights guided the focus on specific GFFR cold chain aspects during the opportunity analysis.

The opportunity analysis, involving a SWOT analysis, addressed both internal and external strengths, weaknesses, opportunities, and threats of the GFFR cold chain in the Port of Hamburg, revealing improvement potentials. The internal aspects, focusing on value chain operations, revealed strengths like buffer storage and additional processing activities, while also highlighting weaknesses like customs scans, the cold chain's groupage network, cold storage capacity, operating area, and port area. Regarding external opportunities and threats, the Port of Hamburg encounters various influences by the broader dynamics of the fruit cold chain and the port itself. These include threats related to vessel scheduling, high operation costs, shipping line connectivity, and climate change. Among these threats, opportunities emerge, such as enhancing the food cluster, investing in port infrastructure, and increasing container volume throughput.

The main potentials identified via the SWOT analysis are improving the customs scanning process and enhancing the food cluster at the Port of Hamburg. Addressing internal weaknesses associated with customs scans is crucial due to disruptions in the GFFR cargo flow. Balancing the number of scans and their impact on cargo flow is essential for improved efficiency. Key considerations involve expanding the number and capacity of customs locations, prioritizing perishable goods, and strategic port allocation of the customs locations. Successful implementation requires the customs authority's active engagement and collaboration with forwarders and importers.

Enhancing the Port of Hamburg's food cluster addresses external threats and opportunities, including shipping line connectivity, volume throughput, and current food cluster limitations. This potentially benefits the GFFR cold chain, boosting demand and potentially attracting shipping lines for a stronger market presence. It also streamlines the groupage network for cost savings. However, in the competitive fresh fruit market, strategic importer clustering—possibly grouping non-competing market importers—is vital. Effective realization requires collaboration among importers, terminal operators, forwarders, and other stakeholders to establish a robust food cluster.

6 Conclusion

Concluding this research, the primary focus for supply chain stakeholders to effectively accommodate the improvement of the global first-mile fresh fruit reefer cold chain lies within maintaining and enhancing the complex relationships between the cold chain's operations and stakeholders. Furthermore, optimizing the GFFR cold chain in the Port of Hamburg may benefit from improving its potential concerning customs scanning procedures and establishing a food cluster network.

Future research aiming to build upon this research is suggested to work on the following research suggestions:

- To enhance understanding, future analysis should integrate quantitative data to evaluate the impact of identified potentials on crucial aspects of the cold chain like the key drivers.
- Incorporating shipping agencies into the research scope is recommended, emphasizing their strategic relevance. This inclusion can enhance cold chain comprehension, potentially unveiling additional critical challenges and approaches for improvement.
- Analyzing the competitive dynamics of the GFFR cold chain in the Port of Hamburg, alongside other ports like Rotterdam and Antwerp, is essential to determine the importance of necessary improvements.

Reflection on the use of VSM in this research is given by the scientific implication of the combined application of VSM with a SWOT analysis. While some prior studies have employed the combination of SWOT and VSM to conduct in-depth system analysis, this research takes a unique approach by utilizing VSM to elaborate on the SWOT analysis. By highlighting focus areas identified through VSM, this approach shifts the perspective from an external-inside view to an inside-outside view. This shift adds depth to the understanding of a system's complexity and operations, offering more than just a strategic viewpoint.

Moreover, in my personal reflection on this approach, I find that evaluating strengths, weaknesses, opportunities, threats, and improvement strategies is more effectively substantiated when considering their fundamental understanding and impact on a system rather than solely from a strategic standpoint. Through this approach, certain strengths and weaknesses were noticed that have a subtle influence on the system, aspects that might have gone unnoticed with an external-inside perspective.

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B. Appendix B - Interview Guides

Appendix B provides the interview guides developed for the semi-structured interviews conducted as part of this research. These guides encompass all contextual information and questions discussed during the interviews. The background study (Chapter 3), value stream map mapping (Chapter 4), and opportunities analysis (Chapter 5) form the basis for the content and focus of the interview questions. The context outlined in the interview guides will be presented in Table B.1 and Table B.2. The interviews were conducted in two rounds, leading to the creation of two distinct interview guides, presented in Section B.1 and Section B.2. The first interview serves as a valuable source of information for building a stakeholder overview and understanding value stream activities. In contrast, the second interview aims to validate the identified value streams and gain insights into stakeholders' perspectives regarding associated challenges, and opportunities.

B.1. Interview guide round 1

The first interview goal is to gather insights into value stream activities and stakeholders' perspectives, functions, and influence in the GFFR cold chain. The provided context in Table B.1 outlines the details for the first interview round, guiding the formulation of relevant interview questions.

Table B.1.: Context appointed in the interview guide round 1

Context	Content
Introduction	The introduction will give a short introduction of the interviewer and participant. A recap of the research goal is given, and the participant is informed about the upcoming content of the interview.
Stakeholder background	The company will be discussed (shortly) in general which provides more background information about its services, commodities handled, and goals/focus.
Position in GFFR cold chain	In this part, questions are asked about the stakeholder's relation with the GFFR cold chain. Questions are asked about which GFFR cargo is handled and which GFFR services the stakeholder provides.
Value stream structure	The goal of this context is to understand the value stream of the stakeholder's services. This includes questions about the material and information activities, processes, functions, and order of these aspects.
Added value segments	After creating an overview of the stakeholder's value streams in the GFFR cold chain, the added-value aspects of the cold chain are discussed.
Future goals	At last, the future goals for the GFFR cold chain will be asked to get an understanding of the overall goals of the GFFR cold chain and its processes.

Introduction - 5 min

- Self-introduction
- Recap research
- Goal of the interview
- Recording and processing data
- Introduction participant

Stakeholder cold chain background - 5 min

- Can you elaborate a bit more about your company (X)?
  - What is your business about?
  - What services does X provide in general, and which are specified for the cold chain?
  - What commodities of the cold chain do you provide these services for?
  - What is your most transported/handled commodity?

Position in GFFR cold chain - 10 min

- How is X connected to the GFFR cold chain? (stakeholder categories)
- What commodities of fruit does your company handle?
- What services does your company provide for the cold chain specified for the fruit commodities?
- What is -in your perspective- the position and/or function of the company in the GFFR cold chain?
- What is your influence/power in the GFFR cold chain?

Value stream structure - 25 min

You explained to me about the services your company provides. Can you elaborate more about:

- Which activities related to the material flow are provided by your services?
  - Which activities are performed by your company?
  - What processes are related to these services/activities?
  - What function is connected to the processes?
  - What is the order of the processes?
  - Can you give me a time indication of the product cycle per process?
  - Can you give me an indication of the volume of reefer fruit cargo handled per process?
- Which activities related to the information flow are of relevance to performing the activities mentioned before?
- What is your company's perspective on the present value streams of the GFFR cold chain?

Added value segments - 10 min

- What is from your company's perspective added-value aspects in the GFFR cold chain?
  - What activities/processes?
  - What material flows?
  - What information flows?

Future goals - 5 min

- What is X its main goal or focus for the future state of the GFFR cold chain?

B.2. Interview guide round 2

The second interview goal is to validate the value streams identified by the research and gain a deeper understanding of stakeholders' perspectives regarding the challenges and opportunities linked to these value streams. The contextual framework for the second interview round is outlined in Table B.2, encompassing the foundation for the interview questions formulated based on this context.

Table B.2.: Topics appointed in the interview guide round 2

Context	Content
Introduction	The introduction will give a short introduction of the research progress and will provide a recap of the research goal. The participant is informed about the upcoming content of the interview. For new participants, also an introduction of the interviewee and participant is included.
Validation VSM	Questions will be asked about the presented insights of the value stream mapping. These questions will validate the value stream structures and added-value aspects presented from the stakeholder's perspective.
Internal challenges and opportunities	The goal of this part is to ask questions about the challenges and opportunities presented by the value stream structures in the GFFR cold chain in the Port of Hamburg. This part will mainly focus on the value stream maps presented by the interviewee.
External challenges and opportunities	Next to the internal challenges and opportunities, external ones will be asked, specified for the fruit cold chain and the Port of Hamburg. These questions will support the broader scope and external influences of the fruit cold chain and the Port of Hamburg on the GFFR cold chain in the Port of Hamburg.
Port of Hamburg's potential	In this part, the stakeholder's power and interest in accommodating to improve the GFFR cold chain in the Port of Hamburg will be questioned, specified on the presented challenges and opportunities. This will help to get insight into the Port of Hamburg's potential.

Introduction - 5 min

- Recap research
- Goal of the interview
- Recording and processing data
- (Introduction participant & interviewee)

Validation VSM - 10/15 min

The value stream mappings presented in this research will be discussed (per aspect).

- Is this VSM representative of the value chain structure in the Port of Hamburg?
- Do the added-value segments presented match your understanding?
- Do you have comments on what should be adapted or not?
- What aspects do you agree/disagree with?

Internal challenges and opportunities - 10 min

- What are, in your perspective, the challenges of the presented (and/or adapted) VSM of the GFFR cold chain in the Port of Hamburg?
- What are, in your perspective, the opportunities of the presented (and/or adapted) VSM of the GFFR cold chain in the Port of Hamburg?

External challenges and opportunities - 10 min

- What are, in your perspective, the challenges of the fruit cold chain and the Port of Hamburg?
- What are, in your perspective, the opportunities of the fruit cold chain and the Port of Hamburg?

Port of Hamburg's potential - 15/20 min

- What are the key factors for your company to determine the choice of port supply chains in the GFFR cold chain?
- What are, in your perspective, the requirements and conditions to participate in the future growth of the fruit market? What should the Port of Hamburg do?
- What are the growth perspectives of the Port of Hamburg?

- What is the interest of your company in accommodating the improvement of challenges X, Y, and Z?
- What is the power of your company in accommodating the improvement of challenges X, Y, and Z?
- What do you think will be the effectiveness of X, Y, and Z?
- Are additional aspects/actions needed to implement X, Y, and Z?
- Should the port attract new-value-generating activities?

- What is the interest of your company in accommodating opportunities X, Y, and Z?
- What is the power of your company in accommodating opportunities X, Y, and Z?
- What do you think will be the effectiveness of X, Y, and Z?
- Are additional aspects/actions needed to implement X, Y, and Z?

- Who has to be involved to take action, which *other* stakeholders are essential?

C.Appendix C - Interview analysis

In this section, the interview coding methodology employed for analyzing the interviews is discussed. The transcribed interviews undergo coding to detect and categorize subjects, similarities, and differences within the interview data. This coding process offers a consolidated view of responses according to topics, allowing for comparisons with relevant aspects of this research. The thematic codes are established in alignment with the research objectives.

At first, the interview results are categorized per interview round (1 or 2) and per stakeholder category to enhance the structure and facilitate analysis and comparison. Subsequently, thematic codes are assigned. The following codes are employed:

- 1.. - interview results from round 1 added with the other coding themes
- 2.. - interview results round 2 added with the other coding themes
- PA - perspective from the port authority
- CA - perspective from the custom authority
- TO - perspective from the terminal operator
- CO - perspective from cold storage operator
- FO - perspective from forwarder
- IM - perspective from the importer
- NE - perspective from the network provider
- CHA - aspects that form challenges in the GFFR cold chain
- OPP - aspects that form opportunities in the GFFR cold chain

Finally, the outcomes will be presented following the code encoding structure. This compilation of interview data categorized by themes will facilitate comparisons and present a conclusion from the interview findings.

Value stream mapping for analyzing cold chain dynamics into fresh fruit imports

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Keywords: Value stream mapping, VSM, reefer, cold chain, fresh fruit

September 11, 2023

Abstract

This paper explores how ports, such as Hamburg, are adapting their logistics to enhance supply chain efficiency, with a specific focus on the evolving global first-mile fresh fruit reefer (GFFR) cold chain. It discusses the use of value stream mapping (VSM) from an inside-out perspective to analyze operations, challenges, and opportunities for improvement. Through VSM and opportunity analysis, it identifies key issues and opportunities, stressing the need to improve customs scanning and establish a food cluster network at the Port of Hamburg. In summary, this study underscores the significance of effectively managing GFFR cold chain relationships, with proposed improvements addressing weaknesses and capitalizing on opportunities for competitiveness.

1 Introduction

Ports operations play a crucial role within maritime transportation and international supply chains, effectively facilitating the seamless flow of information, commodities, and financial resources (Tongzon, Chang, and Lee, 2009; Bo and Meifang, 2021; Song, 2021). Over the past few decades, the landscape of supply chain operations has undergone significant transformations, driven by structural and strategic shifts, with ports adopting a corporate approach to streamline their logistics. The wave of the corporatization of port authorities in Europe reflects the increasing business and market-oriented approach to port management and logistics (Notteboom, 2017). This transformation has the potential to change the dynamics of logistics and value-driven activities, as well as the effectiveness of supply chains (Notteboom, 2017; Md ibrahim and Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020). Moreover, this change highlights the critical importance of logistics efficiency to port competitiveness (Alavi et al., 2018; Stock, Greis, and Kasarda, 2000).

Alongside this shift towards a corporate approach, the dynamic nature of supply chain operations has been shaped by increases in demand in various industries. Which has led to expanding global supply chain operations. Notably, the global food trade, particularly in fresh fruit, has witnessed substantial growth (Klopott, 2019). This supply chain stands out as sensitive and vulnerable due to the significant impact on human health standards (Unurjargal, 2019; World Health Organization, 2018), the perishable characteristics of the products involved, and the specialized refrigerated equipment facilitating the global fresh fruit reefer cold chain (Unurjargal, 2019; Klopott, 2019; Jedermann et al., 2014; Arduino, Carrillo Murillo, and Parola, 2015; Mercier et al., 2017; Castelein, Geerlings, and Van Duin, 2020). An interesting observation in this evolving cold chain landscape is the varying readiness of different segments to capitalize on the increased demand for fresh fruit trade, as demonstrated in the case of the Port of Hamburg. Motivated by this operational gap, the Hamburg Port Authority investigated improvement strategies to enhance the port's competitive position.

Focused on a case study at the Port of Hamburg, the objective of this research is to explore process and value structures, identifying challenges and opportunities for improvement. This aims to support supply chain stakeholders in accommodating the improvement potential within the Port of Hamburg.

This paper continues with a literature review in Section 2. In Section 3, the value stream mapping (VSM) approach is discussed as the primary methodology employed, crucial for exploring process and value structures and identifying areas for improvement. Section 4 outlines the practical application of VSM, which played an essential role in shaping this research and driving both direct and indirect outcomes. Section 5 presents the research findings, reflecting how VSM guided this study, leading to various outcomes. The paper concludes in Section 6, offering a conclusion, highlighting future research recommendations, and providing a reflection on the implication of the VSM methodology.

2 Literature review

The literature review served to understand the different aspects of the explored global first-mile fresh fruit reefer (GFFR) cold chain and how these aspects are connected.

2.1 Fresh fruit supply chain

The fresh fruit supply chain shares similarities with the general food supply chain, encompassing the physical movement from farmers to end-consumers (Xu et al., 2020; Zhang et al., 2022). However, it requires temperature control, typically achieved through refrigeration technology (Chen and Yang, 2022; Han et al., 2021; Zhao et al., 2018), to maintain the proper temperature range and extend the shelf-life while ensuring food safety and quality for consumers (Li et al., 2021). Temperature and humidity are critical factors influencing fresh fruit quality and longevity (Abeles, Morgan, and Saltveit, 1992; Behdani, Fan, and Bloemhof, 2019; Hamburg Süd, 2019; Van Duin et al., 2019; Kumar, Singh, and Layek, 2020), with a standard temperature range of fresh fruit typically set above -5°C and an accepted deviation of +/- 1°C of its set point temperature during transportation (Van Duin et al., 2019).

2.2 Reefer cold chain

Cold chain refers to temperature-controlled transportation for perishable products, primarily facilitated by refrigerated containers, or reefers, which hold over 80 % of the market share (Jedermann et al., 2014; Arduino, Carrillo Murillo, and Parola, 2015; Mercier et al., 2017; Castelein, Geerlings, and Van Duin, 2020). A reefer provides cost-effective logistics and adaptable temperature management throughout the supply chain (Rodrigue and Notteboom, 2017; Goedhals-Gerber, Stander, and Van Dyk, 2017). Reefer containers cool the circulated air using two fans and direct the cooled air through and around the cargo (Castelein, Geerlings, and Van Duin, 2020; Hamburg Süd, 2019; Fefelova, 2018). Notably, chilled cargo's cooled airflow passes through the content, while frozen cargo's airflow goes around it (Fefelova, 2018). Fresh fruit is typically transported as chilled cargo, although the preferred temperature varies by fruit type.

2.3 Global first-mile fresh fruit (GFFR) cold chain

The GFFR cold chain explored in this research encompasses various stages. It begins with the global fresh fruit (GF) supply chain, which includes processes like harvesting, processing, packaging, storing, transportation, and retailing, all while maintaining the desired temperature range (Acciaro et al., 2018; Unurjargal, 2019; Behdani, Fan, and Bloemhof, 2019; Shabani, Torabipour, and Saen, 2015; Mercier et al., 2017; Kitinoja, 2013). The cold chain aspect initiates during transportation when products are containerized in reefers. This GF cold chain, containerized in reefer containers, is referred to as the global fruit reefer (GFR) cold chain. After the GFR cargo completes its long-range international journey from the port of origin to the destination port, which often takes several weeks, the products must be unloaded from the ship and stored in cold storage facilities. They remain in cold storage until they are ready for transport to distribution centers in the hinterland (Behdani, Fan, and Bloemhof, 2019; Castelein, 2021). This research focuses on the movement of cargo from its arrival at the importing port terminal to the distribution centers in the inland area, the first-mile importing flow of the global fresh fruit reefer cold chain, which is referred to as the GFFR cold chain.

2.4 GFFR cold chain analysis

While academic research extensively covers topics related to the food reefer cold chain (Acciaro et al., 2018; Unurjargal, 2019; Behdani, Fan, and Bloemhof, 2019; Shabani, Torabipour, and Saen, 2015; Mercier et al., 2017; Kitinoja, 2013) and restructuring of port logistics (Notteboom, 2017; Sletmo, 1999; Pallis et al., 2011; Mangan, Lalwani, and Fynes, 2008; Md ibrahim and Wang Xuefeng, 2023; Zeng et al., 2022; Guo, 2020; Alavi et al., 2018), there exists an empirical research gap concerning the integration of supply chain logistics within the food cold chain.

Current port logistics analyses often overlook supply chain structures, resulting in this research gap. Most studies on food cold chain logistics concentrate on the entire cold chain without specific attention to the import logistics value processes, potentially neglecting the efficiency of individual components like import first-mile processes. Consequently, there is a notable absence of an operational structure for the import-oriented reefer cold chain in the fresh fruit segment, a lack of substantiated value chain structure, and a limited understanding of the primary challenges and opportunities for integration and improvement in these systems. Addressing these research gaps by exploring opportunities for improvement could enhance the port's competitive position.

3 Methodology

Focused on the Port of Hamburg, a case study was conducted involving several research elements, including a literature and background review, value stream mapping (VSM), and opportunity analysis. These research elements were also supported by interview and SWOT methodologies. By combining the findings from these research elements, the research presents the improvement potentials within the Port of Hamburg. As VSM played an essential role in shaping this research and driving both direct and indirect outcomes, this methodology is highlighted.

The value stream mapping methodology makes a valuable contribution to supply chain analysis by facilitating an inside-out perspective in the opportunity analysis. Unlike the traditional approach of first identifying strengths, weaknesses, opportunities, and threats and then focusing on these aspect structures, this methodology focuses on GFFR cold chain improvement potentials from the value chain structure. It offers an alternative perspective to the main strategic viewpoint typically employed. By doing so, it aids in uncovering competitive aspects and insights that might otherwise be overlooked, providing a deeper understanding of opportunities for improvement from a different angle.

Value Stream Mapping (VSM) is a methodology developed to collect all actions (both value-added and non-value-added) required in a supply chain to bring a product through its essential main flows (Rother and Shook, 2003). VSM provides a transparent, unbiased, fact-based insight into how processes should be managed to achieve and sustain high-performance levels (Deming, 2000; Martin and Osterling, 2014). VSM's broader outlook encompasses both individual processes and the entire process overview, crucial for considering relationships with various business partners along the same supply chain (Dinesh et al., 2007; Rother and Shook, 2003). Given the complex nature of the GFFR cold chain involving numerous stakeholders, this holistic approach proves relevant and valuable.

The VSM approach in this research involves strategically reviewing the supply chain's activities and mapping these processes. Within the context of this research, the representation of physical and information flows of the global fresh fruit reefer container cold chain is created by the following six steps (partly based on (Rother and Shook, 2003)):

1. Identification specific value stream to be reviewed (scope)
2. Identify material flow
3. Identity information flow
4. Analyze flow categories
5. Analyze critical issues
6. Identify improvement potentials

4 Application VSM

The application of value stream mapping (VSM) in this research serves to comprehensively analyze the current state of operations, revealing critical issues and areas with potential for improvement. Notably, this VSM provides an integral view of the system, encompassing multiple stakeholders involved in the handling of GFFR cargo. This approach extends beyond operational aspects, focusing on the organizational aspects of material and information flows related to GFFR cargo.

The current state map is constructed starting from end-customer processes and services, and then moving upstream. This approach aligns with the principle that product flow should be driven by customer demand (Chen and Cox, 2012). To gather relevant data, interviews were conducted in the same order, commencing with importing stakeholders and concluding with terminal operators. This sequential approach was crucial in understanding the specific focus areas of the value stream maps.

Initially, the activities and processes within the GFFR cold chain were categorized according to their respective operating locations. This categorization aimed to provide insights into the diverse influences of various stakeholders. Subsequently, these activities and processes were interconnected through material and information flows. However, before focusing on the material and information flows of GFFR cargo handling, it was essential to identify the various value streams that could emerge. Seven distinct value streams were identified, primarily shaped by four key factors: distribution choices, the efficiency of customs scans, the effectiveness of troubleshooting activities, and the proficiency of additional processing activities. Based on these seven value streams, four alternative current state maps were created, each focusing on a specific aspect of the reference current state map, presented in Figure 1. Developing the reference map played an essential role in maintaining a holistic perspective of the system rather than limiting the viewpoint to specific aspects.

The VSM revealed numerous material and information flows stemming from the diverse range of processes and stakeholders involved in this cold chain. However, the significance of these operations, material flows, and information flows remains undetermined by solely mapping them out. The segmentation of value streams serves to highlight critical issues and areas with potential for enhancement within the cold chain. The classification consists of three distinct categories: value-adding (VA) streams, non-value-adding (NVA) streams, and necessary but non-value-adding (NNVA) streams. Based on this classification and interviews, critical issues and improvement potentials were identified, as illustrated in Figure 2 in red and blue.

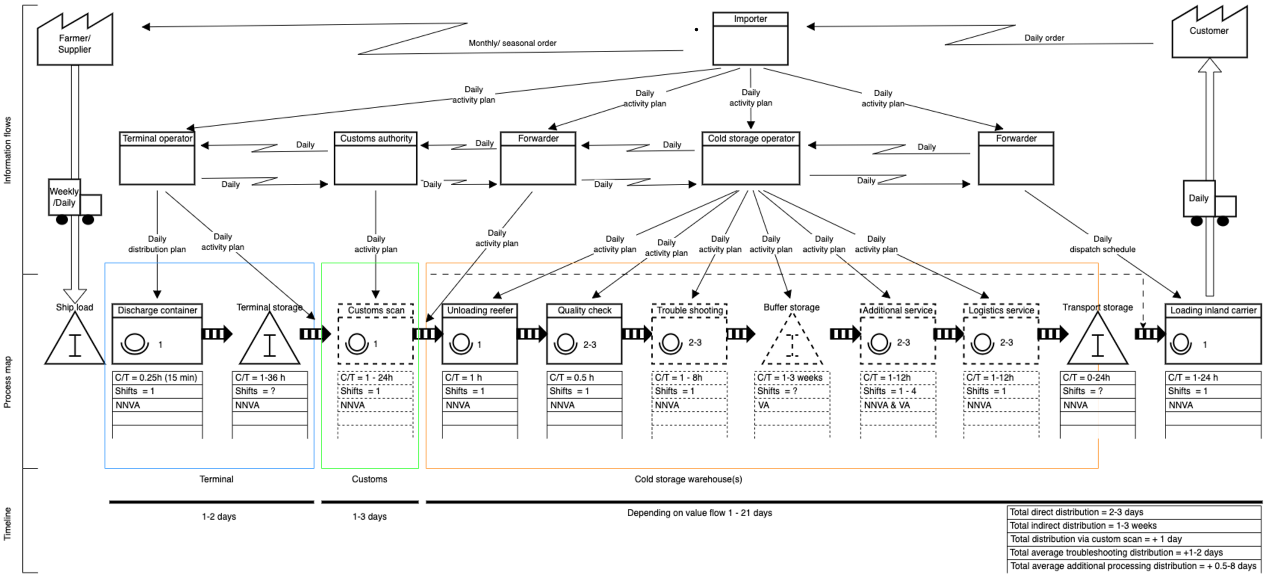

Figure 1: *VSM reference current state map GFFR cold chain Port of Hamburg*

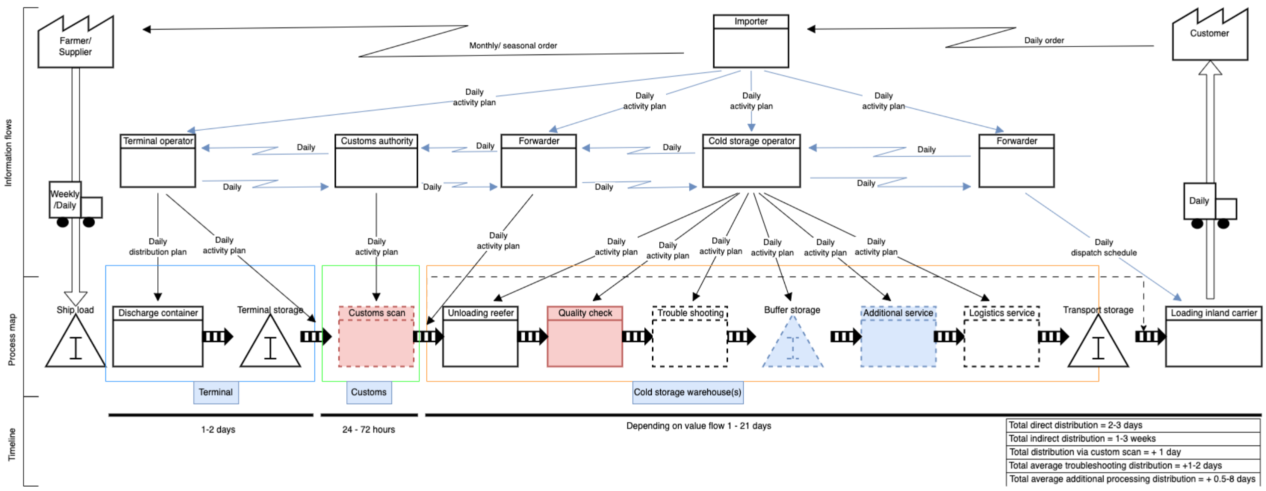

Figure 2: *VSM visualization critical issues (red) and improvement potentials(blue) for GFFR cold chain in the Port of Hamburg*

The complexity of numerous operations, stakeholders, material flow alternatives, and information sharing within this GFFR cold chain underscores the significance of understanding the complex relationships between these elements to enhance efficiency and improve the dynamics of the cold chain.

The utilization of VSM in the SWOT analysis, which is part of the opportunity analysis, is particularly valuable in identifying critical issues and potential areas for improvement. Furthermore, the VSM perspective is applied to assess the SWOT strategies. This latter application of VSM contributes significantly to understanding the relevance of improvement opportunities for the GFFR cold chain.

5 Results

Through literature review and interviews, the background study categorized five key stakeholder categories influencing the GFFR cold chain at the Port of Hamburg: (port and customs) authorities, terminal operators, cold storage operators, forwarders, and importers. These stakeholders nurture interconnections across diverse supply chain stages, highlighting this cold chain's complexity. Value stream mapping provided deeper insight into these interdependencies, revealing the material and information flows that cross operations and stakeholders.

Various material flows were identified by the value stream mapping, and categorized into four alternative current state maps: direct distribution (including customs scans), indirect distribution, distribution with troubleshooting activities, and distribution with additional processing and logistics services activities.

Information flows facilitated cargo movement across these material flows, with stakeholders exchanging information daily to link operations together. The GFFR cold chain in the Port of Hamburg features numerous material and information value streams originating from diverse processes and stakeholders. The complexity of connecting these elements highlights the importance of managing their relationships for optimal cold chain efficiency. Value stream mapping revealed the underlying structure of the value chain, highlighting critical issues like customs scans and quality checks, as well as potential improvements such as additional services, buffer storage, information exchange, and location strategy. These insights guided the focus on specific GFFR cold chain aspects during the opportunity analysis.

The opportunity analysis, involving a SWOT analysis, addressed both internal and external strengths, weaknesses, opportunities, and threats of the GFFR cold chain in the Port of Hamburg, revealing improvement potentials. The internal aspects, focusing on value chain operations, revealed strengths like buffer storage and additional processing activities, while also highlighting weaknesses like customs scans, the cold chain's groupage network, cold storage capacity, operating area, and port area. Regarding external opportunities and threats, the Port of Hamburg encounters various influences by the broader dynamics of the fruit cold chain and the port itself. These include threats related to vessel scheduling, high operation costs, shipping line connectivity, and climate change. Among these threats, opportunities emerge, such as enhancing the food cluster, investing in port infrastructure, and increasing container volume throughput.

The main potentials identified via the SWOT analysis are improving the customs scanning process and enhancing the food cluster at the Port of Hamburg. Addressing internal weaknesses associated with customs scans is crucial due to disruptions in the GFFR cargo flow. Balancing the number of scans and their impact on cargo flow is essential for improved efficiency. Key considerations involve expanding the number and capacity of customs locations, prioritizing perishable goods, and strategic port allocation of the customs locations. Successful implementation requires the customs authority's active engagement and collaboration with forwarders and importers.

Enhancing the Port of Hamburg's food cluster addresses external threats and opportunities, including shipping line connectivity, volume throughput, and current food cluster limitations. This potentially benefits the GFFR cold chain, boosting demand and potentially attracting shipping lines for a stronger market presence. It also streamlines the groupage network for cost savings. However, in the competitive fresh fruit market, strategic importer clustering—possibly grouping non-competing market importers—is vital. Effective realization requires collaboration among importers, terminal operators, forwarders, and other stakeholders to establish a robust food cluster.

6 Conclusion

Concluding this research, the primary focus for supply chain stakeholders to effectively accommodate the improvement of the global first-mile fresh fruit reefer cold chain lies within maintaining and enhancing the complex relationships between the cold chain's operations and stakeholders. Furthermore, optimizing the GFFR cold chain in the Port of Hamburg may benefit from improving its potential concerning customs scanning procedures and establishing a food cluster network.

Future research aiming to build upon this research is suggested to work on the following research suggestions:

- To enhance understanding, future analysis should integrate quantitative data to evaluate the impact of identified potentials on crucial aspects of the cold chain like the key drivers.
- Incorporating shipping agencies into the research scope is recommended, emphasizing their strategic relevance. This inclusion can enhance cold chain comprehension, potentially unveiling additional critical challenges and approaches for improvement.
- Analyzing the competitive dynamics of the GFFR cold chain in the Port of Hamburg, alongside other ports like Rotterdam and Antwerp, is essential to determine the importance of necessary improvements.

Reflection on the use of VSM in this research is given by the scientific implication of the combined application of VSM with a SWOT analysis. While some prior studies have employed the combination of SWOT and VSM to conduct in-depth system analysis, this research takes a unique approach by utilizing VSM to elaborate on the SWOT analysis. By highlighting focus areas identified through VSM, this approach shifts the perspective from an external-inside view to an inside-outside view. This shift adds depth to the understanding of a system's complexity and operations, offering more than just a strategic viewpoint.

Moreover, in my personal reflection on this approach, I find that evaluating strengths, weaknesses, opportunities, threats, and improvement strategies is more effectively substantiated when considering their fundamental understanding and impact on a system rather than solely from a strategic standpoint. Through this approach, certain strengths and weaknesses were noticed that have a subtle influence on the system, aspects that might have gone unnoticed with an external-inside perspective.

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